Food and Agriculture Organization of the United Nations

ENVIRONMENT AND NATURAL RESOURCES MANAGEMENT

WORKING PAPER

69

ENERGY

ISSN 2226-6062

SUSTAINABILITY OF BIOGAS AND CASSAVA-BASED ETHANOL VALUE CHAINS IN VIET NAM

Results and recommendations from the implementation of the Global Bioenergy Partnership indicators

ENVIRONMENT
AND NATURAL
RESOURCES
MANAGEMENT

WORKING
PAPER

69

ENERGY

SUSTAINABILITY OF BIOGAS AND CASSAVA-BASED ETHANOL VALUE CHAINS IN VIET NAM

Results and recommendations from the implementation of the Global Bioenergy Partnership indicators

Edited by Tiziana Pirelli, Andrea Rossi and Constance Miller (FAO).

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 2018

ISBN 978-92-5-130504-1

CONTENTS

CHAPTER 5

TABLES & FIGURES

TABLES

FIGURES

FOREWORD

The Global Bioenergy Partnership (GBEP) has produced a set of twenty-four indicators for the assessment and monitoring of bioenergy sustainability at the national level. The GBEP indicators are intended to inform policymakers about the environmental, social and economic sustainability aspects of the bioenergy sector in their country and guide them towards policies that foster sustainable development. The indicators, which were agreed upon by GBEP Partners and Observers at the end of 2011, were pilot tested in a diverse range of national contexts in order to assess and enhance their practicality as a tool for sustainable development and to strengthen the capacity of countries to measure bioenergy sustainability.

FAO, which is among the founding members of the Global Bioenergy Partnership, implemented the indicators in Paraguay and Viet Nam, with generous support from the International Climate Initiative (IKI) of the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety of Germany.

The overall objective of the project was to strengthen the capacity of Viet Nam and Paraguay to monitor the environmental, social and economic impacts of their bioenergy sector, through the implementation of the GBEP Sustainability Indicators for Bioenergy and related technical support. Furthermore, the project aimed to inform and support the design of effective sustainable bioenergy policies as part of low carbon development strategies.

This report presents the results of the implementation of the GBEP indicators in Viet Nam, where the project was executed under the leadership of the Vietnam Academy of Agricultural Sciences (VAAS) on behalf of the Ministry of Agriculture and Rural Development (MARD). The application of the GBEP Sustainability Indicators for Bioenergy to the two priority bioenergy pathways identified in Viet Nam – biogas at household, farm and industrial levels, and Cassava-based ethanol - was entrusted to a team of experts from three leading national Centers of excellence: the Institute of Agricultural Environment (IAE) and the Center for Agrarian Systems Research and Development (CASRAD) at VAAS, which took the lead on the environmental indicators and measured part of the economic indicators as well; the Vietnam Japan International Institute for Science of Technology (VJIIST) at the Hanoi University of Science and Technology (HUST), which had the primary responsibility over the economic indicators; and the Asian Institute of Technology Center in Vietnam (AITCV), which led the measurement of the social indicators.

The project provided Viet Nam with an understanding of how to establish the means of a long-term, periodic monitoring of its domestic bioenergy sector based on the GBEP indicators. Such periodic monitoring would enhance the knowledge and understanding of this sector and more generally of the way in which the contribution of the agricultural and energy sectors to national sustainable development could be evaluated.

The implementation of the GBEP indicators in Viet Nam also provided a series of lessons learnt about how to apply them as a tool for sustainable development and how to enhance their practicality.

Maria Michela Moresе
Natural Resources Officer
Project Coordinator

ACKNOWLEDGEMENTS

This report was developed in the framework of the FAO project "Building Capacity for enhancing bioenergy sustainability through the use of GBEP indicators" (GCP/GLO/554/GER), which was funded by the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety of Germany (BMUB). The project was coordinated by Maria Michela Morese (FAO), with Andrea Rossi (FAO) as Lead Technical Officer, Tiziana Pirelli (FAO) as Lead Technical Consultant and Thanh Phuong Nguyen (FAO) as In-Country Coordinator. Constance Miller (FAO) contributed to the editing and proof-reading of the final version of this report. We would like to thank the Ministry of Agriculture and Rural Development (MARD) of the Socialist Republic of Viet Nam and the Viet Nam Academy of Agricultural Sciences (VAAS) for their strong leadership and cooperation in the implementation of the project in the country. We would also like to express our appreciation to the many government bodies, academic institutions, stakeholders and individual experts that, as members of the Multi-Stakeholder Working Group that was established under the project, provided useful feedback and guidance. Furthermore, we would like to express our gratitude to the teams from the Centres of excellence that cooperated with FAO in the implementation of the GBEP Sustainability Indicators for Bioenergy in Viet Nam, which were:

- The Institute of Agricultural Environment (IAE) under VAAS, with Dr. Pham Quang Ha as Team Leader;
- The Center for Agrarian Systems Research and Development (CASRAD) under VAAS, with Dr. Dao The Anh as Team Leader;
- The Asian Institute of Technology Center in Vietnam (AITCV), with Dr. Pham Thi Thanh Thuy as Team Leader; and
- The Vietnam Japan International Institute for Science of Technology (VJIIST) at the Hanoi University of Science and Technology (HUST), with Prof. Van Dinh Son Tho as Team Leader.

Our thanks go also to Horst Fehrenbach from the Institute for Energy and Environmental Research (IFEU), for the training delivered in Viet Nam on the assessment of GHG and non-GHG emissions from biofuels, with support from the Federal Environment Agency (UBA) of Germany; and to the FAO colleagues Holger Matthey and Sergio René Araujo Enciso for the training they carried out on the Aglink-Cosimo Model for the measurement of indicator 10 (Price and supply of a national food basket). We are also thankful to Emily Olsson for her inputs to Chapter 2, to Giovanna Pesci (FAO) for her help in the finalization of this document, and to Federica Maffeo (FAO) for her administrative support. Finally, we would like to express our gratitude to the FAO Regional Office for Asia and the Pacific, the FAO Representation in Viet Nam and especially Song Ha Nguyen, Linh Nguyen and Thuy Dangminh, for their appreciated support on this project.

ABBREVIATIONS AND ACRONYMS

ACR	Contact Reactor
AD	Anaerobic Digester
ADB	Asian Development Bank
AF	Anaerobic Filter Reactor
ASEAN	Association of Southeast Asian Nations
BAU	Business as Usual
BPPMU	Biogas Program for the Animal Husbandry Sector of Viet Nam
CASRAD	Centre for Agrarian Systems Research and Development
CBD	Convention on Biodiversity
CHL	Central Highland
CHP	Combined Heat and Power
COD	Chemical Oxygen Demand
DALY	Disability-Adjusted Life Year
DARD	Department of Agriculture and Rural Development
DO	Diesel Oil
DSFF	Down flow Stationary Fixed Film Reactor
EIU	The Economist Intelligence Unit
EVN	Electricity Vietnam
FAO	Food and Agriculture Organization of the United Nations
FB	Fluidized Bed Reactor
FIT	Feed in Tariff
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GNI	Gross National Income

GSO	General Statistics Office of Viet Nam
GWP	Global Warming Potential
HDPE	High Density Polyethylene
HH	Households
IAE	Institute for Agricultural Environment
IBBH	Indo-Burma Biodiversity Hotspot
IEA	International Energy Agency
IFAD	International Fund for Agricultural Development
ITA	International Trade Administration
LBP	Large Biogas Plants
LCA	Lifecycle Analysis
LCASP	Low Carbon Agricultural Support Project
LHV	Low Heating Value
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
LUC	Land Use Change
MARD	Ministry of Agriculture and Rural Development
MBP	Medium Biogas Plants
MDG	Millennium Development Goal
mEq	Milliequivalent
MOIT	Ministry of Industry and Trade
MONRE	Ministry of Natural Resources and Environment
MRD	Mekong River Delta
NCCC	North Central and Central coastal areas
NMM	Northern Midlands and Mountain areas
OEC	Observatory of Economic Complexity
R&D	Research and Development
RRD	Red River Delta
RuDeC	Rural Development Center

SBP	Small Biogas Plants
SCC	South Central Coast
SE	South East
SE4ALL	Sustainable Energy for All
SNV	Netherlands Development Organisation
SOC	Soil Organic Carbon
SOM	Soil Organic Matter
UASB	Up flow Anaerobic Sludge Blanket
USAID	United States Agency for International Development
UNDP	United Nations Development Programme
UNEP-WCMC	UN Environment World Conservation Monitoring Centre
UNESCO	United Nations Educational, Scientific and Cultural Organization
VAAS	Viet Nam Academy of Agricultural Sciences
VHLSS	Vietnam Household Living Standard Survey
WFP	World Food Programme
WFS	World Food Summit

UNITS

bbl/d	Barrels of oil per day
cmol	Centimol
CO_{2eq}	Carbon Dioxide Equivalent
GJ	Giga Joule
ha	Hectares
kg	Kilogram
kt	Thousand tonnes
ktoe	Thousand tonnes of oil equivalent
kW	Kilowatt
kWh	Kilowatt hour
M litres	Million litres
m^3	Cubic meter
mg	Milligram
MJ	Mega Joule
tonne	Metric tonne (or tonne)
TS	Total solids
USD	United States Dollar
VND	Vietnamese Dong

CHAPTER 1

CHAPTER

1

IMPLEMENTATION OF THE GBEP SUSTAINABILITY INDICATORS FOR BIOENERGY IN VIET NAM

1.1 THE GBEP SUSTAINABILITY INDICATORS FOR BIOENERGY

1.1.1 Overview

The Global Bioenergy Partnership (GBEP) is an international initiative where over 70 Partners and Observers (simply referred to as 'members' throughout the rest of this report), amongst governments, intergovernmental organizations and civil society, work in the areas of the sustainability of bioenergy and its contribution to climate change mitigation. GBEP provides a platform for sharing information and examples of good practice in sustainable bioenergy and the initiative builds its activities upon three strategic areas: sustainable development, climate change, and energy and food security. It also seeks to enhance collaborative project development and implementation, with a view to optimizing the contribution of bioenergy to sustainable development, taking into account environmental, social and economic factors. In December 2011, GBEP published a report with a set of twenty-four sustainability indicators for bioenergy (descriptions are shown in the **Table 1**), with contributions from all members and agreed on a consensus basis (FAO, 2011).

Even though several national and regional initiatives have defined their own sustainability criteria for bioenergy (mainly focused on liquid biofuels), the uniqueness of the work of GBEP lies in the fact that it is currently the only initiative that has built consensus among a broad range of national governments and international organizations on the sustainability of bioenergy, and in the fact that the emphasis is on providing measurements useful for informing national-level policy analysis and development. Moreover, the GBEP work addresses all forms of bioenergy. The GBEP sustainability indicators do not feature directions, thresholds or limits and do not constitute a standard, nor are they legally binding on GBEP members.

GBEP has sought to develop a holistic set of science-based and technically sound indicators for a national evaluation of the domestic production and use of modern bioenergy. All members were invited to contribute with their respective experiences and technical expertise to the development and refinement of the indicators.

GBEP first developed and provisionally agreed on a list of themes, and then established three sub-groups: (1) Environmental – co-led by Germany and UN Environment; (2) Social – led by FAO; and (3) Economic and Energy Security – co-led by IEA and UN Foundation. These sub-groups undertook the detailed work on the indicators for these themes, which were equally divided between the three sub-group headings. The GBEP report on the sustainability indicators of bioenergy also contains a section listing examples of contextual information about cross-cutting issues relating to the legal, policy and institutional framework of relevance to bioenergy and its ability to contribute to sustainable development. It is suggested that this contextual information might aid the analysis of the indicators with the ultimate goal of informing policy development.

During the process of developing the indicators and their underlying methodology sheets, GBEP members took into account and used the work of relevant organizations and international processes related to environmental quality, social welfare and sustainable economic development. Examples of some of the relevant international organizations whose work has informed the development of indicators include the International Energy Agency (IEA), the International Labour Organization (ILO), the UN Development Programme (UNDP), UN Environment, the Food and Agriculture Organization of the United Nations (FAO), the UN Industrial Development Organization (UNIDO) and the World Health Organization (WHO).

The development of the indicators made use of existing guidance documents on sustainable development as discussed in the global community, especially taking into account the Millennium Development Goals (MDGs), the Commission on Sustainable Development (CSD), and Agenda 21. GBEP developed themes that are connected to the social impact of access to modern energy services, notably human health and safety, and rural and social development. Since the publication of the GBEP Sustainability Indicators (FAO, 2011), the Sustainable Development Goals (SDGs) have been internationally accepted. Nearly all of the 17 SDGs are linked to biomass in some way, as either a driver for increased use or as sustainability safeguards (IINAS & IFEU, 2018). Furthermore, access to modern energy services from bioenergy for households and businesses can promote social development and poverty reduction and as such can contribute to achieving various SDGs, including those related to health, education and gender equality (in addition to energy access).

GBEP developed indicators relevant to the economic themes of sustainability, including those that cover the concepts of economic development, energy security, resource availability and efficiency of use, infrastructure development, and access to technology. Indicators related to these themes were informed by the work of the CSD, international organizations, and agencies and ministries within the governments of GBEP members.

Within the environmental pillar, a number of central themes were considered as part of the discussion of the GBEP sustainability indicators, including those related to greenhouse gas emissions, productive capacity of the land and ecosystems, water and air quality, biological diversity, and land-use change. These important aspects were discussed and incorporated within relevant indicators and their underlying methodologies.

Therefore, the development of the indicators was informed by relevant international processes also focusing on these themes, including the Convention on Biological

Diversity (CBD), the Intergovernmental Panel on Climate Change (IPCC) and the UN Framework Convention on Climate Change (UNFCCC).

The selection criteria for the indicators were relevance, practicality and scientific basis. Additionally, the geographic scale was considered, as well as whether the full set of indicators was balanced and sufficiently comprehensive while still practical.

In the following pages, the twenty-four GBEP bioenergy sustainability indicators are set out under the three pillars, with the relevant themes listed at the top of each pillar. The order in which the indicators are presented has no significance. Full supporting information relating to the relevance, practicality and scientific basis of each indicator, including suggested approaches for their measurement, can be found in the methodology sheets for each indicator in the 2011 report on the indicators.

1.2 IMPLEMENTATION OF THE GBEP INDICATORS

The GBEP Sustainability Indicators for Bioenergy have been implemented in multiple countries in various regions of the World. These countries obtained valuable information regarding the performance of their bioenergy sector. More importantly, the application of the indicators provided national institutions with an understanding of how to establish the means of a long-term, periodic monitoring of their bioenergy sector based on the GBEP indicators, resulting in an important enhancement in knowledge and understanding of this sector and indeed more generally of the way in which the contribution of their agricultural and energy sectors to national sustainable development could be evaluated. Furthermore, the implementation of the GBEP indicators provided useful indications on how to enhance their practicality as a tool for sustainable development. On the basis of these indications, the GBEP Task Force on Sustainability was reopened in 2015 and is currently compiling the lessons learnt to provide further step-by-step guidance for future national implementation. This will be compiled into an Implementation Guide to be finalised during 2018.

Given the data requirements and the broad range of necessary scientific expertise in what is a relatively new area, some countries may require technical and financial assistance in order to measure the indicators and use them to inform policymaking. In response, FAO, which is among the founding members of the Global Bioenergy Partnership, began to explore possible ways to implement the indicators in those developing countries that had expressed an interest in such a project. This led to a proposal for a project in Viet Nam and Paraguay, which was accepted for funding by the International Climate Initiative (IKI) of the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety of Germany[1]. The project started in May 2016 and ended in April 2018.

1.3 PROJECT SCOPE AND IMPLEMENTATION APPROACH

The overall objective of the project was to strengthen the capacity of Viet Nam and Paraguay to monitor the environmental, social and economic impacts of their bioenergy sector, through the implementation of the GBEP Sustainability Indicators for Bioenergy and related technical support. Furthermore, the project aimed to inform and support the design of effective sustainable bioenergy policies as part of low carbon development strategies. By pursuing these objectives, the project provided the basis for better planning and management of resources, including soil, water and land use in the two target countries.

[1] The same donor supported a similar project in Colombia and Indonesia between 2011 and 2014.

The implementation of the GBEP indicators led to interesting results and lessons learnt, which were shared and discussed with the representatives of neighbouring countries and relevant regional organizations. The aforementioned lessons learnt were also incorporated into the Implementation Guide that was developed under the GBEP Working Group on Capacity Building as a complement to the report on the GBEP Sustainability Indicators for Bioenergy.

In Viet Nam, the project was executed under the leadership of the Vietnam Academy of Agricultural Sciences (VAAS) on behalf of the Ministry of Agriculture and Rural Development (MARD).

A Multi-Stakeholder Working Group (MSWG) was established at the on-set of the project, bringing together around 50 relevant stakeholders from both the public and private sectors, including government agencies, academic and research institutions, producers' organization and private enterprises. The MSWG was assigned the following tasks:

- Provide guidance on high level issues related to the project implementation (e.g. main project focus);
- Provide and verify data and information required for the measurement of the GBEP indicators;
- Provide feedback on the draft results of this measurement; and
- Contribute to the interpretation of these results and to their mainstreaming into bioenergy decision-making processes.

Building upon the discussions that took place during the first MSWG meeting in June 2016, two priority bioenergy pathways were identified in Viet Nam. They were chosen based on their spread (e.g. household-level biogas), their relevance in terms of policy-making (e.g. Cassava-based ethanol) and the need for further evidence and analysis regarding their competiveness and sustainability The following pathways and the related sustainability issues represented the main focus of the project[2]:

- Cassava-based ethanol; and
- Biogas at household, farm and industrial levels.

Regarding Cassava-based ethanol, two scenarios were analysed:

- Domestic ethanol consumption as of 2016 (assumed to be equal to domestic production) vs. a baseline that was set in 2007, i.e. the year of introduction of the first ethanol support policies in the country; and
- Domestic ethanol consumption to meet a hypothetical E5 mandate for RON92 gasoline in 2016 vs. the aforementioned 2007 baseline.

Three different types/scales of biogas systems were considered: household (from pig manure), farm (also from pig manure), and industrial (from cassava wastewater). In the case of Cassava-based ethanol, two different feedstock cultivation systems were analysed: on flat land and on sloping land.

Biogas systems, especially at household level, have been in place for a few decades in Viet Nam. Therefore, for this assessment of this pathway under the various indicators, the current situation as of 2016 (with biogas) was compared with the Business As Usual (BAU) scenario without biogas.

The application of the GBEP Sustainability Indicators for Bioenergy to the biogas and ethanol value chains in Viet Nam was entrusted to a team of experts from three leading national Centers of excellence, following a thorough process of review and evaluation of their capacity. These were:

- The Institute of Agricultural Environment (IAE) and the Centre for Agrarian Systems Research and Development (CASRAD) at VAAS, which took the lead on the environmental indicators and measured part of the economic indicators as well;
- The Vietnam Japan International Institute for Science of Technology (VJIIST) at the Hanoi University of Science and Technology (HUST), which had the primary responsibility over the economic indicators; and

[2] For a detailed description of the selected pathways in Viet Nam, see Chapter 3.

- The Asian Institute of Technology Centre in Vietnam (AITCV), which led the measurement of the social indicators.

The aforementioned Centres of excellence were supported by FAO and other international experts throughout the project. In particular, FAO, along with experts ***inter alia*** from the donor country, Germany, provided technical support to the national experts during meetings and through electronic and telephonic communication on the meaning of and rationale behind the indicators and their indicative methodological approaches; as well as on how to adapt the existing GBEP methodological approach to the country context; and how to implement the chosen methodologies. FAO reviewed the information provided by the experts from the Centres of excellence through an iterative dialogue and with a view to ensure consistency across the indicators, especially in terms of data inputs and assumptions. In some cases, FAO complemented the drafts prepared by the experts with information available from literature, international databases and other electronic sources.

Throughout the project, three meetings of the MSWG were organized. These meetings played a key role in the validation of the data, the calibration of the assumptions, the discussion and interpretation of the results, and the development of related recommendations. Furthermore, these meetings provided an opportunity to mainstream the results of the implementation of the GBEP indicators into relevant decision-making processes at both policy and investment levels. In the mid-term and final MSWG meetings, selected international experts from intergovernmental organizations, bilateral development agencies and research institutions also participated to share their knowledge and help broaden the community of practice engaged in the implementation of the indicators on the ground.

The results and recommendations emerging from the implementation of the GBEP Sustainability Indicators for Bioenergy in Viet Nam were shared with the representatives of governments from neighbouring countries during a workshop that was held in Hanoi in November 2017. Representatives of relevant regional organizations and development banks attended this event as well. The workshop provided an opportunity to share information on the status of the bioenergy sector and related policies in various countries in Southeast Asia. In addition, participants shared their experiences related to the assessment and management of environmental, social and economic sustainability issues associated with modern bioenergy development. Furthermore, the potential for increased sustainable bioenergy production and use in Southeast Asia and the related barriers were discussed, together with possible regional cooperation opportunities and financing options to exploit this sustainable bioenergy potential.

TABLE 1.

THE GBEP SUSTAINABILITY INDICATORS FOR BIOENERGY

ENVIRONMENTAL PILLAR	
THEMES GBEP CONSIDERS THE FOLLOWING THEMES RELEVANT, AND THESE GUIDED THE DEVELOPMENT OF INDICATORS UNDER THIS PILLAR: GREENHOUSE GAS EMISSIONS, PRODUCTIVE CAPACITY OF THE LAND AND ECOSYSTEMS, AIR QUALITY, WATER AVAILABILITY, USE EFFICIENCY AND QUALITY, BIOLOGICAL DIVERSITY, LAND-USE CHANGE, INCLUDING INDIRECT EFFECTS *	
INDICATOR NAME	**INDICATOR DESCRIPTION**
1. **LIFECYCLE GHG EMISSIONS**	LIFECYCLE GREENHOUSE GAS EMISSIONS FROM BIOENERGY PRODUCTION AND USE, AS PER THE METHODOLOGY CHOSEN NATIONALLY OR AT COMMUNITY LEVEL, AND REPORTED USING THE GBEP COMMON METHODOLOGICAL FRAMEWORK FOR GHG LIFECYCLE ANALYSIS OF BIOENERGY 'VERSION ONE'
2. **SOIL QUALITY**	PERCENTAGE OF LAND FOR WHICH SOIL QUALITY, IN PARTICULAR IN TERMS OF SOIL ORGANIC CARBON, IS MAINTAINED OR IMPROVED OUT OF TOTAL LAND ON WHICH BIOENERGY FEEDSTOCK IS CULTIVATED OR HARVESTED
3. **HARVEST LEVELS OF WOOD RESOURCES**	ANNUAL HARVEST OF WOOD RESOURCES BY VOLUME AND AS A PERCENTAGE OF NET GROWTH OR SUSTAINED YIELD, AND THE PERCENTAGE OF THE ANNUAL HARVEST USED FOR BIOENERGY
4. **EMISSIONS OF NON-GHG AIR POLLUTANTS, INCLUDING AIR TOXICS**	EMISSIONS OF NON-GHG AIR POLLUTANTS, INCLUDING AIR TOXICS, FROM BIOENERGY FEEDSTOCK PRODUCTION, PROCESSING, TRANSPORT OF FEEDSTOCKS, INTERMEDIATE PRODUCTS AND END PRODUCTS, AND USE; AND IN COMPARISON WITH OTHER ENERGY SOURCES
5. **WATER USE AND EFFICIENCY**	• WATER WITHDRAWN FROM NATIONALLY DETERMINED WATERSHED(S) FOR THE PRODUCTION AND PROCESSING OF BIOENERGY FEEDSTOCKS, EXPRESSED AS THE PERCENTAGE OF TOTAL ACTUAL RENEWABLE WATER RESOURCES (TARWR) AND AS THE PERCENTAGE OF TOTAL ANNUAL WATER WITHDRAWALS (TAWW), DISAGGREGATED INTO RENEWABLE AND NON-RENEWABLE WATER SOURCES • VOLUME OF WATER WITHDRAWN FROM NATIONALLY DETERMINED WATERSHED(S) USED FOR THE PRODUCTION AND PROCESSING OF BIOENERGY FEEDSTOCKS PER UNIT OF BIOENERGY OUTPUT, DISAGGREGATED INTO RENEWABLE AND NON-RENEWABLE WATER SOURCES
6. **WATER QUALITY**	• POLLUTANT LOADINGS TO WATERWAYS AND BODIES OF WATER ATTRIBUTABLE TO FERTILIZER AND PESTICIDE APPLICATION FOR BIOENERGY FEEDSTOCK CULTIVATION, AND EXPRESSED AS A PERCENTAGE OF POLLUTANT LOADINGS FROM TOTAL AGRICULTURAL PRODUCTION IN THE WATERSHED • POLLUTANT LOADINGS TO WATERWAYS AND BODIES OF WATER ATTRIBUTABLE TO BIOENERGY PROCESSING EFFLUENTS, AND EXPRESSED AS A PERCENTAGE OF POLLUTANT LOADINGS FROM TOTAL AGRICULTURAL PROCESSING EFFLUENTS IN THE WATERSHED
7. **BIOLOGICAL DIVERSITY IN THE LANDSCAPE**	• AREA AND PERCENTAGE OF NATIONALLY RECOGNIZED AREAS OF HIGH BIODIVERSITY VALUE OR CRITICAL ECOSYSTEMS CONVERTED TO BIOENERGY PRODUCTION • AREA AND PERCENTAGE OF THE LAND USED FOR BIOENERGY PRODUCTION WHERE NATIONALLY RECOGNIZED INVASIVE SPECIES, BY RISK CATEGORY, ARE CULTIVATED • AREA AND PERCENTAGE OF THE LAND USED FOR BIOENERGY PRODUCTION WHERE NATIONALLY RECOGNIZED CONSERVATION METHODS ARE USED

8. **LAND USE AND LAND-USE CHANGE RELATED TO BIOENERGY FEEDSTOCK PRODUCTION**	• TOTAL AREA OF LAND FOR BIOENERGY FEEDSTOCK PRODUCTION, AND AS COMPARED TO TOTAL NATIONAL SURFACE AND AGRICULTURAL AND MANAGED FOREST LAND AREA
	• PERCENTAGES OF BIOENERGY FROM YIELD INCREASES, RESIDUES, WASTES AND DEGRADED OR CONTAMINATED LAND
	• NET ANNUAL RATES OF CONVERSION BETWEEN LAND-USE TYPES CAUSED DIRECTLY BY BIOENERGY FEEDSTOCK PRODUCTION, INCLUDING THE FOLLOWING (AMONGST OTHERS):
	  • ARABLE LAND AND PERMANENT CROPS, PERMANENT MEADOWS AND PASTURES, AND MANAGED FORESTS;
	  • NATURAL FORESTS AND GRASSLANDS (INCLUDING SAVANNAH, EXCLUDING NATURAL PERMANENT MEADOWS AND PASTURES), PEATLANDS, AND WETLANDS

* In light of discussions on the issue and considering the state of the science on quantifying possible indirect land-use change (ILUC) impacts of bioenergy, it has not yet been possible to include an indicator on ILUC. GBEP notes that further work is required to improve our understanding of and ability to measure indirect effects of bioenergy such as ILUC and indirect impacts on prices of agricultural commodities. GBEP will continue to work in order to consolidate and discuss the implications of the current science on these indirect effects, develop a transparent, science-based framework for their measurement, and identify and discuss options for policy responses to mitigate potential negative and promote potential positive indirect effects of bioenergy.

<table>
<tr><th colspan="2">SOCIAL PILLAR</th></tr>
<tr><td colspan="2">THEMES
GBEP CONSIDERS THE FOLLOWING THEMES RELEVANT, AND THESE GUIDED THE DEVELOPMENT OF INDICATORS UNDER THIS PILLAR:

PRICE AND SUPPLY OF A NATIONAL FOOD BASKET, ACCESS TO LAND, WATER AND OTHER NATURAL RESOURCES, LABOUR CONDITIONS, RURAL AND SOCIAL DEVELOPMENT, ACCESS TO ENERGY, HUMAN HEALTH AND SAFETY</td></tr>
<tr><th>INDICATOR NAME</th><th>INDICATOR DESCRIPTION</th></tr>
<tr><td>9. ALLOCATION AND TENURE OF LAND FOR NEW BIOENERGY PRODUCTION</td><td>PERCENTAGE OF LAND – TOTAL AND BY LAND-USE TYPE – USED FOR NEW BIOENERGY PRODUCTION WHERE:
• A LEGAL INSTRUMENT OR DOMESTIC AUTHORITY ESTABLISHES TITLE AND PROCEDURES FOR CHANGE OF TITLE; AND
• THE CURRENT DOMESTIC LEGAL SYSTEM AND/OR SOCIALLY ACCEPTED PRACTICES PROVIDE DUE PROCESS AND THE ESTABLISHED PROCEDURES ARE FOLLOWED FOR DETERMINING LEGAL TITLE</td></tr>
<tr><td>10. PRICE AND SUPPLY OF A NATIONAL FOOD BASKET</td><td>EFFECTS OF BIOENERGY USE AND DOMESTIC PRODUCTION ON THE PRICE AND SUPPLY OF A FOOD BASKET, WHICH IS A NATIONALLY DEFINED COLLECTION OF REPRESENTATIVE FOODSTUFFS, INCLUDING MAIN STAPLE CROPS, MEASURED AT THE NATIONAL, REGIONAL, AND/OR HOUSEHOLD LEVEL, TAKING INTO CONSIDERATION:
• CHANGES IN DEMAND FOR FOODSTUFFS FOR FOOD, FEED AND FIBRE;
• CHANGES IN THE IMPORT AND EXPORT OF FOODSTUFFS;
• CHANGES IN AGRICULTURAL PRODUCTION DUE TO WEATHER CONDITIONS;
• CHANGES IN AGRICULTURAL COSTS FROM PETROLEUM AND OTHER ENERGY PRICES; AND
• THE IMPACT OF PRICE VOLATILITY AND PRICE INFLATION OF FOODSTUFFS ON THE NATIONAL, REGIONAL, AND/OR HOUSEHOLD WELFARE LEVEL, AS NATIONALLY DETERMINED</td></tr>
<tr><td>11. CHANGE IN INCOME</td><td>CONTRIBUTION OF THE FOLLOWING TO CHANGE IN INCOME DUE TO BIOENERGY PRODUCTION:
• WAGES PAID FOR EMPLOYMENT IN THE BIOENERGY SECTOR IN RELATION TO COMPARABLE SECTORS
• NET INCOME FROM THE SALE, BARTER AND/OR OWN CONSUMPTION OF BIOENERGY PRODUCTS, INCLUDING FEEDSTOCKS, BY SELF-EMPLOYED HOUSEHOLDS/INDIVIDUALS</td></tr>
<tr><td>12. JOBS IN THE BIOENERGY SECTOR</td><td>• NET JOB CREATION AS A RESULT OF BIOENERGY PRODUCTION AND USE, TOTAL AND DISAGGREGATED (IF POSSIBLE) AS FOLLOWS:
  • SKILLED/UNSKILLED
  • TEMPORARY/INDEFINITE
• TOTAL NUMBER OF JOBS IN THE BIOENERGY SECTOR AND PERCENTAGE ADHERING TO NATIONALLY RECOGNIZED LABOUR STANDARDS CONSISTENT WITH THE PRINCIPLES ENUMERATED IN THE ILO DECLARATION ON FUNDAMENTAL PRINCIPLES AND RIGHTS AT WORK, IN RELATION TO COMPARABLE SECTORS</td></tr>
<tr><td>13. CHANGE IN UNPAID TIME SPENT BY WOMEN AND CHILDREN COLLECTING BIOMASS</td><td>CHANGE IN AVERAGE UNPAID TIME SPENT BY WOMEN AND CHILDREN COLLECTING BIOMASS AS A RESULT OF SWITCHING FROM TRADITIONAL USE OF BIOMASS TO MODERN BIOENERGY SERVICES</td></tr>
<tr><td>14. BIOENERGY USED TO EXPAND ACCESS TO MODERN ENERGY SERVICES</td><td>• TOTAL AMOUNT AND PERCENTAGE OF INCREASED ACCESS TO MODERN ENERGY SERVICES GAINED THROUGH MODERN BIOENERGY (DISAGGREGATED BY BIOENERGY TYPE), MEASURED IN TERMS OF ENERGY AND NUMBERS OF HOUSEHOLDS AND BUSINESSES
• TOTAL NUMBER AND PERCENTAGE OF HOUSEHOLDS AND BUSINESSES USING BIOENERGY, DISAGGREGATED INTO MODERN BIOENERGY AND TRADITIONAL USE OF BIOMASS</td></tr>
<tr><td>15. CHANGE IN MORTALITY AND BURDEN OF DISEASE ATTRIBUTABLE TO INDOOR SMOKE</td><td>CHANGE IN MORTALITY AND BURDEN OF DISEASE ATTRIBUTABLE TO INDOOR SMOKE FROM SOLID FUEL USE, AND CHANGES IN THESE AS A RESULT OF THE INCREASED DEPLOYMENT OF MODERN BIOENERGY SERVICES, INCLUDING IMPROVED BIOMASS-BASED COOKSTOVES</td></tr>
<tr><td>16. INCIDENCE OF OCCUPATIONAL INJURY, ILLNESS AND FATALITIES</td><td>INCIDENCES OF OCCUPATIONAL INJURY, ILLNESS AND FATALITIES IN THE PRODUCTION OF BIOENERGY IN RELATION TO COMPARABLE SECTORS</td></tr>
</table>

ECONOMIC PILLAR	
THEMES GBEP CONSIDERS THE FOLLOWING THEMES RELEVANT, AND THESE GUIDED THE DEVELOPMENT OF INDICATORS UNDER THIS PILLAR: RESOURCE AVAILABILITY AND USE EFFICIENCIES IN BIOENERGY PRODUCTION, CONVERSION, DISTRIBUTION AND END-USE, ECONOMIC DEVELOPMENT, ECONOMIC VIABILITY AND COMPETITIVENESS OF BIOENERGY, ACCESS TO TECHNOLOGY AND TECHNOLOGICAL CAPABILITIES, ENERGY SECURITY/ DIVERSIFICATION OF SOURCES AND SUPPLY, ENERGY SECURITY/INFRASTRUCTURE AND LOGISTICS FOR DISTRIBUTION AND USE	
INDICATOR NAME	**INDICATOR DESCRIPTION**
17. **PRODUCTIVITY**	• PRODUCTIVITY OF BIOENERGY FEEDSTOCKS BY FEEDSTOCK OR BY FARM/PLANTATION • PROCESSING EFFICIENCIES BY TECHNOLOGY AND FEEDSTOCK • AMOUNT OF BIOENERGY END PRODUCT BY MASS, VOLUME OR ENERGY CONTENT PER HECTARE PER YEAR • PRODUCTION COST PER UNIT OF BIOENERGY
18. **NET ENERGY BALANCE**	ENERGY RATIO OF THE BIOENERGY VALUE CHAIN WITH COMPARISON WITH OTHER ENERGY SOURCES, INCLUDING ENERGY RATIOS OF FEEDSTOCK PRODUCTION, PROCESSING OF FEEDSTOCK INTO BIOENERGY, BIOENERGY USE; AND/OR LIFECYCLE ANALYSIS
19. **GROSS VALUE ADDED**	GROSS VALUE ADDED PER UNIT OF BIOENERGY PRODUCED AND AS A PERCENTAGE OF GROSS DOMESTIC PRODUCT
20. **CHANGE IN THE CONSUMPTION OF FOSSIL FUELS AND TRADITIONAL USE OF BIOMASS**	• SUBSTITUTION OF FOSSIL FUELS WITH DOMESTIC BIOENERGY MEASURED BY ENERGY CONTENT AND IN ANNUAL SAVINGS OF CONVERTIBLE CURRENCY FROM REDUCED PURCHASES OF FOSSIL FUELS • SUBSTITUTION OF TRADITIONAL USE OF BIOMASS WITH MODERN DOMESTIC BIOENERGY MEASURED BY ENERGY CONTENT
21. **TRAINING AND RE-QUALIFICATION OF THE WORKFORCE**	PERCENTAGE OF TRAINED WORKERS IN THE BIOENERGY SECTOR OUT OF TOTAL BIOENERGY WORKFORCE, AND PERCENTAGE OF RE-QUALIFIED WORKERS OUT OF THE TOTAL NUMBER OF JOBS LOST IN THE BIOENERGY SECTOR
22. **ENERGY DIVERSITY**	CHANGE IN DIVERSITY OF TOTAL PRIMARY ENERGY SUPPLY DUE TO BIOENERGY
23. **INFRASTRUCTURE AND LOGISTICS FOR DISTRIBUTION OF BIOENERGY**	NUMBER AND CAPACITY OF ROUTES FOR CRITICAL DISTRIBUTION SYSTEMS, ALONG WITH AN ASSESSMENT OF THE PROPORTION OF THE BIOENERGY ASSOCIATED WITH EACH
24. **CAPACITY AND FLEXIBILITY OF USE OF BIOENERGY**	• RATIO OF CAPACITY FOR USING BIOENERGY COMPARED WITH ACTUAL USE FOR EACH SIGNIFICANT UTILIZATION ROUTE • RATIO OF FLEXIBLE CAPACITY WHICH CAN USE EITHER BIOENERGY OR OTHER FUEL SOURCES TO TOTAL CAPACITY

REFERENCES

FAO. 2011. The Global Bioenergy Partnership Sustainability Indicators for Bioenergy. First Edition. ISBN 978-92-5-107249-3. Available at: www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/Indicators/The_GBEP_Sustainability_Indicators_for_Bioenergy_FINAL.pdf

International Institute for Sustainability Analysis and Strategy (IINAS) & Institute of Energy and Environmental Research (IFEU). 2018. Linkages between the Sustainable Development Goals (SDGs) and the GBEP Sustainability Indicators for Bioenergy (GSI): Technical Paper for the GBEP Task Force on Sustainability. Available at: www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/Indicators/IINAS_IFEU___2018___Linkages_SDGs_and_GSIs_-_final.pdf

CHAPTER 2

CHAPTER

2

COUNTRY CONTEXT AND DOMESTIC BIOENERGY SECTOR

2.1 COUNTRY CONTEXT

2.1.1 Overview

Viet Nam, otherwise known as the Socialist Republic of Viet Nam, is an S-shaped country on the eastern-most part of the Indochina Peninsula. The country's coastline stretches 3 444 km and spans the Gulf of Tonkin, the Gulf of Thailand and the South China Sea (See **Figure 1**). Three quarters of the country is covered with hills and mountains that reach over 3 000 m in elevation. The remainder is comprised of fertile plains that are heavily cultivated and densely populated (MONRE, 2014).

Viet Nam stretches over 15 latitudes (1 650 km) and has a wide variety of climates, with a tropical monsoonal climate causing hot winters in the south and cool winters in the north (Mui, 2006). The average annual precipitation can range from 1 400 mm to 2 400 mm, with 80 to 90 percent of it occurring during the rainy season, which lasts from May to September.

Viet Nam can be divided into six, seven or eight agro-ecological zones, according to different purposes. The classification of the agro-ecological zones in Viet Nam has changed during the past years and depends on the sources of information, as statistical data is reported by provinces, of which some have been re-organized administratively by the government or have even shifted from one region to another (GSO website and MARD, 2017). For this report, the six regions recognised by GSO (GSO website) will be used. These are: Red River Delta (RRD), Mekong River Delta (MRD), North Central and Central Coastal areas (NCCC), Central High Lands (CHL), Northern midlands and Mountainous areas (NMM) and South East (SE). The RRD in the north and the MRD in the south are large areas of delta or coastal regions, which are both low-lying centres of

FIGURE 1.

MAP OF VIET NAM

Source: Greater Mekong Subregion Environment Operations Center, 2012 food production (Mui, 2006). This means that the country is vulnerable to sea level rise and increasing incidence of extreme weather events, and it is expected that Viet Nam will be severely affected by climate change (FAO, 2017a).

Viet Nam is one of the world's most biologically diverse countries and has a high level of endemism. The country lies within the Indo-Burma Biodiversity Hotspot (IBBH) and supports many important ecosystems, including over 110 Key Biodiversity Areas, 62 Important Bird Areas, three UNESCO World Natural Heritage Sites, eight Ramsar wetlands[3], eight UNESCO Biosphere Reserves and four ASEAN Heritage Parks (UNEP-WCMC, 2017). Furthermore, the country is one of the most highly diverse centres for local genetic resources of plants and animals in the world, including about 800 agricultural crop varieties, and 14 key cattle and poultry varieties (MONRE, 2014), making it extremely agro-biodiverse and one of the world's plant breeding centres (CBD, no date)

Viet Nam's expanding population is placing pressure on these natural resources. With a total land area of 331 210 km^2 and a population estimated at over 92 million people, land scarcity is a concern. Viet Nam has one of the world's lowest per capita land endowments, with less than 0.2 hectares of agricultural land available per person (GSO website). Land use intensity is especially high in areas of human settlement and wetland rice agriculture. Across the country, the average population density is 280 people per km^2, but in the RRD that number jumps to 994 people per km^2 (GSO website). Despite the large number of people, Viet Nam's population is predominantly rural, with 68 percent of the total population living in rural areas. However, this situation is changing and each year the urban population grows by roughly three percent (World Bank, 2018).Intensive use of the country's natural resources has helped fuel Viet Nam's recent economic growth (World Bank, 2010). This growth has also been spurred by the series of economic and political reforms, known as the *Doi Moi*, starting in 1986. This policy overhaul effectively abolished central planning and allowed Viet Nam's economy to become increasingly market-oriented and globally integrated. From 1990 to 2016, the country's gross domestic product (GDP) increased steadily, at or above five percent annually (World Bank, 2017). With a GNI per capita of USD 2 100 in 2016, Viet Nam is classified as a "lower-middle-income country" (World Bank, 2017). The country has started to industrialize, transitioning from an agriculture-based economy to one based on manufacturing and services. This shift can be seen in agriculture's declining value added share of GDP. By 2016, the value added of agriculture accounted for only 18.1 percent of GDP while services and industry accounted for 45.5 and 36.4 percent, respectively (see **Figure 2**) (World Bank, 2017).

Today, Viet Nam exports a diverse mix of goods and services. The largest exports, in value terms, are all from the industrial sector – broadcasting equipment, computers and textiles (OEC, no date). The notable exception to this is the export of crude petroleum. While not as significant value-wise, agricultural exports are nonetheless an important part of Viet Nam's economy; the country is a major exporter not only of seafood but also rice, coffee, and pepper (GSO website). Viet Nam's largest trading partners in value terms are the United States, the European Union, and the ASEAN region countries (GSO website).

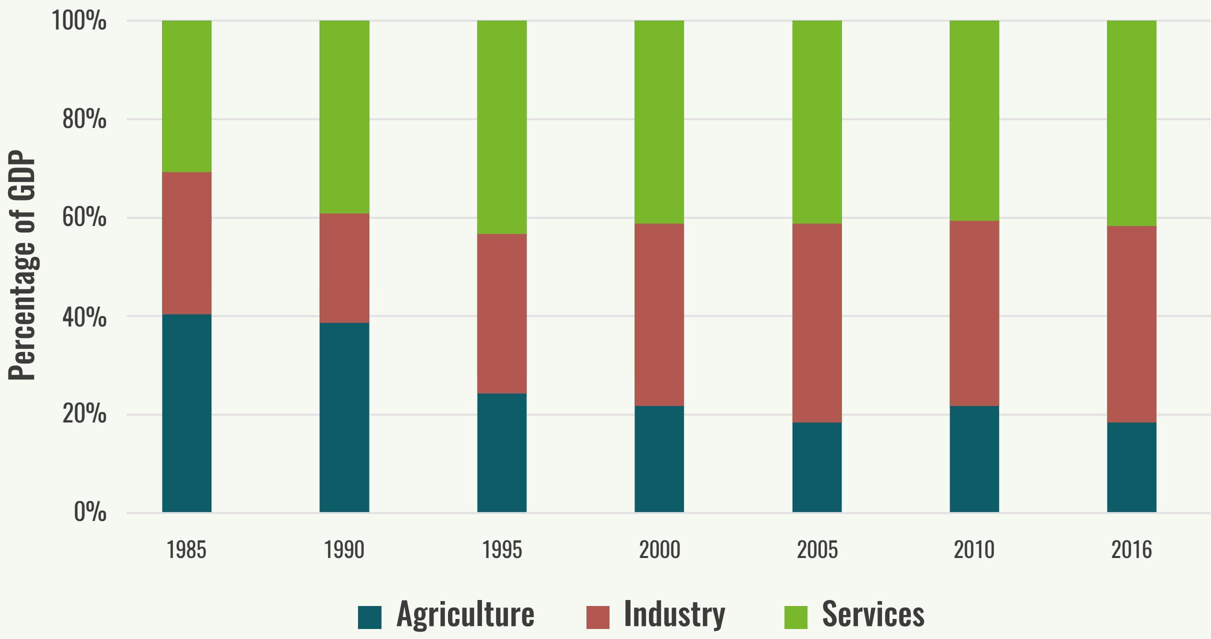
Since the 1990s, Viet Nam was able to simultaneously reduce the instances of poverty and hunger. The percentage of the population living on USD 1.25 per day decreased from 62 percent in 1993 to two percent in 2012. Per capita GDP increased from USD 980 in 1990 to USD 2 186 in 2016 (World Bank, 2017). Furthermore, Viet Nam is one of the countries in the Southeast Asia region that has successfully met the World Food Summit (WFS) goal as well as the Millennium Development Goal (MDG) 1c[4] (FAO, IFAD and WFP, 2015). However, the spillover effects of this rapid development have not been shared equally between the urban and rural populations; there are much higher instances of food insecurity and poverty in rural areas.

[3] The Ramsar Convention is an international treaty promoting the "conservation and wise use" of wetland ecosystems.

[4] The WFS goal was to eradicate hunger in all countries, with an immediate view to reducing the number of undernourished people to half their level in 2001 no later than 2015, and the MDG lc goal was to halve, between 1990 and 2015, the proportion of people who suffer from hunger.

FIGURE 2.

EVOLUTION OF GDP COMPOSITION, 1985-2016



Source: World Bank, 2017

2.1.2 Agriculture

The Vietnamese government has played a large role in shaping the country's agriculture sector as land management was a key part of the initial *Doi Moi* reforms. After reunification in 1976, almost all rural households in the north and a third of rural households in the south belonged to collectivized farms, but many experienced low yields and food shortages. As a result, in 1986, the government allowed land-use rights to be given in usufruct to farmers for 15 years at a time. The government also freed up the prices of goods, interest rates and the foreign exchange rate. These early agricultural reforms combined with trade liberalization encouraged agricultural production, boosted trade and narrowed the gap between international and domestic prices of agricultural inputs and outputs (Son *et al.*, 2006). Further reforms in the 1990s and 2000s, such as the 1993 and 2003 Land Laws, consolidated these gains (see indicator 9 for details).

During this time, use-right contracts were extended to last up to 30 years for annual cropland and 50 years for perennial cropland. Farmers were permitted to exchange, transfer, bequeath, lease or mortgage their existing rights. The government also facilitated access to credit and technical extension services (USAID, 2013). Recently, the focus has been on increasing the agriculture sector's sustainability. In June 2013, the Prime Minister approved the Agricultural Restructuring Plan, which calls for the incorporation of a broader set of sustainable development indicators into physical targets.

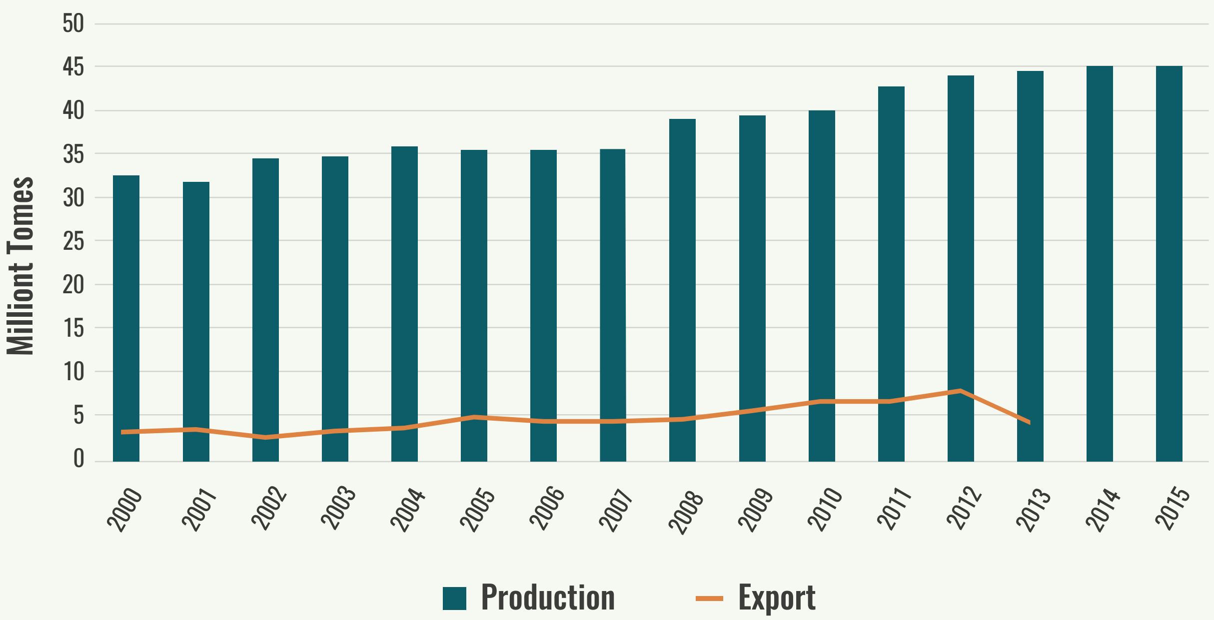
These reforms have had a significant impact on many facets of the agriculture sector, particularly with regard to farm size, employment and productivity. There are now over 100 000 small, private farms across the country. In 2001, 25 percent held less than 0.2 ha of production land, 40 percent of farmers held between 0.2 and 0.5 ha, and about 30 percent held more than 1 ha. Only some 5 600 farmers held 10 ha of cropland or more (World Bank, 2010). Furthermore, many households, particularly in the MRD, have switched from self-sufficient to commercial production. The type of good(s) that are produced depends largely on their location. In hilly and mountainous areas, they are involved in forestation, forest protection, exploitation of forestry products or agroforestry. Farms in coastal areas focus on fishing and/or aquaculture and fish processing, and in the lowlands, they tend to engage in a range of cultivation including animal husbandry, fish breeding, handicraft and rural services.

Agriculture is still considered an important sector due to the large portion of the population, particularly in rural areas, that it employs. As of 2015, 43.62 percent of Viet Nam's population worked in agriculture (World Bank, 2017). Household-based farming still accepts new entrants to the workforce each year, and its ability to absorb labour has been a major factor in curtailing the growth of urban unemployment. However, a diversification of household income has taken place and many households do not derive their principle income from agriculture. Now, many of them continue in agricultural production because it provides a more stable and secure income source than other activities, even though the latter might produce the majority of their income (FAO, 2006).

From 1994 to 2016, agricultural production increased dramatically due increases in agricultural area, labour and especially fertilizer use (World Bank Group, 2017). The increased usage of these fertilizers helped the country increase yields and go from being a net food importer to a net food exporter. No commodity illustrates this change in productivity better than rice, where the yield increased from 3.9 tonnes/ha in 1994 to 5.5 tonnes/ha in 2016 (FAO, 2017b). Rice is Viet Nam's most important crop. Starting in the early 2000s, Viet Nam transformed from a net rice importer into the second largest rice exporter in the world, producing approximately 44 million tonnes of rice in 2013, of which 3.9 million tonnes was exported (FAO, 2017b) (see **Figure 3**). The MRD is considered the country's major granary, accounting for 54 percent of the area cultivated with rice. With its high level of productivity, the MRD has in recent years contributed more than half (56 percent) of Viet Nam's total rice production (GSO website) and about 90 percent of its total rice exports (World Bank, 2010).

FIGURE 3

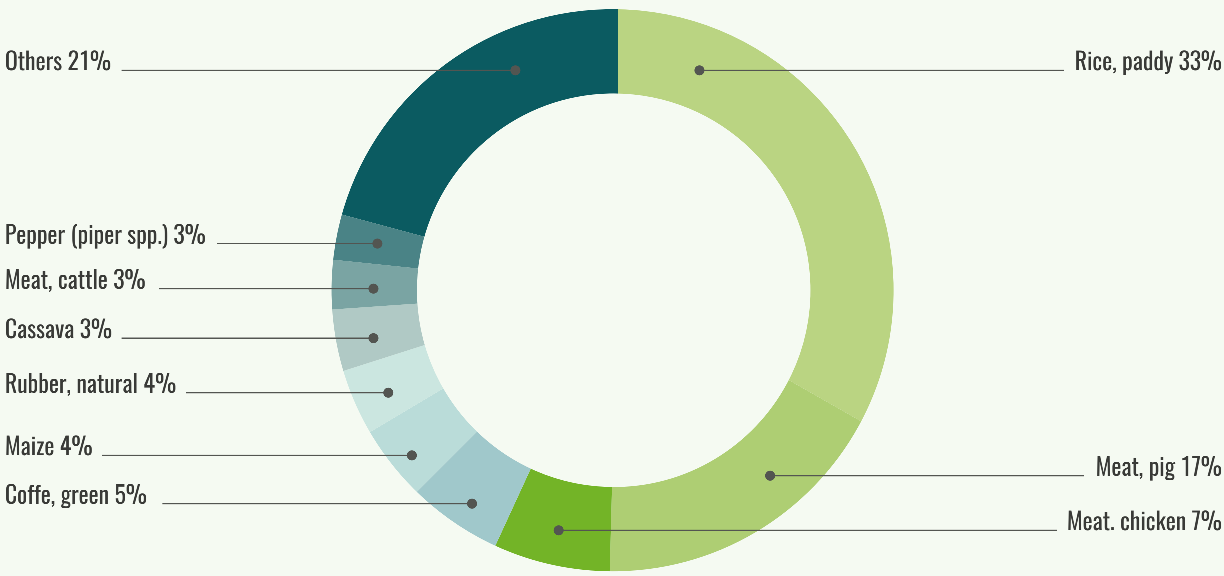
VIETNAMESE RICE PRODUCTION AND EXPORT (2000-2015)



Source: FAO, 2017b

FIGURE 4

TOP TEN COMMODITIES BY PRODUCTION VALUE, 2014



Source: FAO, 2017b

Agricultural production is concentrated in paddy rice, sugar cane, cassava, and vegetables. According to FAO (2017b), in terms of value, in 2014 rice accounted for around one third of total agricultural production. The livestock sector plays an important role as well, with pig meat accounting for 17 percent of total agricultural production, followed by chicken meat (seven percent). Beside rice, other important crops are coffee (five percent), maize (four percent), rubber (four percent) and cassava (three percent) (see **Figure 4**).

2.1.3 Energy

Viet Nam has emerged as an important producer of oil, natural gas and coal. The country's domestic natural gas production meets the internal demand for this fossil fuel and Viet Nam produces a small surplus of crude oil and coal. However, energy consumption – aided by power and fossil fuel subsidies – has increased with the country's economic development, which could hinder Viet Nam's ability to meet energy needs in the near future. Since 2005, the country has imported electricity from neighbouring Laos and China. Recent tensions between China and Viet Nam over China's actions in the South China Sea have prompted the Vietnamese government to push for further energy independence.

In 2015, coal accounted for over one third of the total primary energy supply, followed by biofuels and waste with 21 percent, oil products with 15 percent, natural gas with 13 percent, crude oil with 10 percent and hydro with 7 percent (see **Figure 5**). The country produced about 42 000 thousand tonnes of coal in 2015, which was almost totally (98 percent) consumed on the domestic market. Coal is used mainly for electricity generation and industry (IEA, 2018). Exports of coal were substantially reduced in the last three years as domestic consumption increased since several new coal-fired power plants came online. In an effort to further discourage external sales of coal, the Vietnamese government increased the coal export tax from 10 percent to 13 percent in 2013 (EIU, 2015).

Viet Nam is a net exporter of crude oil. Crude oil production has been volatile, but output has been rising (EIU, 2015). In 2015, Viet Nam produced 16 738 thousand tonnes of crude oil (IEA, 2018). However, with oil consumption increasing year-over-year (between 2004 and 2013, a 70 percent increase was recorded), the country needs to rely on imports of refined oil products in order to satisfy the domestic demand.

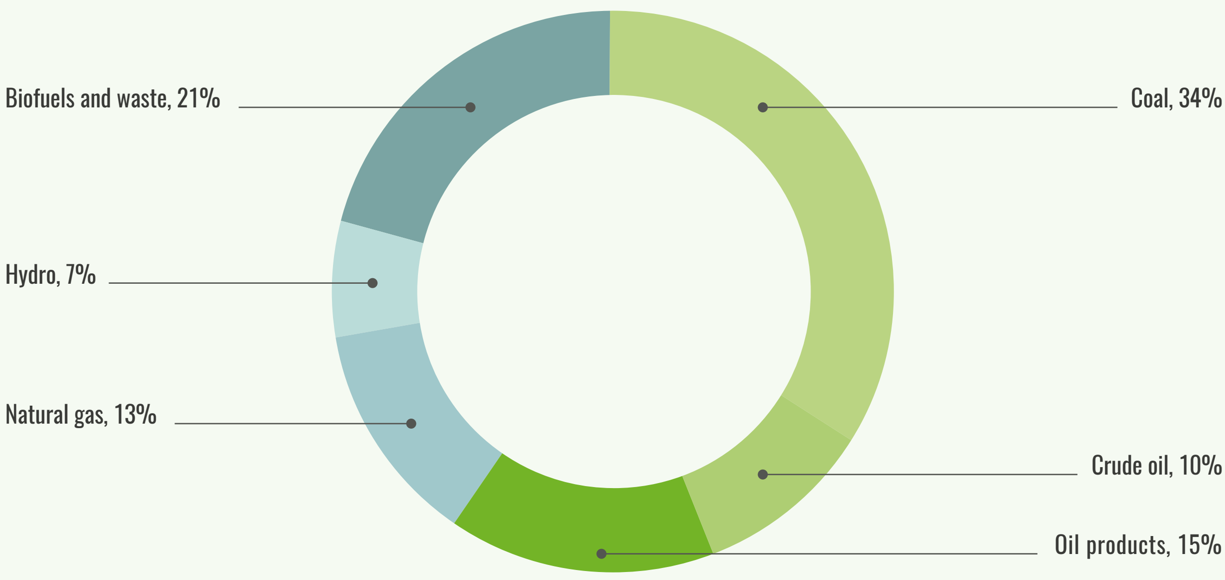
In 2015, Viet Nam consumed 58 180 ktoe of energy (IEA, 2018). In terms of total final energy consumption, in 2015 oil products accounted for 31 percent, followed by biofuels and waste with 25 percent, electricity with 21 percent and coal with 20 percent (see **Figure 6**). Energy consumption for 2015 to 2019 is projected to increase by five percent annually (EIU, 2015). To help meet this growing demand, PetroVietnam, the state-owned oil company, is looking to boost crude oil distillation. The company operates the Dung Quat refinery, which has been in production since 2009 and has a current capacity of 140 000 bbl/d. Three more refineries are being constructed and are expected to be completed by 2020 (ICCT, 2016). By 2018, PetroVietnam also expects two LNG import terminals to come on stream (EIU, 2015).

Electricity Vietnam (EVN), a state-owned enterprise, dominates the power sector: it is the largest buyer of electricity, and holds a monopoly on transmission and distribution (ITA, 2017). Hydropower, natural gas, and coal are the primary fuels used for electricity generation (IEA, 2018). With electricity consumption nearly matching generation in recent years and insufficient investment in new power plants, the electricity grid is under constant strain by the growing economy, and Viet Nam anticipates power demand to more than triple between 2011 and 2020 to 330 billion KWh. Recently, massive investments, even by non-State actors, have been channelled into building new power plants and grids to meet the soaring demand (UNDP, 2012).

Viet Nam has made significant progress in providing access to modern energy for most of the population. The country is rapidly modernising the power grid and other energy distribution networks (SE4ALL, 2014). Grid coverage is nearly complete (99.2 percent), and as of 2014, 99.9 percent of the urban population and 98.9 percent of rural population had access to electricity (World Bank, 2017). However, over one third of Vietnamese households still rely on traditional biomass for cooking (MECON Project, 2014), and almost five percent of them use coal (GSO website). In most cases, biomass is burned in inefficient stoves, leading to a high level of indoor pollution (UN Foundation, 2016).

FIGURE 5

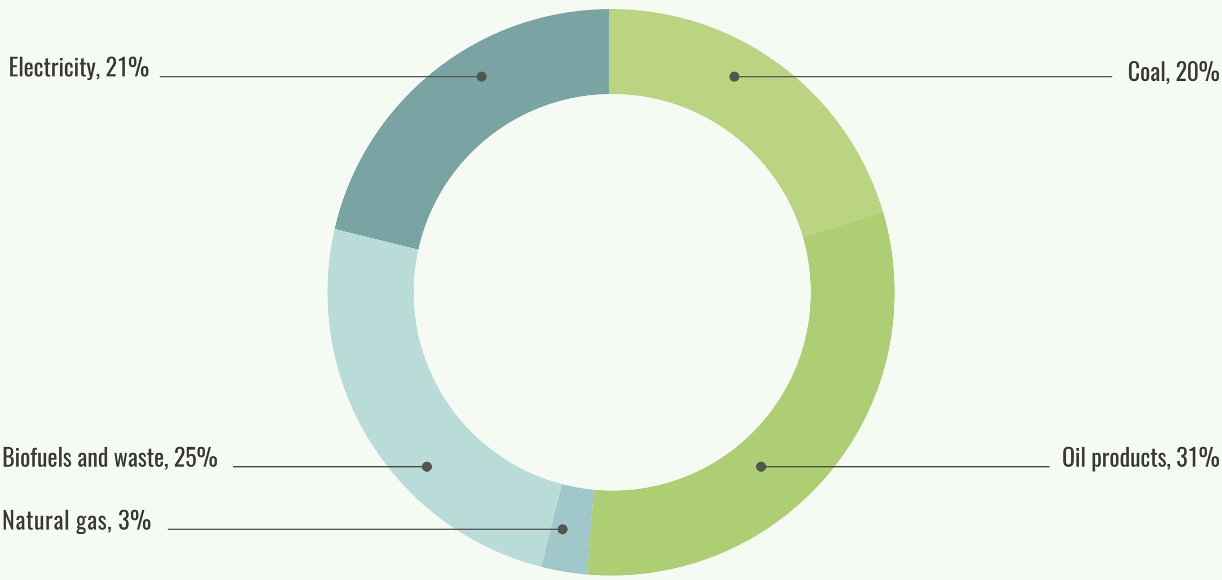
TOTAL PRIMARY ENERGY SUPPLY, 2015



Source: IEA, 2018

FIGURE 6

TOTAL FINAL ENERGY CONSUMPTION, 2015



Source: IEA, 2018

2.2 MODERN BIOENERGY: POLICY, LEGAL AND INSTITUTIONAL FRAMEWORK

2.2.1 Policy and legislation

Viet Nam is endowed with abundant renewable energy resources which are distributed throughout the country.

In 2007, Viet Nam produced an overarching development plan for its energy sector through to the year 2050, which is known as "The Viet Nam National Energy Development Strategy 2020, with Vision to 2050". As part of this plan, the government has committed to prioritizing the development of renewable energies and increasing their share of the energy supply to five percent by 2020 and 11 percent by 2050 (Vietnam Law and Legal Forum, 2007). This restructuring will be an important factor in the country's modernization and industrialization process as the government tries to meet the rapidly growing demand for energy.

ETHANOL

In addition to the aforementioned Strategy, there are also strategic plans for the development of specific types of renewables, including one for biofuels. In particular, in 2007, the "Scheme on Biofuel Development up to 2015, with a Vision to 2025" was adopted, with the Prime Minister's Decision No. 177/2007/QD-TTg of November 20, 2007 (Hai, 2007). The main objectives of the Scheme were:

- To contribute to the goal of energy security, reducing the dependence on petroleum;
- To protect the environment, while contributing to the implementation of the international commitments of the Government of Viet Nam to reduce GHG emissions; and
- To contribute to sustainable income generation for the agricultural sector and promote agricultural sector restructuring.

According to the Scheme, by 2025, the ethanol and biodiesel output should reach 250 000 tonnes, satisfying some one percent of the country's gasoline and diesel demand. To reach this ambitious goal, the government has outlined four main tasks and solutions. They are:

- Conduct research and development with regard to biofuels;
- Develop the biofuel production industry by encouraging other economic actors to invest in biofuel technologies in Viet Nam;
- Build biofuel development potential through increasing human resources know-how and modernizing machinery; and
- Increase international information and technology transfers.

As stipulated in the Prime Minister Decision No. 177/2007/QD-TTg of November 20, 2007, the Ministry of Industry and Trade (MOIT) was charged with coordinating and efficiently implementing this plan. It was also put in charge of the budget and selection of which biofuels projects would be eligible for investment. The MARD was tasked with planning how biofuel feedstocks will be developed as well as formulating and organizing the application of policy incentives and support for the production of biomass for biofuel production. The Ministry of Science and Technology is to coordinate with the MOIT on the organization and development of the research and development (R&D) projects related to biofuel. There are also two other ministries that have minor roles – the Ministry on of Planning and the Ministry of Finance (responsible for allocation of funds and providing guidance on the use of funds) and the Ministry of Education and Training (responsible for organizing the training of human resources to satisfy the biofuel development need).

The Prime Minister's Decision No. 53/2012/QD-TTg, dated 22 November 2012, establishing the Road map for application of biofuels in Viet Nam, indicates applicable blending rates of biofuels with conventional fuels for road-motorized vehicles using gasoline and diesel in Viet Nam and the road map for the implementation. Biofuels produced and distributed include E5, E10, B5 and B10. According with this Decision, starting from 1 December 2014 mandatory supply of E5 should have been required in seven cities and provinces including Ha Noi, Ho Chi Minh City (HCMC), HaiPhong, Da Nang, Can Tho, QuangNgai and Ba Ria-Vung Tau. Furthermore, the same mandate for E5 should have been applied from 1 December 2015 in the entire Country, while starting from 1 December 2016 an E10 mandate should have been applied in the above mentioned seven cities and provinces and being expanded to the whole economy starting from 1 December 2017. However, the aforementioned targets were not reached and the adoption of the country-wide E5 mandate was delayed.

An important factor affecting the competitiveness of the domestic ethanol industry is the pricing policies and mechanisms for gasoline and ethanol.

The gasoline retail price is controlled by the MOIT and established through the methodologies explained within the Circulars 83/2014-ND-CP and 189/BTC-QLG 18/3/2014. An example of a detailed calculation for establishing the retail price of ethanol and conventional gasoline (Mogas 92) is described in **Table 2**.

In case of E5 fuel, some items are modified in comparison with gasoline:

- Two percent lower VAT for E5 compared to conventional gasoline (eight percent VAT tax for E5 and ten percent VAT tax for gasoline, as of 1 Jan 2016, No. 6, **Table 2**);
- Zero deduction in E5 price for the Petroleum Price Stabilization Fund (compared with a deduction of 300 VND in price setting for conventional gasolines, No 9, **Table 2**); and
- Tax for environmental protection of 12.9 USD cents/litre (~ 2 850 VND/litre) for E5 in comparison with 13.6 USD cents/litre (3 000 VND/litre) for Mogas 92. This equates to a 0.7 USD cents (150 VND) lower environment tax for 1 litre of E5 compared to conventional gasoline price (No 10, **Table 2**);

In 2015 through to 2016 Quarter 1, E5 price regulation aimed at creating a price difference of 1.36-2.26 USD cents/litre (300-500 VND/litre) compared to conventional gasoline. However, the difference was not high enough to encourage customers to consume E5 fuel, and this caused low demand for ethanol fuel and weak absorption in the national market.

BIOGAS

Biogas technology was introduced in Viet Nam nearly 30 years ago and has gained huge popularity in the last 20 years (Ngan, 2011).

The project "Biogas Program for the Animal Husbandry Sector of Viet Nam" (BPPMU) is implemented by Livestock Production Department (under MARD) in cooperation with Netherlands Development Organization – SNV. The project began in 2003 and had three phases:

- Phase I (2003 - 2006): the project was implemented with a EUR 2.5 million grant from the Netherlands government, and covered 12 provinces nationwide.
- The bridging phase (2006): the preparatory year for phase II.
- Phase II (2007 – 2015), the project was deployed nationwide.

"The Biogas project makes a contribution to implement the national strategy on environmental protection in the period of 2010 – 2020 with the aim to halt pollution acceleration, remedy degraded areas and improve the environment quality and ensure sustainable development of the country is achieved; guarantee that all people are entitled to live in an environment with good quality of air, land and water measuring up to standards stipulated

TABLE 2.

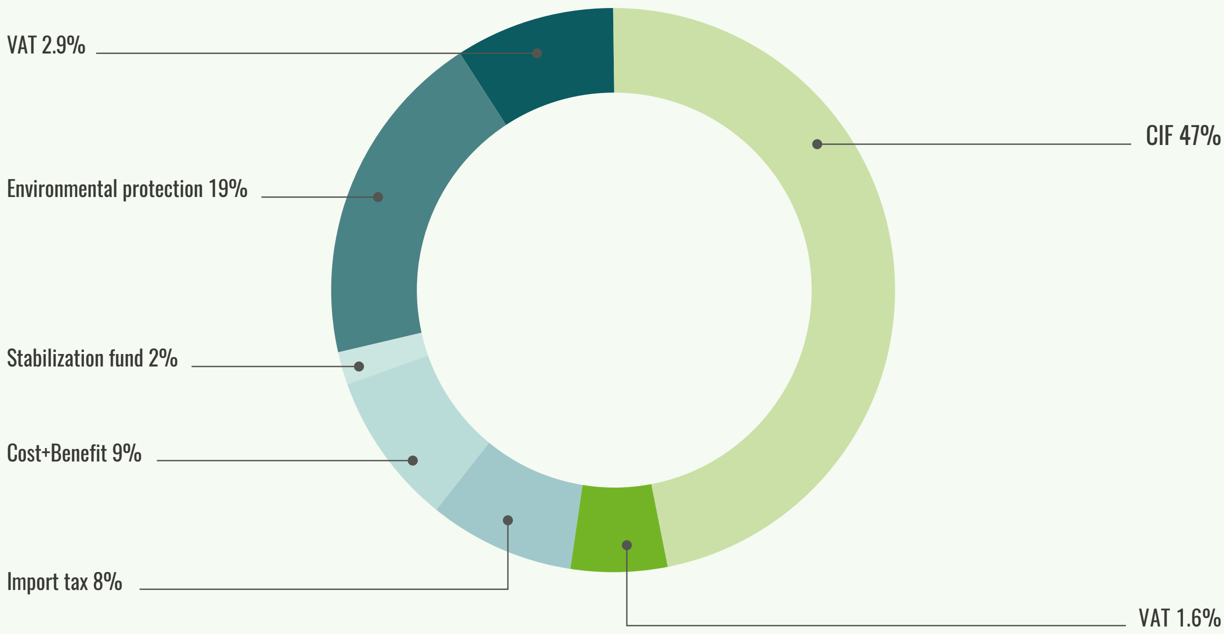
THE PRICE CALCULATION OF E5 AND GASOLINE MOGAS92 FOR 20 MARCH 2016

NO	ITEMS		UNIT	GASOLINE 92	E5
	INTERNATIONAL PRICE				
1	MEDIUM PRICE FOR 15 DAYS (FOB)		USD/BARREL	49.949	49.949
2	TRANSPORTATION AND INSURANCE (IF)		USD/BARREL	2.5	2.5
3	MEDIUM EXCHANGE RATE FOR 15 DAYS OF VCB		VNĐ/USD	22 328	22 328
	INTERBANK EXCHANGE RATE SYSTEM		VNĐ/USD	22 260	22 260
4	CIF (NO.4=NO.1+NO.2)		USD/BARREL	52.45	52.45
	CIF FOR BASE PRICE		VNĐ/LITRE, KG	7 252	7 252
	CIF PRICE FOR CALCULATION IMPORT TAX AND VAT TAX		VNĐ/LITRE, KG	7.23	7.23
5	IMPORT TAX	RATE	PERCENT	18.08	18.08
		VALUE	VNĐ/LITRE, KG	1 307	1 307
6	VAT	RATE	PERCENT	10	8
		VALUE	VNĐ/LITRE, KG	854	683
7	FIX COST		VNĐ/LITRE, KG	1 050	1 250
8	FIX BENEFIT		VNĐ/LITRE, KG	300	300
9	TRANSFER FOR PETROLEUM PRICE STABILIZATION FUND		VNĐ/LITRE, KG	300	0
10	TAX FOR ENVIRONMENT PROTECTION		VNĐ/LITRE, KG	3 000	2 850
11	VAT		VNĐ/LITRE, KG	1 406	1 364
12	BASE PRICE		VNĐ/LITRE, KG	15 469	15 006
13	RETAIL PRICE OF PETROLIMEX		VNĐ/LITRE, KG	13 750	13 320
14	DIFFERENCE BETWEEN RETAIL PRICE AND BASE PRICE		PERCENT	11.11	11.24
			VNĐ/LITRE, KG	1 719	1 686
15	PAID BY PETROLEUM PRICE STABILIZATION FUND		VNĐ/LITRE, KG	370	363
16	BASE PRICE (PREVIOUS)		VNĐ/LITRE, KG	14 122	13 684
17	DIFFERENCES WITH PREVIOUS RETAIL PRICE		PERCENT	9.54	9.66
			VNĐ/LITRE, KG	1 347	1 322

Source: based on Circular 83/2014-ND-CP and Circular 189/BTC-QLG 18/3/2014

FIGURE 7

TAXES AND FEES FOR GASOLINE IN VIET NAM



Source: IEA, 2018

by the State" (SEI, Thi Xuan Thu Le, 2015). As of 2011, nearly 150 000 biogas units have been constructed by the BPPMU (Giao, 2011).

Thanks to the cooperation between Viet Nam and the Netherlands, the Asian Development Bank and the World Bank, and to the government support, the number of anaerobic digestion systems has significantly increased over the past two decades.

BIOELECTRICITY

In 2014, the Viet Nam Prime Minister issued the decision 24/2014/QD-TTg, the first decision on supporting mechanism for the Development of Biomass Power Projects in Viet Nam. The MOIT is responsible for the coordination and implementation of the plan, including the provision of national technical standards for biomass power projects. The Ministry of Finance, in coordination with the MOIT and the MONRE, is to prescribe mechanisms to provide Viet Nam Environment Protection Fund-funded financial support to off-grid biomass power projects in accordance with current regulations.

Decision 24/2014/QD-TTg stipulated that, "Biomass energy used to produce electricity shall include: by-products, waste in agricultural production, processing agricultural and forestry products and other crops/trees that may be used as fuel for electricity production" (Dung, 2014). The plan included the development of biomass power projects both connected and not connected to the grid, and incentivized also the expansion of combined heat and power (CHP) projects. In this last case, Decision 24 established a Feed in Tariff (FIT) of 1 220 VND/kWh (fixed at 5.8 USD cents) for investors that wanted to sell their surplus power to the grid.

On 11 March 2016, MOIT issued, via Decision 942/QD-BCT, the Avoided Cost Tariff (AVCT) to be applied to all biomass power projects except CHP projects and bagasse-based extraction-condensing power generation projects for sugar mills. According with this decision, the above mentioned biomass power projects can sell their surplus electricity to the grid at around 7.4 USD/Cent/kWh, depending on the region the project is located in.

On 18 March 2016, the Prime Minister of Viet Nam approved the "Revised National Power Development Master Plan for the 2011-2020 period with the vision to 2030 (the "Revised

Power Master Plan VII"), which puts strong emphasis on energy security, energy efficiency, renewable energy development and power market liberalisation.

The plan sets out four specific targets for the country's power development from 2016 to 2030, by prioritizing the development of power generation from the renewable energy so that the proportion of electricity generated from the renewable energy (not included large and middle hydro power and pumped storage) will reach seven percent by 2020 to over ten percent by 2030. Furthermore the plan promotes the rural electrification program in rural, mountainous and island areas so that most of the rural households will have access to and use the electricity (IAEA, 2016).

REFERENCES

CBD. no date. Country Profiles: Viet Nam – Main Details. Available at: www.cbd.int/countries/profile/?country=vn

Dung, N.T. 2014. Prime Minister Decision No. 24/2014/QD-TTg dated March 24, 2014, on support mechanism for development of biomass power projects in Vietnam. Hanoi. Available at: http://hethongphapluatvietnam.net/decision-no-24-2014-qd-ttg-dated-march-24-2014-on-support-mechanism-for-development-of-biomass-power-projects-in-vietnam.html

EIU. 2015. Industry Report, Energy: Vietnam. Available at: http://country.eiu.com/filehandler.ashx?issue_id=753206059&mode=pdf

FAO. 2006. Rapid growth of selected Asian economies: Lessons and implications for agriculture and food security in the Republic of Korea, Thailand and Viet Nam. Available at: www.fao.org/docrep/009/ag089e/AG089E08.htm

FAO, IFAD and WFP. 2015. The State of Food Insecurity in the World 2015. Meeting the 2015 international hunger targets: taking stock of uneven progress. Rome, FAO. Available at: www.fao.org/3/a-i4646e.pdf

FAO. 2017a. Integrating Agriculture in National Adaptation Plans (NAP-Ag): Viet Nam. Available at: www.fao.org/in-action/naps/partner-countries/vietnam/en/

FAO. 2017b. FAOSTAT. Available at: www.fao.org/faostat/en/#data [Accessed 20 Jan 2018]

Giao, H.K. 2011. Công nghệ khí sinh học quy mô hộ gia đình (Household biogas technology). Hà Nội.

Greater Mekong Subregion Environment Operations Center. 2012. Greater Mekong Subregion Atlas of the Environment (2nd Edition). Available at: http://portal.gms-eoc.org/maps?cmbIndicatorMapType=archive&cmbIndicatorTheme=33&cmbIndicatorMap=33 [Accessed 8 March 2018]

GSO website. Statistical data: Agriculture, Forestry and Fishery. Available at: www.gso.gov.vn/default_en.aspx?tabid=778

Hai, H.T. 2007. Prime Minister Decision No. 177/2007/QD-Ttg of November 20, 2007, Approving the scheme on development of biofuel up to 2015, with a vision to 2025. Available at: http://theredddesk.org/sites/default/files/decision_177-2007-ttg_eng_2.pdf

IAEA. 2016. Country Nuclear Power Profiles, 2016 Edition: Viet Nam. Available at: www.pub.iaea.org/MTCD/Publications/PDF/cnpp2016/countryprofiles/Vietnam/Vietnam.htm

ICCT. 2016. Case study: refineries in Viet Nam. Working Paper 2016-3. Stephanie Searle, Chris Malins. Available at: www.theicct.org/sites/default/files/publications/Case_Study_Refineries_Vietnam.pdf

IEA. 2018. Viet Nam: Balances for 2015. Available at: www.iea.org/statistics/statisticssearch/report/?country=Vietnam&product=balances

ITA. 2017. Vietnam – Power Generation. US Department of Commerce. Available at: www.export.gov/article?id=Vietnam-Power-Generation [Accessed 6 Feb 2018]

MARD. 2017. Restructure of forestry sectors.

MECON Project. 2014. Household energy efficiency: a socio-economic perspective, Vietnam. Available at: www.meconproject.com [Accessed 15 Apr 2017]

MOIT. 2015. Biofuel Development in Vietnam. Presentation at 3rd GBEP Bioenergy Week.

Indonesia. Available at: www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/2015_events/3rd_Bioenergy_Week_25-29_May_Indonesia/26_5_3_HIEU.pdf

MONRE. 2014. Vietnam National Biodiversity Strategy to 2020, vision to 2030. Available at: www.cbd.int/doc/world/vn/vn-nbsap-v3-en.pdf

Mui, N.T. 2006. Country Pasture/Forage Resource Profiles: Viet Nam. FAO. Available at: https://ees.kuleuven.be/klimos/toolkit/documents/661_Vietnam.pdf

OEC. no date. What does Vietnam export? (2015). Available at: http://atlas.media.mit.edu/en/visualize/tree_map/hs92/export/vnm/all/show/2015/

SE4ALL. 2014. Viet Nam: Rapid Assessment and Gap Analysis. Sustainable Energy for All, Washington.

Son, D.K., Que, N.N., Dieu, P.Q., Trang, T.T.T. and Beresford, M. 2006. Policy reform and the transformation of Vietnamese agriculture. Rapid Growth of Selected Asian Economics. Available at: www.fao.org/docrep/009/ag089e/AG089E08.htm

Stockholm Environment Institute (SEI), Thi Xuan Thu Le. 2015. Bio-slurry Management and Utilization and Need for Training. Available at www.ccacoalition.org/en/resources/manure-management-report-bio-slurry-management-and-utilization-and-need-trainingManagement_EN.pdf

UNDP, 2012. Case study power sector reform in Vietnam. Available at: www.vn.undp.org/content/dam/vietnam/docs/Publications/Power%20Sector%20Case%20Study_Energy%20Alliance_2012.pdf

UNEP-WCMC. 2017. Protected area profile for Viet Nam from the World database of protected areas, November 2017. Available at: www.protectedplanet.net

UN Foundation. 2016. Country profiles: Vietnam. Available at: http://cleancookstoves.org/country-profiles/70-viet-nam.html [Accessed 6 Feb 2018]

USAID. 2013. Property rights and resource governance profile: Vietnam. Available at: https://usaidlandtenure.net/wp-content/uploads/2016/09/USAID_Land_Tenure_Vietnam_Profile.pdf

Vietnam Law and Legal Forum. 2007. Decision No. 1855/QD-TTg of December 27, 2007, Approving Vietnam's National energy development strategy up to 2020, with 2050 vision. Official Gazette. Issue No.s 08-09/December 2007. Available at: http://faolex.fao.org/docs/pdf/vie78162.pdf

World Bank. 2010. Potential climate change mitigation opportunities in the agriculture and forestry sector in Vietnam: Background Paper. Available at www.wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2010/11/25/000333037_20101125031815/Rendered/PDF/581020WP0P11061port1revised0June029.pdf

World Bank. 2017. World Development Indicators: Vietnam. Available at: http://data.worldbank.org/country/vietnam.

World Bank. 2018. World Development Indicators. Available at: http://databank.worldbank.org/data/reports.aspx?source=2&country=VNM

CHAPTER 3

CHAPTER

3

DESCRIPTION OF SELECTED BIOENERGY PATHWAYS IN VIET NAM

3.1 CASSAVA-BASED ETHANOL

The Cassava-based ethanol value chain consists of five phases: cassava farming; cassava chips processing; ethanol production; ethanol distribution and blending; and ethanol use. These phases and the associated steps are shown in **Figure 8**, together with the related energy inputs (both direct and indirect).

3.1.1 Cassava Cultivation[5]

Cassava is the third most important crop in Viet Nam, after rice and corn, in terms of harvested area (566 500 ha in 2015) and total production (almost 10.7 million tonnes of fresh cassava in 2015). It is grown all over the country (see **Table 3** and **Figure 9**), with one crop season per year in the North and in the Centre, and three crop seasons every two years in the South (Ham *et al,* 2016).

The cassava farm size in Viet Nam is small and cassava farms in the Southeastern Region are on average double the size of those in North Viet Nam. The cassava area per farm for all of Viet Nam is on average 0.27 ha, with extremes for the Southeast (0.85 ha) and the North Mountainous Region (0.20 ha). When farms are classified according to size, 31.6 percent of the sampled farms are small scale (area smaller than 0.6 ha), 35.5 percent are medium scale (area between 0.6-1.05 ha), and the remaining 33 percent are large scale (area larger than 1.05 ha) (Binh *et al.*, 1996).

[5] Most of the information reported in this section refer to the North and the South of Viet Nam. Cassava cultivation practices in the Centre of the country are similar to those in the North.

FIGURE 8

CASSAVA-BASED ETHANOL VALUE CHAIN IN VIET NAM AND RELATED ENERGY INPUTS

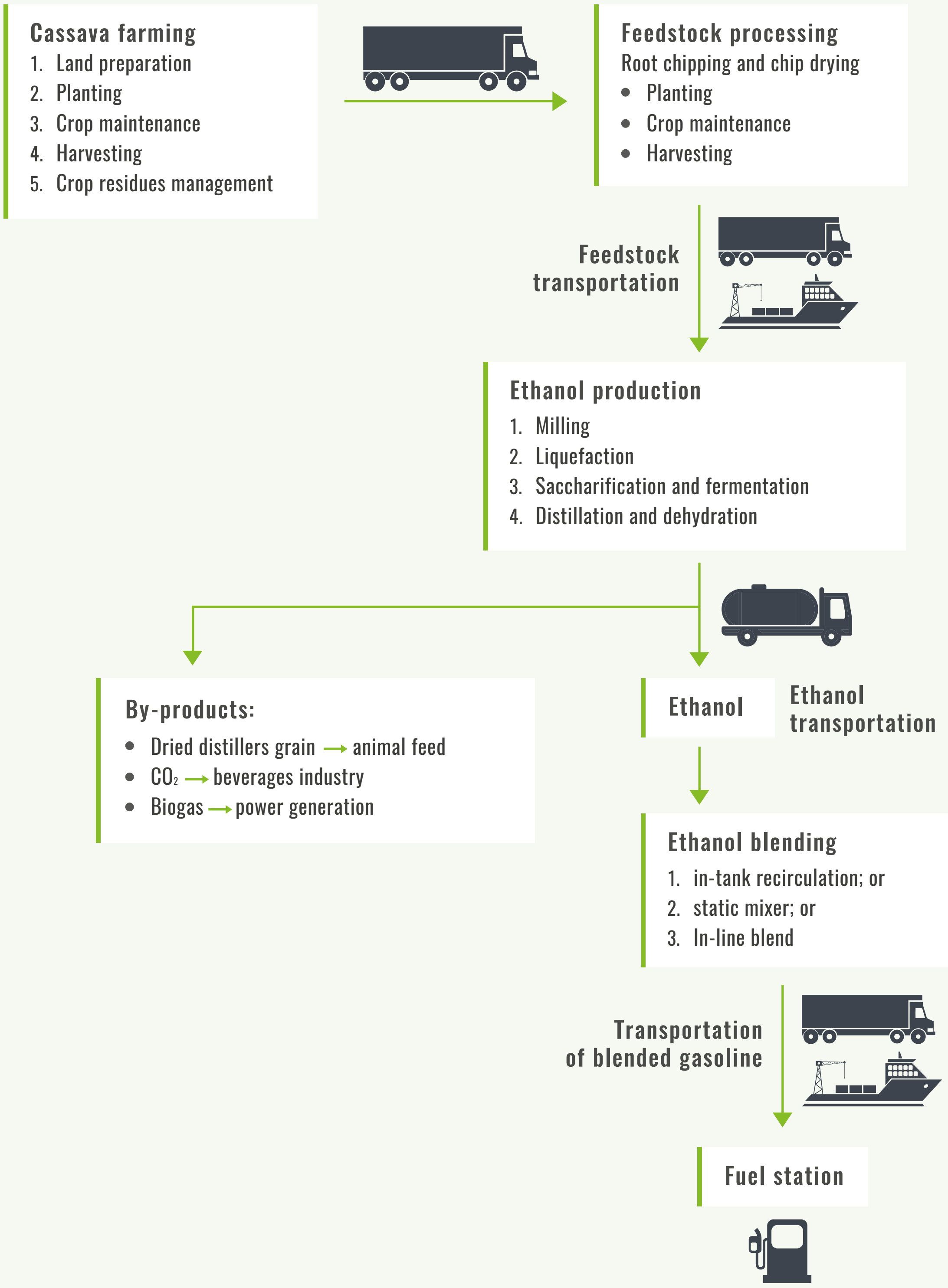


TABLE 3.

CASSAVA HARVESTED AREA AND PRODUCTION BY PROVINCE, 2015

	HARVESTED AREA (1000xha)	PRODUCTION – FRESH CASSAVA (1000xtonne)
VIET NAM	566.5	10 673.7
YIEN BAI	15.8	305.0
SON LA	31.2	359.5
NGHE AN	17.4	410.0
QUANG NGAI	19.7	376.4
BINH DINH	13.6	335.5
PHU YEN	23.0	397.2
BINH THUAN	30.9	510.8
KON TUM	39.5	590.2
GIA LAI	63.7	1 180.9
DAK LAK	34.0	666.5
BINH PHUOC	17.7	410.9
TAY NINH	57.6	1 868.3
DONG NAI	15.8	399.2

Source: GSO website

Cassava farming in Viet Nam occurs mainly in two different situations – i.e. in flat zones set in delta areas and in hilly/mountainous areas with a degree of slope higher than eight percent – both of which were analysed in this study.

Cassava farming consists of the following steps:

1 Land preparation
2 Planting
3 Crop maintenance
4 Harvesting
5 Crop residue management

a. Land preparation

Cassava land preparation methods vary across agro-ecological regions. On sloping lands both in the North and in the South of Viet Nam, most cassava fields are ploughed once, while in the flat land such as in the South Central Coastal regions ploughing occurs twice (BinhThuan's DARD, 2016). The common soil preparation technique and plantation design for cassava production in Viet Nam could be described as follows:

- Cultivated land must necessarily be cleared of tree roots and plant residues. Soil is levelled and weeds handled;
- Ploughing is performed once on sloping lands and twice in flat lands;
- On sloping land, minimum soil preparation is carried out to limit erosion and drift. If the soil has a significant slope (> eight percent) then ploughing is avoided;
- In the mountainous region in the North, as most of cassava production occurs in sloping areas, soil preparation for cassava planting is almost completely manual or performed by animal traction. In the South of Viet Nam, as soil is flat and cassava plantation is more intensive, soil preparation is done by machine. **Figure 10** represents land preparation by animal traction (left) and by machine (right) for cassava production in South and Southwest of Viet Nam, such as in Tay Ninh province (Loan *et al.* 2013).

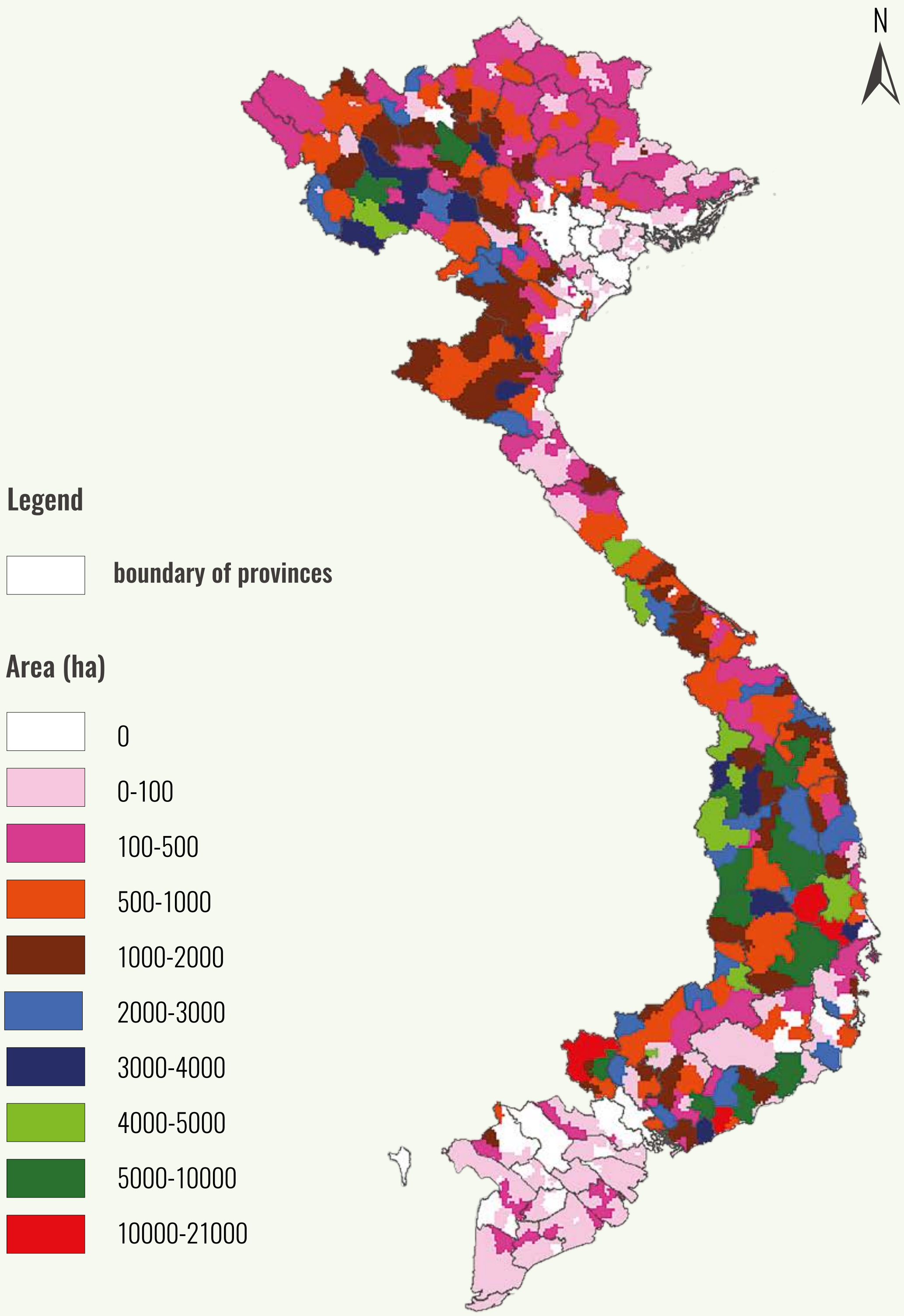
b. Planting

In the North, cassava cultivation is usually rain fed. The cassava planting season occurs 2-3 months before the beginning of the rainy season, in late February or March. In the South, cassava can be planted both in February and in September.

In the North, where soil is more prone to erosion because of slopes, cassava is cultivated in row plantations on contours, and crop rotation

FIGURE 9

CASSAVA HARVESTED AREA, 2016



Source: Elaborated by IAE as part of this study

FIGURE 10

LAND PREPARATION BY ANIMAL TRACTION (LEFT) AND MACHINE (RIGHT).

Source: Loan et al.*, 2013*

and/or intercropping with legumes is often used. The density of cassava plantation depends on soil fertility. Good soil can support high density (from 12 500 to 13 500 shoots per ha) while low fertility soils can only support reduced crop density (10 000 shoots per ha) (Hung, 2005; Tam, 2011).

c. Crop maintenance

The amount of fertilisation varies depending on the region and the slope of the land where the cassava is farmed. On flat land there is a high input level (**Table 4**) and on sloping land with an incline higher than eight percent, the input level is much lower (**Table 5**).

For cassava cropping, farmers apply both synthetic and organic fertilizers, such as farm yard manure, compost or crop residues. Fertilization rate is a function of soil fertility, target yield and crop variety used. Normally, in the South of Viet Nam, where there is higher plant density because soil is more flat, farmers fertilize more than in the North.

A low amount of inputs is used for cassava plantation in sloping land. In fact, soils in these areas are poor and prone to erosion. As a consequence, cassava yield on sloping land is very low – 8.0-18.9 tonne/ha according to Dieu (2015) and 12-18 tonne/ha according to the Department of Crop Production (2016). Fertilizer efficiency in these areas is low due to a high level of leaching and runoff. In these areas, a significant amount of soil can be lost, depending on rain intensity and slope degree, as well as on the type and intensity of soil cover.

WEEDING

Weed control is performed by hand, or using a small tractor and herbicides. The amount of herbicide used depends on the region and on the active substance of the product. For example, when Dual Antacid or Antaco is sprayed at pre-germination phase, it is used at a rate about of 2.5 litres/ha. However, only 1.2 litres/ha of Dual Antacid or Antaco are used if weeding by hand is combined with spraying 25 to 30 days after planting (BinhThuan's DARD, 2016).

PESTICIDES AGAINST DISEASES

Some pesticide is commonly applied. The common pests and diseases and their relevant pesticides are shown in **Table 6**.

d. Harvesting

Cassava harvesting is usually performed 7-11 months after the planting season. In the North, it is generally still performed by hand, while in flat areas in the South harvesting is commonly performed by machine.

e. Crop residue management

Up to now, no studies on the management of cassava residues were performed so far. After cassava root harvest, shoots are often left in the field corners, dried by sun and then used as fuel for cooking. A small percentage of shoots is reused for seeding in the following crop seasons. Shoot biomass is then left decomposing or burned.

TABLE 4.

CASSAVA CULTIVATION ON FLAT LAND IN SOUTH VIET NAM: HIGH INPUTS

	UNIT	AVERAGE	SOURCE
CULTIVATION			
CASSAVA YIELD	tonne/ha/year	25.0	GSO WEBSITE
WATER CONTENT	percent	65.0	VCA (2017)
HARVEST RESIDUE	tonne/ha/year	15.5	Ha (2016)
BURNING OF RESIDUES		NO	IAE (2017)
FERTILIZER & PESTICIDES			
MANURE	kg N/ha/year	39.2	IAE (2017)
N-FERTILIZER	kg N/ha/year	138.5	IAE (2017)
P_2O_5	kg P_2O_5/ha/year	115.5	IAE (2017)
K_2O	kg K_2O/ha/year	105.3	IAE (2017)
CAO	kg $CaCO_3$/ha/year	600.0	IAE (2017)
STILLAGE	kg N/ha/year	0.0	
PESTICIDES	kg/ha/year	2.0	IAE (2017)
SEEDS			
CASSAVA CUTTINGS	kg/ha/year	750.0	Ha (2016)
ENERGY			
DIESEL	litre/ha/year	22.5	IAE (2017)
ELECTRICITY CONSUMPTION (FOR IRRIGATION)	kWh/ha/year	45.0	IAE (2017)

TABLE 5.

CASSAVA CULTIVATION ON SLOPING LAND IN NORTH VIET NAM: LOW INPUTS

CULTIVATION	UNIT	AVERAGE	SOURCES
YIELD			
CASSAVA YIELD	tonne/ha/year	14.75	DCP (2016); GSO WEBSITE
WATER CONTENT	percent	65	VCA (2017)
HARVEST RESIDUE	tonne/ha/year	12.07	
BURNING OF RESIDUES		NO	Ha (2016)
FERTILIZER & PESTICIDES			
N-FERTILIZER	kg N/ha/year	50	FCRI (2016)
MANURE	kg N/ha/year	36	FCRI (2016); DCP(2008)
P_2O_5	kg P_2O_5/ha/year	50	FCRI (2016)
K_2O	kg K_2O/ha/year	60	FCRI (2016)
CAO	kg $CaCO_3$/ha/year	100	Ha (2016)
STILLAGE	kg N/ha/year	0	
PESTICIDES	kg/ha/year	0	Ha (2016)
SEEDS			
CASSAVA CUTTINGS	kg/ha/year	875	Ha (2016)
ENERGY			
DIESEL	litre/ha/year	0	Ha (2016)
ELECTRICITY CONSUMPTION (FOR IRRIGATION)	kWh/ha/year	0	Ha (2016)

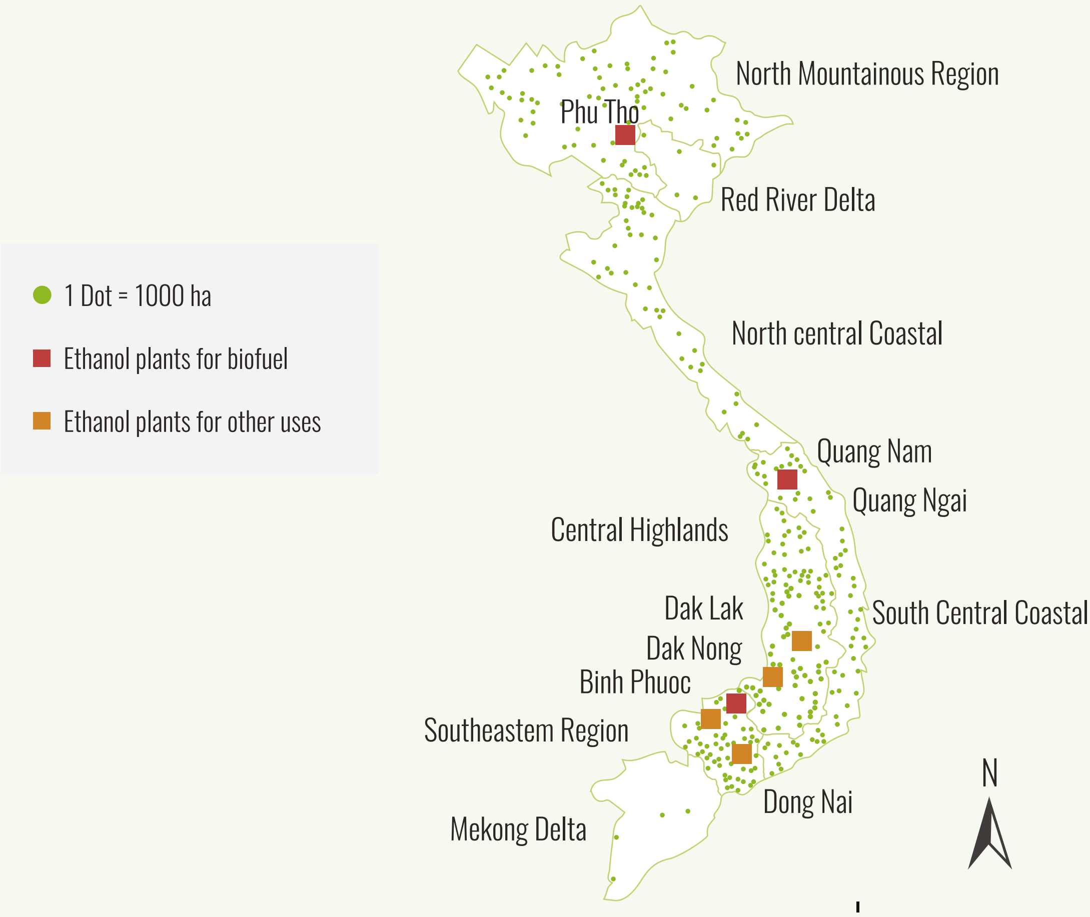
TABLE 6.

COMMON PESTS AND DISEASES AND THEIR RELEVANT PESTICIDES

PEST/DISEASE	EXAMPLES OF COMMON PESTICIDES
BEETLES	ONCOL
RED SPIDERS	ADMIRE, COMITY, NISSORUN
BEDBUGS	SK ENSPRAY, DC-TRON PLUS, MAP PERMETHRIN, WIMAX, CARBOFURAN, VIBASU, VICAP, VISA, PADAN, REGENT, DIAZINON
ROOT ROT, BURN LEAVES	BENLATE, BENLATE-C, COPPER-B, BAVISTIN
SPOTTED LEAVES	SCORE, CARBENZIM, CARBENDO
POWDER	MANOZED, KUMULUS, SUMI EIGHT, CARBENDO, SCORE

FIGURE 11

LOCATIONS OF CASSAVA AREAS AND ETHANOL PLANTS IN VIET NAM, 2012



Source: GSO website

3.1.2 Cassava chips processing

After harvesting, 40-60 percent of cassava roots are chopped into small pieces or chips by machine or sliced manually into chips, then distributed on a large cement floor and sun-dried. A diesel tractor with a special attachment is used to turn the chips several times per day. The harvest period occurs in the cold season when there is less sunshine so cassava roots must be thinly sliced and two to three days are required for drying. The typical conversion ratio of fresh roots to dried chips is 2.4-3.0 kg per kg of fresh cassava. However, frequent changes in the weather, such as rain or sudden increases in temperature, may result in substandard quality of dried cassava chips and large losses due to rotting.

Various kinds of chipping machines have been introduced so far in the country. In large-scale or industrial size farms, cassava is sliced using machines before being delivered to ethanol plants in the form of dried chips. However, since the average cultivated area of cassava per household in the country is very small (< 0.5 hectare), most Vietnamese farmers use a simple hand-held chipping knife.

There are two ways feedstock is delivered to the ethanol production plants: 1) Cassava is transported from cultivation areas directly to the plants; and 2) Cassava is transported from the main production areas to ports and from the exporting ports to the plants. The transportation occurs on 40 tonne trucks (full load).

3.1.3 Ethanol conversion

The ethanol production process from cassava feedstock consists of four main steps:

- Milling: the main purpose of this step is to make cassava feedstock physically suitable for downstream processing, i.e. cooking, starch hydrolysis, fermentation and distillation, and dehydration. This step includes impurity removal (metal detection and removal of slurry-sand and soil by hydro cyclone) and size reduction by milling.
- Liquefaction: cassava starch is cooked to rupture the granular structure and hence improve its exposition to enzyme hydrolysis. Cooking is performed at a temperature greater than a gelatinization temperature and commonly in a presence of liquefying enzymes, i.e. α-amylase to liquefy cooked slurry.
- Saccharification and fermentation: the liquefied slurry is cooled down to 32 °C, and afterward glucoamylase and yeast are added together. While glucoamylase produces glucose, yeast can use glucose to produce ethanol immediately.
- Distillation and dehydration: the fermentation broth is subjected to distillation to concentrate the ethanol to 95 percent and then dehydration to remove water, yielding anhydrous ethanol (99.5 percent).

Besides ethanol, by-products include Dried Distillers Grains sold for animal feed production, biogas used as a supplemental energy, and CO_2 collected for sale. According to a survey conducted for the scope of this study, the conversion ratio of dried chips to ethanol is on average 2.3 kg/litre (VJIIST, 2017).

3.1.4 Ethanol distribution and blending

Ethanol is sold to oil companies and delivered to blending stations by trucks. At the blending stations, three methods can be used: 1) in-tank recirculation; 2) static mixer; and 3) in-line blending. The first two methods require tanks for handling the ethanol fuel, while in the "in-line blend" method, gasoline and ethanol are blended directly in-line before being transferred by truck and ship to the gasoline station for domestic consumption. At the blending stations, the tank blending process uses pumping machines to deliver gasoline and ethanol into one tank and to perform recirculation within this storage tank. Most of the petroleum distribution companies choose the "in-line blend" method and several blending systems have been installed so far across the country.

According to MOIT (2012), there are five enterprises that are prepared for the production of E5 fuel in Viet Nam, including PetroVietnam and Petrolimex. E5 gasoline has been distributed in seven provinces and cities in Viet Nam since December 2012 (Decision 53/2012/QD-TTg and Decision 173/2014/-TTg), including Quang Ngai, Da Nang, Hanoi, Ho Chi Minh City, Hai Phong, Ba Ria-Vung Tau, and Can Tho.

TABLE 7

CAPACITY AND OPERATION STATUS OF ETHANOL PLANTS IN VIET NAM

NO.	NAME OF FACTORY	CAPACITY		LOCATION (PROVINCE)	OPERATION STATUS
		Ethanol (Ml/year)	Cassava chip (Tonne/year)		
ETHANOL PLANTS FOR THE FUEL MARKET					
1.	PHUTHO BIO-ENERGY CO.	100	250 000	PhuTho	NOT OPERATIONAL
2.	DAI TAN ETHANOL PLANT	120	300 000	Quang Nam	OPERATIONAL
3.	DUNG QUAT ETHANOL PLANT BSR-BF	100	250 000	QuangNgai	NOT OPERATIONAL
4.	ORIENT BIO-FUEL CO.	100	250 000	BinhPhuoc	NOT OPERATIONAL
5.	TUNG LAM ETHANOL FACTORY	76	190 000	Dong Nai	OPERATIONAL
	TOTAL CAPACITY	496	1 240 000		
ETHANOL PLANTS FOR OTHER MARKETS					
6.	DAI VIET CO.	68	170 000	DakNong	
7.	QUY NGUYEN CO.	50	125 000	BinhPhuoc	
8.	ETHANOL DAKLAK JOINT STOCK CO.	66	165 000	DakLak	

Source: Elaborated from Loan T. Le **et al.**, *2013 and MOIT, 2017*

3.1.5 Current ethanol production and consumption

At present, Viet Nam has five plants dedicated to ethanol production for the fuel market, of which only two are operational. The capacity and operation status of the five fuel ethanol plants are shown in **Table 7**.

At the moment, there are no flex-fuel vehicles circulating in Viet Nam. However, as mentioned above, ethanol is blended with gasoline for use in conventional engines. Total national consumption of ethanol in 2016 was around 29 500 m^3, contributing marginally to the gasoline Mogas 92 market (MOIT, 2017).

3.2 BIOGAS

3.2.1 Biogas technologies in Viet Nam

Viet Nam has a tropical and humid climate during the entire year, with annual average temperature ranging from 23 °C to 27 °C, which suits ADs' needs by providing good conditions for microbial activity that aid in obtaining a high percentage of methane in the biogas (Ho, Kilgour and Lucas, 2015).

According to the Department of Livestock Production (MARD, 2016), the biogas technologies for anaerobic digesters (ADs) applied so far in Viet Nam are the following:

- KT1 - Chinese technology;
- KT2 and KT3, i.e. floating biogas digester (India);
- Biogas bags made of nylon polyethylene (PE); and
- Biogas cover with tarpaulin HDPE, i.e. composite digester.

The biogas systems consist of a brick domed digester vessel designed either as a KT1 plant or a KT2 plant. The KT1 has a fixed-dome shape verses the KT2 that has a shallower or flatter shape to accommodate for the higher water tables of Southern Viet Nam. KT1 and KT2 models have been developed according to the biogas sector standard 10TCN 492:499-2003 and 10TCN 97:102-2006 issued by the Ministry of Agriculture and Rural Development (Biogas Program for the Animal Husbandry Sector in Viet Nam, no date).

TABLE 8

BIOGAS PLANTS IN VIET NAM, 2015

TYPE OF TECHNOLOGY USED	TOTAL	FARM SCALE (MBP and LBP)	HOUSEHOLD SCALE (SBP)
TOTAL NUMBER OF BIOGAS PLANTS	465 370	15 370	450 000
KT1, KT2	226 412	4 032	201 469
COMPOSITE	97 320	2 390	89 147
OTHER TYPES	141 638	8 948	159 384

Source: MARD, 2016

Biogas bags made of polyethylene (PE) cost between a quarter and a fifth of the price of the construction of rigid ADs, so they are very attractive to small farmers. In addition, this type of bag is easy to install, simple to operate, easy to repair, and does not require specific skills for its construction or management. The disadvantage is that biogas bags need to avoid sunlight and mechanical damage.

The composite digester was introduced in Viet Nam in 2008. This model originates from China and is produced in large numbers by several companies in Viet Nam. The main advantage of the biogas composite is the high durability (the lifetime is 20 years). The construction and installation works are simple, fast and do not require training of masons. Furthermore, the composite AD can be excavated and moved to another location, so it is suitable in areas of urbanization (Ngan, 2011). The disadvantages of this model are its high cost and that is difficult to transport.

According to the Department of Livestock Production (MARD, 2016), the ADs currently existing in Viet Nam can be classified depending on their scale/volume as follows: Small Biogas Plants (SBP), Medium Biogas Plants (MBP) and Large Biogas Plants (LBP). The SBP digesters are installed at household level and often fed with animal manure, mainly from pigs; they have an average volume of 10 m^3. The MBP digesters have an average volume of 500 m^3 and the LBP digesters have an average volume of 2000 m^3. SBP and MBP digesters can be fed with animal manure or with the residues/waste of agro-industrial processes. The total number of ADs installed in Viet Nam, by type of technology and scale/volume, is shown in **Table 8**. According to the Department of Feedstock production, only 90 percent of all installed ADs are currently operational.

Digestate is the name assigned to the residue from the anaerobic digestion. It is a liquid product, rich in organic compounds and mineral nutrients, generally used as fertilizer and soil amendment. Once it is collected from the digester, the digestate must be stored before being applied to the fields. The anaerobic digestion process continues in the tank, therefore an additional amount of biogas is produced during the storage period. In Viet Nam, this amount of biogas is further recovered because the digestate is still stored in a closed biogas tank.

3.2.2 Biogas at household level

Biogas production

Most biogas plants in Viet Nam are simple, small-scale reactors that can use a wide range of different biomasses available on farms as feedstock. However, the feedstock most used by households is pig manure, and only a small number of households input cow/buffalo and/or poultry manure (see **Table 9** for an overview of the potential biogas yield from these different feedstocks). The manure is not separated before feeding into the digesters but is scraped off the concrete floor into the AD together with washing water.

The average size of biogas plants at household scale is 10 m^3 and the amount of animals per household mostly determines the size of the biogas plant. The smallest digester has a minimum feedstock requirement of around 20 kg/day, roughly equivalent to two bovines or six pigs.

Technology applied in biogas at household scale is anaerobic fermentation with biodigesters made from composite, plastic bags, steel (floating AD) and fired bricks (fixed dome AD). Where the brick dome digesters predominate, the standard size of these digesters is 6-8 m^3.

The household digesters are often not heated and they operate at the temperature of surrounding soil in which they are buried. In the North, the average air temperature is around 34 °C, which is very suitable for bacterial fermentation, but during winter the temperature drops to 10-15 °C, thus biogas production during winter is lower than in summer and is not sufficient for the needs of people, especially in the mountainous regions.

Some households do not feed the digesters with manure and water at the recommended volume ratio (1:3), instead they use a greater amount of water for cleaning the pigpen and flushing manure into the digesters, and only stop adding water when the pigpen is clean, so the manure is very dilute. This fact, combined with a low retention time (from 1 to 20 days) compared to the optimal conditions, causes low biogas yield at household scale. In contrast, some households add too much slurry to the AD leading to surplus biogas being produced, exceeding the household's requirements so these households have to release biogas into the atmosphere, with negative impact on the environment.

Many households install filter equipment made from China and/or Viet Nam to remove H_2S from the gas collected from digesters.

Biogas use

At household level, biogas is mostly used for feeding cookstoves and for lighting. In the case of lamps, the average number of biogas lamps per house is 1.8, with average lighting time of 3.19 hours daily. However, biogas lamps are not popular in the domestic market, so households have difficulties when biogas lamps are damaged. Thus, the number of household using biogas for lighting is not high and only account for 2 percent of all households who have biogas plants (Dũng, 2011).

The average number of stoves per house is 1.65, with 3.5 hours of cooking daily (Dũng, 2011). Biogas stoves are either produced in Viet Nam or imported from China. The single biogas stove made in Viet Nam consumes 0.22-0.40 m^3 biogas per hour, while the double imported biogas stove consumes 0.30-0.70 m^3 biogas per hour (Cuong *et al,* 2011). The biogas demand for each person in a family of Viet Nam is around 0.15-0.30 m^3/day. Therefore, for a household of six people, the minimum amount of biogas required is 1.8 m^3 per day, which is equivalent to a biogas plant of 5 m^3, requiring six to ten pigs or two buffalos (Cuong *et al.*, 2011).

Some households use biogas to keep piglets or small chickens warm in winter in the North, to run freezers, to store fruits and cereals or to incubate poultry eggs. However, these applications have been restricted due to the fact that biogas from small size facilities is often only enough for cooking.

TABLE 9

AMOUNT OF MANURE PRODUCED AND POTENTIAL DAILY BIOGAS YIELD

ANIMAL TYPE	ANIMAL BODY WEIGHT (kg/animal)	MANURE EFS (percent of body weight)		MANURE AMOUNT (kg/animal/day)	DRY MATTER (TS, percent)	C/N RATIO	BIOGAS YIELD (litre/kg manure/day)
	RANGE	SOLID	LIQUID				
BUFFALO	360-500	5.0	4-5	18-25	16-18	24-25	15-30
COW	300-400	5.0	4-5	15-20	18-20	24-25	16-32
PIG	60-200	2.0	3	1.2-4	24-33	12-15	40-60
POULTRY	0.45-1.15	4.5	-	0.02-0.05	25-50	5-15	50 - 60

Source: Cuong et al, *2011*

3.2.3 Biogas at farm and industrial levels

Biogas production

In Viet Nam, industries which have high organic content, including large-scale animal farms (pig farms, cow farms, etc.), sugar industry, cassava processing factories, food processing industry, beer industry, and domestic and urban solid waste landfill, are now recognized as suitable industries for anaerobic treatment process and biogas production.

At industrial scale, biogas plants are coupled with:

- Large scale animal farms. In this case, biogas plants apply covered anaerobic lagoons with simple construction and operation techniques and low investment. Their average volume is 500 m^3. The main feedstock used for biogas production is animal manure and slurry; and
- Beverage factories, and food and agricultural product processing factories (e.g. cassava starch production). In this case, the main feedstocks used for biogas production are the following:
  - Organic wastes (wastewater) and agro-based industrial by-products from food processing, seafood processing, slaughterhouse/meat processing and wastewater from beverage industries;
  - Cassava residues from cassava starch processing and Cassava-based ethanol plants; and
  - Agricultural residues such as rice husk, sawdust, etc.

Technologies applied in industrial biogas in Viet Nam include:

- Lagoon;
- Plug flow;
- Contact Reactor (ACR);
- Anaerobic Filter Reactor (AF);
- Down flow Stationary Fixed Film Reactor (DSFF);
- Up flow Anaerobic Sludge Blanket (UASB); and
- Fluidized Bed Reactor (FB).

ADs are usually located on the farms or in the industrial plants, therefore no energy is consumed for collecting the feedstock and delivering it to the AD. Wastewater is transported by pumps; for food, beverage and agricultural products processing, this consumes energy withdrawn from electricity grid, whereas for ethanol plants the electricity is produced onsite from coal. The ADs have no extra heat requirements but in order to maximize production at industrial scale, thermal energy produced from the use of biogas is partially recycled in the biogas generation process.

The biogas plants at industrial level often contain the biogas treatment system which removes hydrogen sulphide from the biogas produced in the AD. This treatment system is designed based on the adsorption technique (using iron oxide or activated carbon) or membrane technology.

The biogas produced is usually consumed in loco therefore no energy consumption occurs for distributing/delivering it to the final users.

Biogas use

None of the products of biogas (biogas, biogas wastewater and digestate) from households, farms and cassava processing factories are sold to third parties.

Biogas produced from animal manure at farm scale (MBP and LBP) is only used for cooking, heating and lighting in the household. No heat or power production from biogas occurs so far at farm scale.

The main use of biogas at the industrial level in Viet Nam is heat production to replace fuel oil or coal for distillation or product drying. Excess gas is burned (flared) or discharged directly into the environment. Power generation from biogas (for own consumption) takes place as well in part of the cassava processing plants. Wastewater from biogas production at the industrial level is not used, and the solid residue is used partly as crop fertilizer.

REFERENCES

Binh Thuan's Department of Agriculture and Rural Development (DARD), 2016. Process of cassava cultivation *(Issued under Decision No. 740 / QD-SNN)*.

Binh, P.T. Hung, N.M., Tru, L.C. and Henry, G. 1996. Socio-economic aspects of cassava production, marketing and rural processing in Vietnam. *In*: R.H. Howeler (Ed.). Cassava Production, Processing and Marketing in Vietnam. Proc. Workshop, held in Hanoi, Vietnam. Oct 29-31, 1992. pp. 113-158.

Biogas Program for the Animal Husbandry Sector in Vietnam. no date. Technology applied in project feature of biogas-digester model KT1&KT2. Available at: http://biogas.org.vn/english/Introduction/Technology.aspx

Cuong, N.D. et al, 2011. Exploring Biogas Market Opportunities in Viet Nam. Report of the Project Development Programme (PDP) South-East Asia. German Federal Ministry of Economics and Technology. Available at: www.scribd.com/document/164287352/Giz2011-en-Exploring-Biogas-Market-Opportunities-Vietnam

Department of Crop Production. 2008. Nutrient composition of manure. Available at www.cuctrongtrot.gov.vn/DetailInfomation.aspx?InfomationID=IN00002180

Department of Crop Production. 2016. Report: Results of the implementation of 2016 work and plan implementation 2017 field of cultivation.

Dieu, H.K. 2015. Study on growth, development and main technical method for new cassava varieties in some provinces of the Northern Mountain Viet Nam. PhD Thesis in Agriculture. Thai Nguyen University.

Dũng, N.Q. 2011. Biogas User Survey (BUS) 2010-2011. Biogas development program for livestock sector in Vietnam 2007-2012.

Giao, H.K. 2011. Công nghệ khí sinh học quy mô hộ gia đình (*Household biogas technology*). Hà Nội.

GSO website. Statistical data: Agriculture, Forestry and Fishery. Available at: www.gso.gov.vn/default_en.aspx?tabid=778. Accessed 24/01/2018.

Ha, P.Q. 2016. Personal Communication. Adapted from different sources.

Ho, T.B., Roberts T.K. and Lucas, S. 2015. Small-Scale Household Biogas Digesters as a Viable Option for Energy Recovery and Global Warming Mitigation—Vietnam Case Study. Journal of Agricultural Science and Technology A 5, 387-395.doi: 10.17265/2161-6256/2015.06.002.

Hung, N.V. 2005. Study the effects of planting date on yield of cassava varieties KM94 in Taiyuan, Journal of Agriculture & Rural Development No. 16/2004.

Institute of Agricultural Environment (IAE). 2017. Survey conducted within this study on April 2017 for the collection of primary data from local farmers. The survey was conducted in the provinces of Phu Tho and Tay Ninh.

Institute of Agricultural Science for Southern Viet Nam (IASVN). 2014. Knowledge Bank: Nutritional needs for cassava (*in Vietnamese*). Available at: http://iasvn.org/chuyen-muc/Nhu-cau-dinh-duong-cho-San-4484.html.

Ham, L.H., Kim, H., Mai, N.T.T., Mai, N.B. and Howeler, R. 2016. The cassava revolution in Viet Nam. *World congress on root and tuber crops. Pp 1 - 48.* **Available from:** www.gcp21.org/wcrtc/ppt/PS06-LeHuyHam.pdf

Loan T. Le, Wesseler Justus, Zhu Xueqin and van Ierland Ekko C. 2013. Energy and greenhouse gas balances of Cassava-based ethanol in Viet Nam, Biomass and Bioenergy 51:125–135. DOI 10.1016/j.biombioe.2013.01.011

MARD. 2016. Real situation and solutions for environmental treatment of livestock production. Report Document 2016.

MOIT. 2012. Available at: http://dtinews.vn/en/news/018/26281/vietnam-to-popularise-bio-fuel-over-next-three-years.html

MOIT. 2017. FAO Regional workshop Nov.16-17 "Sustainable Bioenergy Production and Use in Southeast Asia: Lessons Learnt and Future Opportunities, The orientation in the production and use of biofuels in Vietnam, Dr. Do Xuan Dong, Department of Science and Technology. Available at: www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/AG2/Viet_Nam_project/Final_Mettings/Dong_Do-Xuan.pdf

Ngan, N.V.C. 2011. Small-scale anaerobic digesters in Vietnam - development and challenges. *Journal of Vietnamese Environment*, Vol. 1, No. 1, pp 12-18.

Tam, H.M., 2011. The results of the study to determine the appropriate crop structure on coastal sandy coastal areas of South Central Coast. Journal of Agricultural Science and Technology, Vietnam, (4), p. 92-96

Viet Nam Finance. 2017. Viet Nam Export Import Report 2016 (translated from Vietnamese). Available at: http://vietnamfinance.vn/upload/news/hoanghung_btv/2017/3/29/BC%20XNK%202016.pdf Accessed 08/01/2018.

VJIIST. 2017. Surveys conducted within this study on April 2017 in feedstock production areas in Phu Tho, Tay Ninh province, ethanol plants, transportation activities mapping (including vehicles for cassava chips, ethanol and biofuel transportation) and E5 stations.

CHAPTER 4

CHAPTER

4

RESULTS OF GBEP SUSTAINABILITY INDICATORS FOR BIOENERGY IN VIET NAM

ENVIRONMENTAL PILLAR

4.1 INDICATOR 1: LIFECYCLE GHG EMISSIONS

Nguyen Thi Anh Tuyet[1], Cao Huong Giang[2], Pham Quang Ha[2], Van Dinh Son Tho[1]
[1]Vietnam Japan International Institute for Science of Technology (VJIIST) at the Hanoi University of Science and Technology (HUST)
[2]Institute of Agricultural Environment (IAE), Viet Nam Academy of Agricultural Sciences (VAAS)

DESCRIPTION:

Lifecycle greenhouse gas emissions from bioenergy production and use, as per the methodology chosen nationally or at community level, and reported using the GBEP Common Methodological Framework for GHG Lifecycle Analysis of Bioenergy 'Version One'

MEASUREMENT UNIT(S):

Grams of CO_2 equivalent per megajoule (gCO_{2eq}/MJ)

4.1.1 Implementation of Indicator 1 in Viet Nam

For the measurement of Indicator 1 (GHG emissions), researchers performed a Lifecycle Assessment (LCA) for both pathways – Cassava-based ethanol and manure-based biogas[6]. For Cassava-based ethanol production, the stages of the value chain included in the LCA were: the feedstock production, transformation and delivery to the ethanol plant; biomass processing into biofuels; and biofuel transportation, storage and distribution. The GHG emissions associated with Cassava-based ethanol were compared with those of gasoline. In the case of biogas, the comparison was made with two other 'modern' fuels that could be used to displace traditional biomass use for cooking, i.e. LPG and natural gas.

The specific methodology was selected and adapted for the measurement of the indicator in Viet Nam. The three GHGs considered – carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) – were aggregated to the CO_2 equivalent (CO_{2eq}) using the Global Warming Potential (GWP) factors. The GHG emissions from ethanol and biogas production were calculated using the guidelines from BioGrace and the European Commission, respectively.

Primary data were collected through surveys conducted in feedstock production areas in Phu Tho, Tay Ninh province, ethanol plants, transportation activities mapping (including vehicles for cassava chips, ethanol and biofuel transportation) and E5 stations (VJIIST, 2017). Secondary data included technical documents for ethanol production provided by ethanol plants, peer reviewed publications, emission factors (EF) of Viet Nam, IPCC guidelines and the BioGrace database. Based on the survey (conducted as part of this research) and other studies, the emission sources from ethanol and biogas production were identified and are listed in **Table 10** and **Table 14**, respectively.

4.1.2 Key findings

Cassava-based ethanol production

A detailed description of the phases of cassava cultivation can be found in Chapter three.

Regarding the cassava cultivation phase, in Viet Nam, cassava is primarily cultivated on agricultural land. In some regions, such as the Central Highlands and the South East, lands currently used for cassava were probably previously forestry areas. In this analysis, the LCA input data of LUC and cassava planting are provided in indicator 18.

Two different scenarios for cassava cultivation were considered in the analysis, reflecting the real situation in the country – cultivation in sloping and flat areas, with low and high input level, respectively. After harvest, cassava is manually sliced and dried in the sun before delivery to ethanol plants in the form of dried chips (final water content is about 14 percent, on average). The conversion ratio of fresh root to dried chips is 2.5 kg/kg (Indicator 18). Transport of the cassava occurs using 40 tonne trucks (full load), either from the cultivation areas or the main exporting port to the plants. For round trips, diesel consumption for the 40 tonne trucks is on average 0.28 litres/km.

There are four sub-processes to convert dried cassava chips to ethanol: 1) milling, 2) liquefaction, 3) saccharification and fermentation, and 4) distillation and dehydration. Besides ethanol, by-products include Dried Distillers Grains sold for animal feed production, biogas used as supplemental energy, and CO_2 collected for sale. The conversion ratio of dried chips to ethanol is on average 2.3 kg/litre (Indicator 18).

The ethanol product is sold to oil companies and delivered to blending stations by 30 m^3 trucks. For round trips, diesel consumption for the 30 m^3 trucks is on average 0.28 litre/km (Indicator 23). At the blending stations, three methods can be used: 1) in-tank recirculation; 2) static mixing; and 3) in-line blend. The first two methods require tanks for handling the ethanol fuel, while in the "in-line blend" method,

[6] Biogas is produced from manure at both household and farm level in Viet Nam. At industrial level, cassava starch wastewater is the main feedstock; this could not be analysed here due to lack of data.

gasoline and ethanol are blended directly in line before being transferred by truck and ship to the gasoline station. Therefore, most of the petroleum distribution companies choose the "in-line blend" method and several blending systems have been installed across the country.

TABLE 10

LCA INPUT DATA FOR CASSAVA-BASED ETHANOL PRODUCTION IN VIET NAM

LAND USE CHANGE			
LAND USE CHANGE (ALUC)		539	kg CO_2eq/ha/y
CULTIVATION			
	FLAT LAND	SLOP LAND	
YIELD			
CASSAVA	25.00	14.75	tonnes/ha/y
WATER CONTENT	65	65	percent
HARVEST RESIDUE	15.50	12.07	tonnes/ha/y
FERTILIZER& PESTICIDES			
N-FERTILIZER	138.5	50.0	kg N/ha/y
MANURE	39.2	36.0	kg N /ha/y
P_2O_5-FERTILIZER	115.5	50.0	kg P_2O_5 /ha/y
K_2O-FERTILIZER	105.3	60.0	kg K_2O /ha/y
CAO-SOIL CONDITIONER (KG $CaCO_3$)	600	100	kg $CaCO_3$ /ha/y
STILLAGE	0	0	kg N /ha/y
PESTICIDES	2	0	kg /ha/y
SEEDS			
CASSAVA CUTTINGS	750	875	kg/ha/y
ENERGY			
DIESEL	22.5	0	litres/ha/y
EMISSIONS FROM DIESEL USAGE (AGRICULTURE)			
ELECTRICITY CONSUMPTION (FOR IRRIGATION)	45.0	0	kWh/ha/y
ELECTRICITY MIX	ELECTRICITY MIX VIET NAM		
TRANSPORT OF CASSAVA ROOTS			
TRANSPORT LOSSES		0.000	kg / kg cassava
DISTANCE		10.0	km
TRANSPORT VEHICLE	TRUCK (40 TONNES) FOR DRY PRODUCTS		
FUEL	DIESEL		
CHIPPING (MANUALLY PERFORMED)			
YIELD		0.400	kg chips / kg cassava
DIESEL		0.00000	litres / kg cassava

TRANSPORT OF CASSAVA CHIPS *		
TRANSPORT LOSSES	0.000	kg / kg cassava chips
DISTANCE	288.96	km
TRANSPORT VEHICLE	TRUCK (40 TONNES) FOR DRY PRODUCTS	
FUEL	DIESEL	
**PROCESSING - ETHANOL PLANT ** **		
ETHANOL	0.345	kg ethanol / kg cassava chips
CO-PRODUCTS	0	
CO_2	0.630	kg / kg ethanol
STILLAGE CAKE	0.075	kg / kg cassava chips
WATER CONTENT OF STILLAGE	20.0	percent
BIOGAS (REUSED AS ENERGY SOURCE)		
CHEMICALS		
SULPHURIC ACID (H2SO4)	0.0031	kg / kg ethanol
ALPHA-AMYLASE	0.0019	kg / kg ethanol
AMMONIA (NH3)	0.0057	kg / kg ethanol
UREA	0.0047	kg / kg ethanol
SODIUM HYDROXIDE (NAOH)	0.0025	kg / kg ethanol
DAP	0.0034	kg / kg ethanol
ENERGY		
ELECTRICITY CONSUMPTION	0.274	kWh / kg ethanol
ELECTRICITY MIX	ELECTRICITY MIX VIET NAM	
METHANE FROM BIOGAS	1.008	MJ / kg ethanol
HARD COAL	8.160	MJ / kg ethanol
WOOD CHIPS	3.547	MJ / kg ethanol
ALLOCATION OVER MAIN- AND CO-PRODUCT		
HEATING VALUE PRODUCTS SUM	0.0	MJ
EMISSIONS ALLOCATED TO ETHANOL	78.3	percent
TRANSPORT ETHANOL TO BLENDING/FILLING STATION * **		
TRANSPORT		
DISTANCE	522	km
TRANSPORT VEHICLE	TRUCK (30 m^3) FOR LIQUIDS	
FUEL	DIESEL	
BLENDING/FILLING STATION		
ELECTRICITY CONSUMPTION	0.005	kWh / kg ethanol
ELECTRICITY MIX	ELECTRICITY MIX VIET NAM	

* For transportation, GHG emissions from diesel consumption were calculated by multiplying the EF of diesel with the quantity.
** Value are expressed as average of three different ethanol plants.
*** For transportation, GHG emissions from diesel consumption were calculated by multiplying the EF of diesel with the quantity.

The technical data provided by three ethanol plants has been used as inputs in this analysis. The total GHG emissions of the ethanol production was calculated as 1100 g CO_{2eq}/kg of product, of which the main contribution comes from burning solid fuels for steam production (used for slurry preparation, liquefaction, fermentation, distillation and dehydration) in the ethanol conversion stage (**Table 11**). The GHG emissions from the ethanol plants are partly balanced by the amount of biogas produced as a co-product that can be used for Combined Heat

TABLE 11

GHG EMISSIONS FROM CASSAVA-BASED ETHANOL PRODUCTION IN VIET NAM

		GREENHOUSE GASES					
		g $CO_{2fossil}$	g CO_2 biogenic	g $CH_{4fossil}$	g CH_4 biogenic	g N_2O	g CO_{2eq}
LAND USE CHANGE							
LAND USE CHANGE (ALUC)	PER HECTARE		539216				
CULTIVATION (FLAT LAND)							
FERTILIZER & PESTICIDES							
N-FERTILIZER	PER HECTARE	509 680	0	1037	0	326	632 647
P_2O_5-FERTILISER	PER HECTARE	130 343	0	242	0	3.90	137 550
K_2O-FERTILISER	PER HECTARE	61 014	0	115.7	0	1.392	64 322
CAO- SOIL CONDITIONER (KG $CaCO_3$)	PER HECTARE	25 205	0	54.5	0	0.915	28 641
PESTICIDES	PER HECTARE	37 740	0	71.7	0	0.0676	39 563
N2O FIELD EMISSIONS - MINERAL FERTILIZER	PER HECTARE					2 884	859 363
N2O FIELD EMISSIONS - ORGANIC FERTILIZER	PER HECTARE					878	261 584
EMISSIONS FROM FIELD BURNING OF RESIDUES	PER HECTARE				0	0	0
SEEDS							
CASSAVA CUTTINGS	PER HECTARE	47 929	0	0	0	0	47 929
ENERGY							
DIESEL	PER HECTARE	67 815	0	107	0	0.42	71 509
EMISSIONS FROM DIESEL USAGE (AGRICULTURE)	PER HECTARE			1.03		2.5	784
ELECTRICITY CONSUMPTION (FOR IRRIGATION)	PER HECTARE	23 004	0	40.338	0	0.638	24 203
CULTIVATION SUM	PER HECTARE PER KG OF CASSAVA						
CULTIVATION (SLOPING LAND)							
FERTILIZER & PESTICIDES							
N-FERTILIZER	PER HECTARE	184 000	0	375	0	118	228 392
P_2O_5-FERTILISER	PER HECTARE	56 425	0	105	0	1.69	59 545
K_2O-FERTILISER	PER HECTARE	34 766	0	65.9	0	0.793	36 651
CAO- SOIL CONDITIONER (KG $CaCO_3$)	PER HECTARE	4 201	0	9.1	0	0.152	4474
PESTICIDES	PER HECTARE	0	0	0.0	0.000	0.0000	0
N2O FIELD EMISSIONS - MINERAL FERTILIZER	PER HECTARE					1041	310 239
N2O FIELD EMISSIONS - ORGANIC FERTILIZER	PER HECTARE					806	240 231
EMISSIONS FROM FIELD BURNING OF RESIDUES	PER HECTARE				0	0.0	0

SEEDS							
CASSAVA CUTTINGS	PER HECTARE	55918	0	0.000	0	0.000	55918
ENERGY							
DIESEL	PER HECTARE	0	0	0	0	0.00	0
EMISSIONS FROM DIESEL USAGE (AGRICULTURE)	PER HECTARE			0.00		0.0	0
ELECTRICITY CONSUMPTION (FOR IRRIGATION)	PER HECTARE	0	0	0.000	0	0.000	0
CULTIVATION SUM	**PER HECTARE**	**335310**	**0**	**554**	**0.000**	**1967**	**935449**
	PER KG OF CASSAVA	**23**	**0**	**0.038**	**0.0000000**	**0.133**	**63**
TRANSPORT OF CASSAVA ROOTS							
DIESEL	PER KG OF CASSAVA	0.69	0	0.00111	0	0.0000	0.72
TRANSPORT SUM	**(PER KG CASSAVA)**	**0.69**	**0**	**0.00111**	**0**	**0.0000**	**0.72**
CHIPPING							
DIESEL	PER KG OF CASSAVA	0	0	0.00000	0	0.0000	0.00
CHIPPING SUM	**PER KG OF CASSAVA**	**0.00**	**0**	**0.00000**	**0**	**0.0000**	**0.00**
TRANSPORT OF CASSAVA CHIPS							
DIESEL	PER KG OF CASSAVA CHIPS	19.96	0	0.03198	0	0.0006	20.93
TRANSPORT SUM	**PER KG OF CASSAVA CHIPS**	**19.96**	**0**	**0.03198**	**0**	**0.0006**	**20.93**
PROCESSING - ETHANOL PLANT							
CHEMICALS							
SULPHURIC ACID (H2SO4)	PER KG ETHANOL	0.85	0	0.0017	0	0.000	0.85
ALPHA-AMYLASE	PER KG ETHANOL	1.84	0	0.0035	0	0.000	1.94
AMMONIA (NH3)	PER KG ETHANOL	13.80	0	0.0257	0	0.000	14.46
UREA	PER KG ETHANOL	7.93	0	0.0433	0	0.000	9.02
SODIUM HYDROXIDE (NAOH)	PER KG ETHANOL	1.94	0	0.0043	0	0.000	2.07
DAP	PER KG ETHANOL	5.19	0	0.0000	0	0.000	5.19
ENERGY							
ELECTRICITY CONSUMPTION	PER KG ETHANOL	140	0	0.246	0	0.004	148
ELECTRICITY MIX							
METHANE FROM BIOGAS	PER KG ETHANOL	0	0	0.00	0	0.000	0
HARD COAL	PER KG ETHANOL	836	0	3	0	0.005	905
WOOD CHIPS	PER KG ETHANOL	14	0	0	0	0.000	14
ETHANOL PLANT SUM	**PER KG ETHANOL**	**1021.51**	**0**	**3.04**	**0**	**0.0095**	**1100**
CUMULATED EMISSIONS	**PER KG ETHANOL**	**1249**	**0**	**3.41**	**0.0000**	**0.98**	**1626**
CUMULATED ALLOCATED EMISSIONS	**PER KG ETHANOL**	**978**	**0**	**2.67**	**0.0000**	**0.77**	**1273**
TRANSPORT OF ETHANOL TO BLENDING/FILLING STATION							
TRANSPORT							
DISTANCE	PER KG ETHANOL	38.83	0	0.0622	0	0.0011	40.71
BLENDING/FILLING STATION							
ELECTRICITY CONSUMPTION	PER KG ETHANOL	2.58	0	0.0045	0	0.0001	2.71
TRANSPORT & BLENDING/FILLING STATION SUM	**PER KG ETHANOL**	**41.41**	**0**	**0.0667**	**0**	**0.0012**	**43.42**
FUEL USE							
EMISSIONS FROM ETHANOL USAGE	**PER MJ OF ETHANOL**	**0.00**	**0**	**0.0008**	**0**	**0.0032**	**0.97**

and Power (CHP) generation. The allocation for dry stillage as another co-product also acts to balance GHG emissions; the stillage is precipitated, centrifuged, dried (using biogas) and then sold for cattle feed.

Liquid CO_2 is another co-product of the ethanol pathway; the CO_2 emitted from the fermentation process is collected and sold to third parties. However, it is not taken into consideration because of the lack of data available on the electricity required for CO_2 liquidation. Therefore, the eventual effect is the GHG emissions minus the CO_2 emitted from the fermentation process. The liquid CO_2 collected from ethanol plants is sold to fire protection facilities or beverage plants, where it is loaded into the fire extinguisher or beverage bottles, respectively. Therefore, this collected CO_2 still causes indirect GHG impacts.

Taking into account the emissions from using biofuel, the total GHG emissions of the ethanol product are 59.2 g CO_{2eq}/MJ ethanol, of which 54 percent come from the ethanol processing and a further 31 percent come from cassava cultivation (**Figure 12**).

Comparison with gasoline, in terms of product life cycle, shows that total GHG emissions from Cassava-based ethanol is about 62 percent of the total GHG emissions from gasoline (**Table 12** and **Figure 13**), even if fuel consumption efficiency per kilometre of the biofuel and gasoline are similar. This means that the use of E5 and E10 as a substitute for gasoline would achieve a GHG emission reduction.

The environmental benefits of producing ethanol in the current situation (described for the period of 2013-2016) and if the five percent mandate is accomplished (estimated for 2018) are shown in **Table 13** In 2018, if Viet Nam accomplishes the E5 mandate, thus replacing all RON92 by E5, the amount of fossil fuel replaced by ethanol will be equal to 2.1 billion MJ/year. It should be noted from the Table that, if the E5 mandatory policy is implemented in 2018, annual reduction obtained by substituting RON92 by E5 will be around 74 000 tonne CO_2 (assuming production of cassava on flat land).

FIGURE 12

TOTAL GHG EMISSIONS FROM CASSAVA-BASED ETHANOL PRODUCTION (CONTRIBUTION OF THE DIFFERENT STEPS OF THE VALUE CHAIN, IN PERCENTAGE)

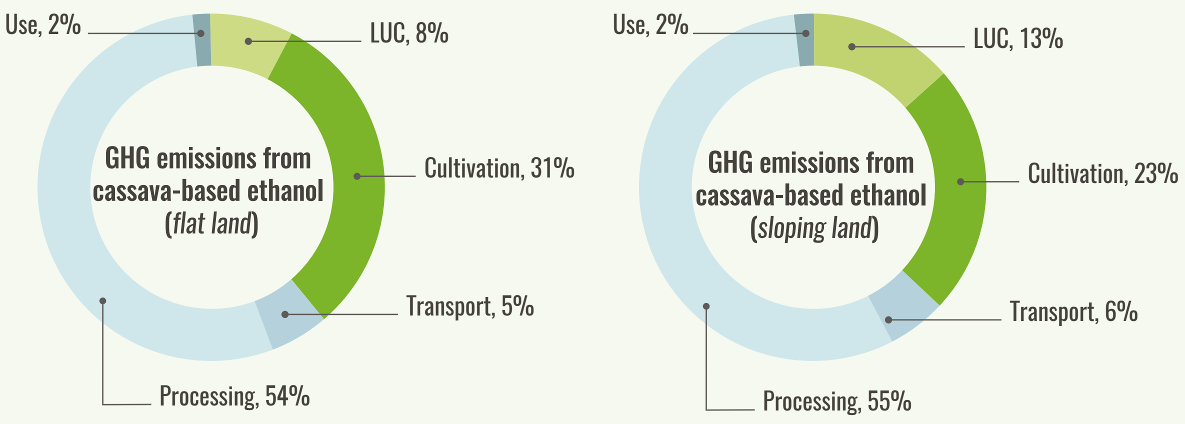


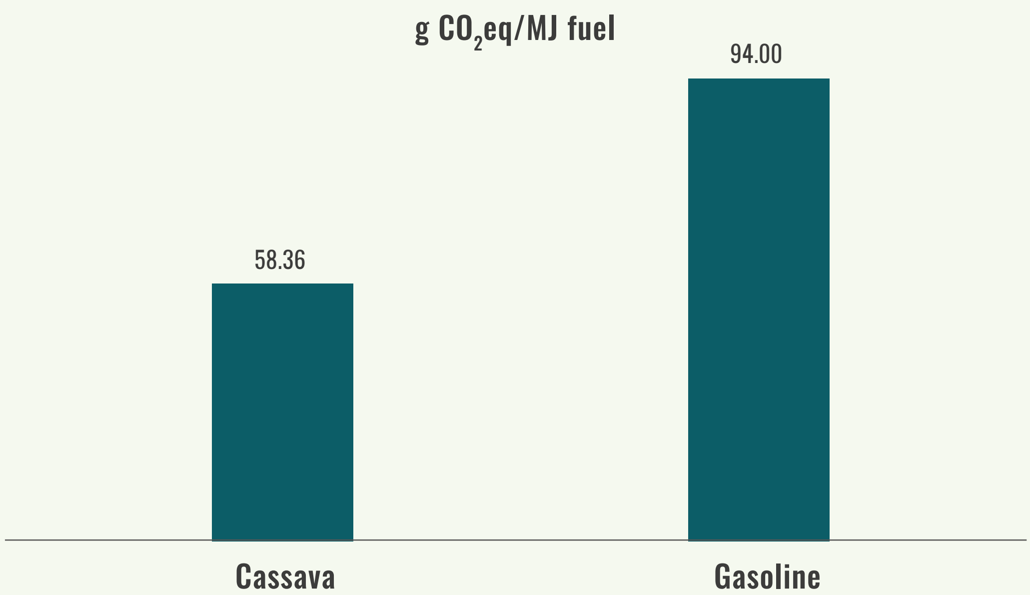
TABLE 12

GHG EMISSION BALANCE: COMPARISON BETWEEN CASSAVA-BASED ETHANOL AND GASOLINE

	ETHANOL FROM		GASOLINE (FOSSIL PETROL)	SAVING	
	CASSAVA (FLATLAND)	CASSAVA (SLOPLAND)		CASSAVA (FLATLAND)	CASSAVA (SLOPLAND)
	G CO_2eq/MJ ETOH	G CO_2eq/MJ ETOH	G CO_2eq/MJ GASOLINE		
LUC	4.56	7.74			
CULTIVATION	18.34	13.42			
TRANSPORT	3.21	3.21			
PROCESSING	32.15	32.15			
USE	0.97	0.97			
TOTAL	**59.23**	**57.49**	**94.00**	**34.77** G CO_2eq/MJ **37%**	**36.51** G CO_2eq/MJ **39%**

FIGURE 13

TOTAL GHG EMISSIONS: COMPARISON BETWEEN CASSAVA-BASED ETHANOL(*) AND GASOLINE



(*) this is an average of the emissions produced in flat and sloping cassava cultivated areas)

Manure-based biogas pathway in Viet Nam

Biogas is mostly produced in Viet Nam by anaerobic digestion of a feedlot manure. GHG emissions from the livestock raising process are entirely attributed to the main products (e.g. meat, milk) and not to manure, which is considered as a residue/waste. Therefore the GHG emissions from the livestock activities have not been taken into account in the assessment of the GHG emissions derived from the biogas pathway. In Viet Nam, the digestion tanks, called anaerobic digesters (AD), are usually located nearby animal lodgings. The anaerobic digestion process produces biogas (methane and carbon dioxide) as the main product and digestate as the co-product.

About 0.056 m^3 of biogas is produced from each

TABLE 13

GASOLINE SUBSTITUTION BY ETHANOL AND RELATED GHG EMISSION SAVINGS IN VIET NAM

YEAR	ETHANOL PRODUCTION		GASOLINE SUBSTITUTED BY ETHANOL AND CO_2eq REDUCTION**	
	m^3/year	MJ/year	MJ/year	Tonnes CO_2 eq./year
2013	37 000	780 700 000	294 802 971	10 249
2014	25 300	533 830 000	201 581 491	7 008
2015	15 200	320 720 000	121 108 248	4 210
2016	29 500	622 450 000	228 810 798	7 955
2018*	267 850	5 651 635 000	2 134 134 481	74 194

* Scenario where all RON 92 is replaced with E5

** Estimation for flat land case

TABLE 14

LCA INPUT DATA FOR PIG MANURE-BASED BIOGAS AT HOUSEHOLD LEVEL

MANURE		
MANURE	1.00	kg/kg
WATER CONTENT	71.5	percent
TRANSPORT OF MANURE		
DISTANCE	0.00	Km
TRANSPORT VEHICLE	N.A.	
FUEL	N.A.	
BIOGAS PLANT - ANAEROBIC FERMENTATION		
BIOGAS YIELD	0.603	MJ/kg manure
ENERGY		
ELECTRICITY CONSUMPTION	0.00813	kWh / MJ biogas
ELECTRICITY MIX	Electricity mix Viet Nam	
ENERGY FOR CHP FROM GRID	0.0100	MJ / MJ biogas
BIOGAS USE - COOKING OR LIGHTING		
HEAT TRANSFER IN BIOGAS STOVE (FOR COOKING)	32	percent
ELECTRICITY (BIOGAS-BASED) FOR LIGHTING	0	percent

kg of fresh manure, which has an average water content of 71.5 percent (in the range of 67 – 76 percent; Vu *et al.*, 2015). The biogas is collected and then burned on-site, mostly in biogas stoves but also sometimes in small generators, to produce heat and power, respectively.

Digestate is the name assigned to the residue from the anaerobic digestion. It is a liquid product, rich in organic compounds and mineral nutrients that is generally used as a fertilizer and soil amendment. Once it is collected from the digester, the digestate must be stored before being applied to the fields. The anaerobic digestion process continues in the tank, therefore an additional amount of biogas is produced during the storage period. In Viet Nam, this biogas is recovered because the digestate is stored in a closed biogas tank.

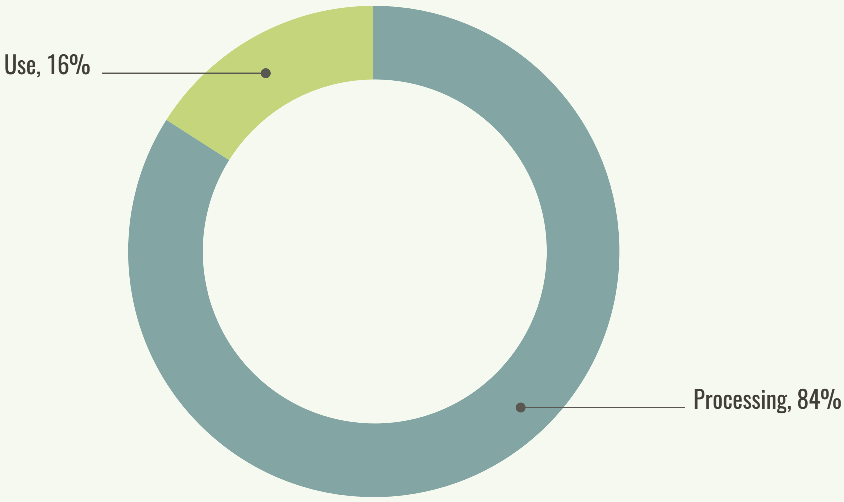
TABLE 15

GHG EMISSIONS FROM PIG MANURE-BASED BIOGAS PATHWAY

	GREENHOUSE GASES (PER MJ_{BIOGAS})					
	g $CO_{2fossil}$	g $CO_{2biogenic}$	g $CH_{4fossil}$	g $CH_{4biogenic}$	g N_2O	g CO_{2eq}
BIOGAS TANK - ANAEROBIC FERMENTATION						
ENERGY	2.58	0	0.00453	0	0.00007	2.72
EMISSIONS FROM DIGESTATE STORAGE - MANURE	0	0	0	0.20	0	5.0
FERMENTATION SUM	**3**	**0**	**0**	**0.20**	**0.00007**	**7.72**
BIOGAS USE - COOKING						
EMISSIONS FROM BIOGAS STOVE USED (BURNING)	1.42	0	0.0025	0	0	1.49
EMISSIONS FROM ELECTRICITY SUPPORTED	0	0	0	0	0	0
BIOGAS USE SUM	**1.42**	**0**	**0.0025**	**0**	**0**	**1.49**

FIGURE 14

GHG EMISSIONS FROM PIG MANURE-BASED BIOGAS PATHWAY (SHARES OF PROCESSING AND USE)

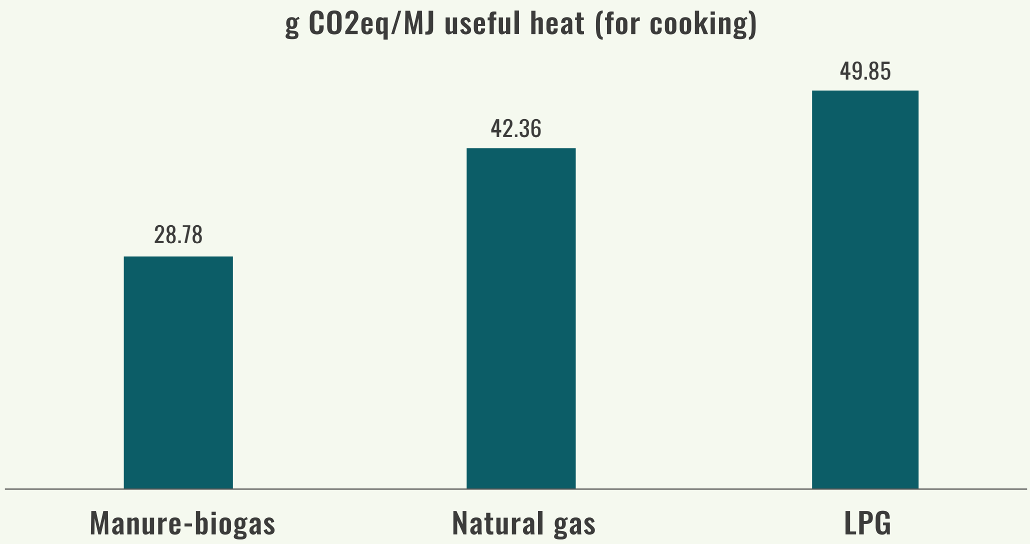


The GHG emissions from biogas production (both from anaerobic digestion and storage of digestate) are 7.72 g CO_{2eq}/MJ_{biogas}. The GHG emissions from biogas use are 1.49 g CO_{2eq}/MJ_{biogas} (**Table 15**). Therefore, the total GHG emissions from the biogas pathway is 9.21 g CO_{2eq}/MJ_{biogas}, of which 16 percent comes from the use of biogas (**Table 15** and **Figure 14**).

When biogas is used for cooking purposes, the average efficiency of biogas cook-stoves produced in Viet Nam, is 32 percent. During the burning process, CH_4 is converted into CO_2, resulting in total GHG emissions of 28.78 g CO_{2eq}/MJ useful heat (**Figure 15**). The average efficiency of imported natural gas or LPG cook-stoves is 59 percent. Total GHG emissions from natural gas and LPG are 42.46 g CO_{2eq}/MJ useful heat and 49.50 g CO_{2eq}/MJ useful heat, respectively (**Figure 15**). This means that using biogas, compared with natural gas or LPG, can achieve 32 percent and 42 percent GHG emission reductions, respectively, even though the efficiency of the biogas cook-stoves is currently much lower than that for natural gas or LPG.

FIGURE 15

GHG EMISSIONS: COMPARISON OF BIOGAS WITH NATURAL GAS AND LPG



4.1.3 Main conclusions and recommendations

Approach used

Regarding the cassava cultivation phase, two different scenarios (cultivation in sloping and flat areas, with low and high input level, respectively) reflecting the real situation in the country were considered in the analysis. Primary data were collected through surveys conducted in feedstock production areas in Phu Tho and Tay Ninh province, ethanol plants, transportation activities mapping (included vehicles for cassava chips, ethanol and biofuel transportation), and E5 stations (VJIIST, 2017). Secondary data included technical documents for ethanol production provided by ethanol plants, scientific publications, Emission Factors (EFs) of Viet Nam, IPCC guidelines, and BioGrace database.

Results

Ethanol production and use (for transportation) result in total GHG emissions of 57.5–59.2 gCO_{2eq}/MJ of product, which is a 37-39 percent (depending on where cassava is cultivated) GHG emission savings in comparison to gasoline.

The manure-based biogas pathway has GHG emissions of 9.21 gCO_{2eq}/MJ of biogas (or 28.78 gCO_{2eq}/MJ useful heat), which represents a 32-42 percent GHG emissions saving in comparison with cooking using commercial cookstove running on natural gas and LPG. Although the results show a large percentage of emission savings from the biogas pathway, the biogas-based energy conversion equipment is still poorly developed and the heat conversion efficiency is still low. Therefore, there is significant room for future improvement in this technology to further increase the GHG emission savings.

Practices and policies to improve sustainability

Based on the LCA of the Cassava-based ethanol pathway performed under this indicator, further GHG emissions savings could be achieved by:

- Improving the efficiency of the feedstock cultivation stage, e.g. through the introduction of improved varieties and management practices.
- Technology improvements within the processing stage:
  - There were three plants taken into account in the analysis that have different characteristics. Plant A uses Chinese technology, plant B uses French technology and Plant C uses Indian technology. Energy consumption for ethanol processing in plant A is higher than that in plants B and C.
  - The amount of CO_2 collected as co-product in plant A is lower in comparison to its potential.
  - Approximately 30 percent of the power supply for the three plants is derived from biogas, with coal accounting for the remaining 70 percent. Reducing the share of this fossil fuel and replacing it with less carbon intensive options such as biogas or other renewables, could significantly improve the GHG emission profile of Cassava-based ethanol.
- Improving the efficiency of blended fuel combustion.
- Improving the management of the feedstock provisioning network in order to reduce total distance of cassava transportation.

Based on the life cycle inventory of the manure-based biogas pathway, it seems that no electricity production from biogas occurs in Viet Nam, neither at small nor at medium production scale. If electricity was generated from this biogas and supplied to the grid, GHG emission savings could be achieved.

Future monitoring of Indicator 1 in Viet Nam

The GBEP Common Methodological Framework (FAO, 2009) has proven to be a reliable tool for reporting the methodology applied in GHG LCA of bioenergy production and use, estimating and comparing GHG emissions from different energy sources at the national level.

The implementation of Indicator 1 in Viet Nam has confirmed the relevance of this tool in order to inform policy makers about the sustainability of the national bioenergy industry, since one of the reasons for pursuing increased use of bioenergy worldwide is its potential to reduce GHG emissions by displacing fossil fuels. Its value could be further exploited by calculating LCA values using the major different methodologies of relevance to Viet Nam (in this study BioGrace was used) and comparing these methodologies using the Framework, step-by-step, to allow analysis of the effect of methodological differences on the LCA results.

Evaluation through the use of the GBEP General Framework also provides an opportunity to explore and describe the major types of raw material production and to gain in-depth information on the effectiveness of each production stage.

For the Cassava-based ethanol LCA, there is no direct data for GHGs in cassava production in Viet Nam; until now, modelling has been used for estimation. Calibration and field measurements should be established. For the cassava case, to fully calculate the total GHGs emitted from the life cycle, net C-sequestration in the soil should be included.

In order to fill data gaps (**Table 16**), Future monitoring of indicator 1 in Viet Nam should focus on:

- Exchange of information among relevant stakeholders along the value chain;
- Developing specific EFs for Viet Nam;
- Frequently checking input and output data;
- Building an LCA database for Viet Nam;
- Classifying technology as well as production scale of each bioenergy product; and
- Strengthening human capacity for developing and updating LCA databases.

TABLE 16

SUMMARY OF DATA GAPS TO FILL FOR BETTER LCA

DATA	SCALE/AREA	MEASUREMENT UNIT
ELECTRICITY USED FOR BIOGAS DIGESTERS	Farm/national	kW/MJ of biogas
LEAKAGE RATIO OF BIOGAS DIGESTERS	Farm/national	percent
BACKGROUND DATA OF STILLAGE CAKE	National or EU	g/kg of stillage cake
ELECTRICITY CONSUMPTION OF WET MANURE COLLECTION, BIOGAS PRODUCTION OF PIG FARMS	Farm/national	kW or kWh/m^3
FUEL CONSUMPTION OF WET MANURE COLLECTION, BIOGAS PRODUCTION OF PIG FARMS	Farm/national	litres/m^3 or litres/d
ACTUAL TRANSPORTATION DISTANCES OF CHIPS AND ETHANOL	National	km
AMOUNT OF BIOGAS USED FOR WASTEWATER TREATMENT AND BIOGAS PLANTS IN ETHANOL PLANTS	Plants	m^3 or percent

Besides cooking, converting biogas into electricity has a huge theoretical potential in the country. Further LCA analyses could be carried out on:

- Wastewater-based biogas (in cassava starch plants);
- Manure-based biogas on industrial-scale farms; and
- Biogas use for CHP.

REFERENCES

BioGrace. Harmonised Calculations of Biofuel Greenhouse Gas Emissions in Europe. Utrecht (Netherlands), BioGrace project. Available online at www.biograce.net

EC. 2009. Directive 2009/72/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. Official Journal of the European Union. Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:140:0016:0062:EN:PDF

FAO. 2009. The Global Bioenergy Partnership Common Methodological Framework for GHG Lifecycle Analysis of Bioenergy. First Edition. ISBN 978-92-5-107249-3. Available at: www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/2009_events/7th_SC_NY/GBEP_GHG_report_2306.pdf

IPCC. 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan. Available at: www.ipcc-nggip.iges.or.jp/public/2006gl/index.html

VJIIST. 2017. Surveys conducted within this study on April 2017 in feedstock production areas in Phu Tho, Tay Ninh province, ethanol plants, transportation activities mapping (including vehicles for cassava chips, ethanol and biofuel transportation) and E5 stations.

Vu T.K.V., Vu D.Q., Jensen L.S., Sommer S.G., Bruun S. 2015. Asian-Australas J Anim Sci. 2015 May; 28(5): 716–729. doi: 10.5713/ajas.14.0683.

4.2 INDICATOR 2: SOIL QUALITY

Pham Thi Thanh Nga, Pham Quang Ha
Institute for Agricultural Environment (IAE), Viet Nam Academy of Agricultural Sciences (VAAS)

DESCRIPTION:

Percentage of land for which soil quality, in particular in terms of soil organic carbon, is maintained or improved out of total land on which bioenergy feedstock is cultivated or harvested.

MEASUREMENT UNIT(S):

Percentage

4.2.1 Implementation of Indicator 2 in Viet Nam

For the Cassava-based ethanol pathway, there is some research in Viet Nam on the quality of soil related to cassava cultivation under different management practices. However, the scale of the studies is small and does not fully and accurately assess the effect of cassava production on all relevant factors that define the soil quality. Regarding the biogas pathway, studies on the effects of digestate application on agricultural land are limited and no specific data are available, only general comments.

For the testing of indicator 2 in Viet Nam, data were retrieved from national statistics (GSO website) and from ministerial statistics (MARD). Besides national statistics, further data were collected from national Research Institutes and through a survey, conducted within this study, in April 2017, in the provinces of Phu Tho and Tay Ninh (IAE, 2017).

4.2.2 Key findings

Cassava-based ethanol

According to FAO (2011), soil quality should be monitored by considering at least five key factors that contribute to soil degradation:

- Loss of Soil Organic Matter (SOM), leading to decreased carbon and soil fertility;
- Soil erosion, leading to soil loss (especially of fertile topsoil);
- Accumulation in soils of mineral salts (salinization) from irrigation water and/or inadequate drainage, with possible adverse effects on plant growth;
- Soil compaction, reducing water flow and storage, and limiting root growth; and
- Loss of plant nutrients, e.g. through intensive harvest.

These factors are interlinked. For example, erosion removes soil surface, the soil fraction in which most SOM is found, which affects soil water retention, and soil compaction in the surface layer can increase runoff, thereby further increasing soil and water losses.

In Viet Nam, cassava is planted mainly on the following soil types:

- Yellow - red soil develops on clay stone and metamorphic rock

This soil is formed and develops on fine granules, such as clay, so weathering often has heavy mechanical components. Yellow-red soil develops on clay and metamorphic rocks that have some common properties: soils form on different heights with different gradients. This soil is yellow – red (2.5-10YR) that goes down to the lower levels. The soil layer thickness is from 0.60 - 1.20 m (thicker soil layer is found on the mica slate in Vinh Phuc, Phu Tho and Tuyen Quang). The stratification is very clear: Floor A, B, C. In general, this type of soil is scarcely porous (porosity is about 40 percent). Sour soil (pH_{KCl} 4.0-4.5). Organic matter content varies from 1.8 to 2.5 percent OM; the total protein content varies from 0.1 to 0.2 percent N. The content of poorly digestible substances: about 1-5 mg P_2O_5 / 100 grams of soil, potassium less than 5 mg / 100g soil. The total potassium is usually medium to moderate (0.5-1.0 percent K_2O), the soil grows on more potassium-rich mica flakes (> 1.5 percent K_2O)

- Yellow red soil grows on magma acid rock

Magma acid in Viet Nam is composed of many kinds of granite, liparite, rhyolite, pocphia quartz. Soil developed on these rocks usually have thin layer of soil (average about 1m back). The soil is reddish yellow (2.5-10YR). The mechanical component of the soil is usually medium, as it is washed away so that the surface layer may be lighter than the lower one. Sour soil (pH_{KCl}~ 4). The humus layer is thin, organic matter varies from 1.5-2.2 percent OM. Low total phosphorus content (0.003-0.006 percent P_2O_5), total potassium (1.7-2.0 percent K_2O); low digestible phosphorus (5-7 mg P_2O_5/100g of soil); average digestible potassium (10-15 mg K_2O/100g of soil).The content of exchanged alkaline cationic is low (Ca^{2+} is about 3-4 mEq/100g of soil, Mg^{2+} is about 2-3 mEq/100g of soil). The Cation Exchange Capacity (CEC) in the soil is also low, fluctuating in the range of 5-10 mEq/100g of soil.

▶ The greyish soil

This land group has light mechanical component (30-50 percent sand), poorly structured surface, often severely limited in the dry season. The soil is usually sour to very sour (pHKCl fluctuates in the range of 3.5-4.5), natural low fertility characteristics. Organic matter content is from poor to very poor (0.5-1.0 percent OM); the content of total and digestible substances is low (total protein: 0.04-0.08 percent N, total phosphorus: 0.03-0.06 percent P_2O_5, total potassium: 0.2-0.4 percent K_2O, digestible phosphorus: 4-5 mg P_2O_5/100g of soil, digestible potassium: 5-6 mg K_2O/100g of soil). It is characterized by low absorption capacity (4-7 mEq/100g soil) and low saturation level (below 50 percent).

TABLE 17

MAIN SOIL TYPES FOR CASSAVA CULTIVATION IN VIET NAM

	YELLOW - RED SOIL FORMED ON CLAY STONE AND METAMORPHIC ROCK	YELLOW-RED SOIL ON MAGMA ACID ROCK	GREYISH SOIL
PARENT MATERIAL	CLAY, PARAGON	GRANITE, LIPARITE, RHYOLITE, POCPHIA QUARTZ	
MECHANICAL COMPONENT	HEAVY	MEDIUM	LIGHT 30-50 PERCENT SAND
COLOUR	YELLOW-RED (2.5-10YR)	YELLOW-RED (2.5-10YR)	
THICKNESS (M)	0.60-1.20	1.0	
STRATIFICATION	CLEAR STRATIFICATION		LOW
POROSITY (PERCENT)	40		
ACIDITY (pH_{KCl})	4.0-4.5	~ 4	3.5-4.5
ORGANIC MATTER CONTENT (PERCENT)	1.8-2.5	1.5-2.2	0.5-1.0
NITROGEN CONTENT (PERCENT)	0.1-0.2		0.04-0.08
DIGESTIBLE PHOSPHORUS (P_2O_5) CONTENT (MG/100 GRAMS OF SOIL)	1-5	5-7	4-5
DIGESTIBLE POTASSIUM CONTENT (MG/100 GRAMS OF SOIL)	5	10-15	5-6
TOTAL POTASSIUM (K_2O) CONTENT (PERCENT)	0.5-1.0	1.7-2.0	0.2-0.4
TOTAL PHOSPHORUS (P_2O_5) CONTENT (PERCENT)		0.003-0.006	0.03-0.06

FIGURE 16

SOIL MAP OF VIET NAM (INLAND

Source: the centre of database establishment for Environmental resources in Viet Nam, Geography institute 1999

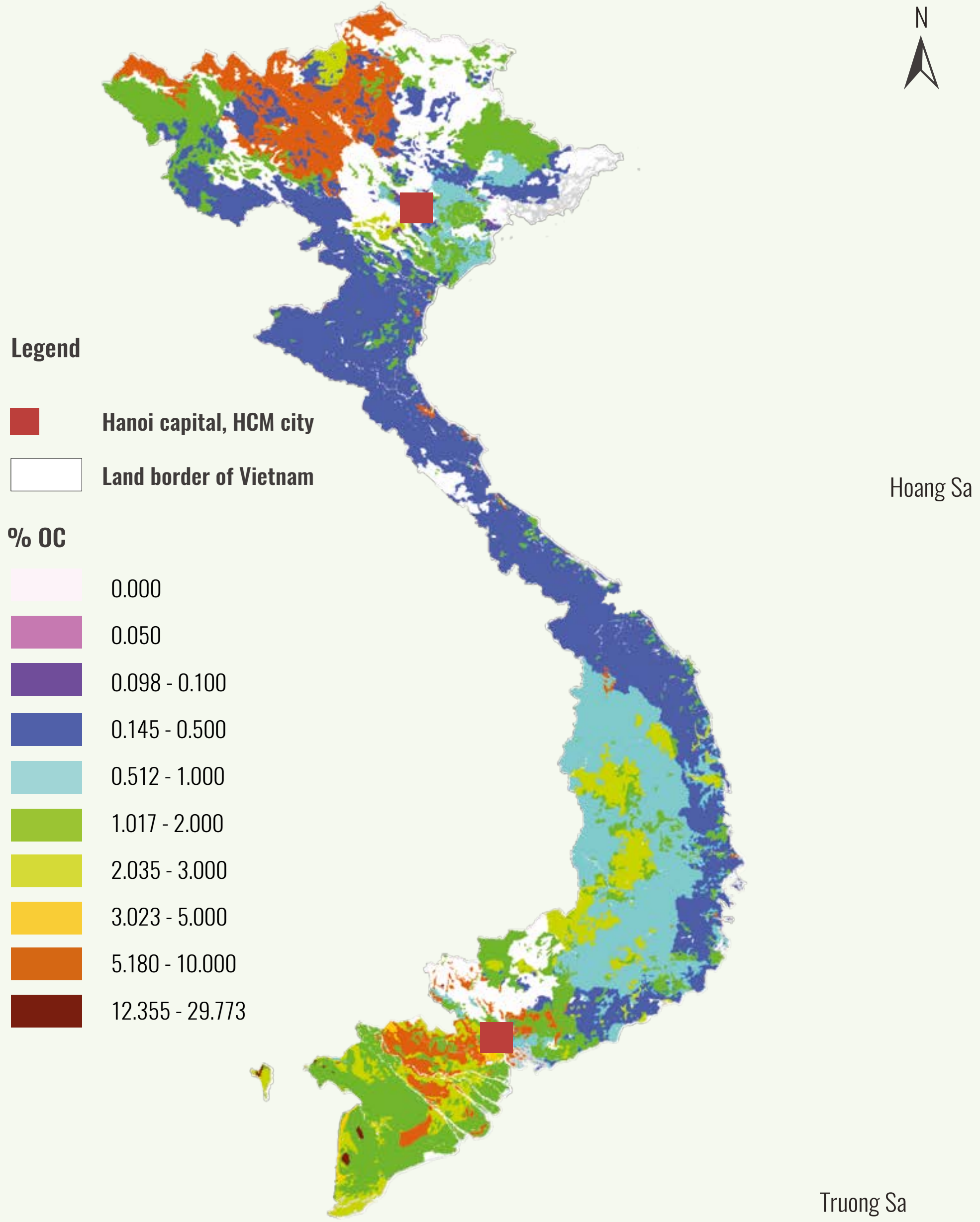
a. Soil organic carbon

Soil Organic Carbon (SOC) is the total organic carbon of a soil excluding carbon from undecayed plants and animal residues. It is the major component of Soil Organic Matter (SOM). The amount of SOM directly affects several aspects of soil function, so SOC is commonly used as an indicator to assess soil quality and productivity.

SOC is affected by changes in production management practices. For example, removal or burning of plant residues following (agricultural or forestry) harvest leaves the soil without adequate protection, causing the loss of SOM through surface erosion due to rainfall and/or wind. Moreover, the presence of plant residues contributes to restoration of SOM through decay.

FIGURE 17

SOC MAP OF VIET NAM



Source: elaborated by IAE as part of this study

Organic carbon within the soil serves several functions. From a practical agricultural standpoint, it is especially important for:

(i) Maintaining nutrient levels, providing plant-available nutrients such as nitrogen, phosphorus, potassium, sulphur and iron;
(ii) Improving soil structure and minimizing soil erosion; and
(iii) Increasing or maintaining soil porosity, thus facilitating air and water infiltration and water retention.

Therefore the measurement of SOC serves as a useful proxy for other aspects of soil quality and productivity.

In general, cassava is planted on flat land in Viet Nam, mainly in the Southeast and in a small

TABLE 18

SOIL MONITORING POINTS IN DOAN HUNG DISTRICT OF THE PHU THO PROVINCE

NO	SAMPLED AREA LABEL	COORDINATES		LAND MANAGEMENT
		X	Y	
1	DH1	105⁰11'503"	21⁰35'486"	CASSAVA CULTIVATION
2	DH3	105⁰12'273"	21⁰31'294"	FOREST TREE PLANTATION
3	DH4	105⁰10'569"	21⁰32'574"	MARGINAL LAND, UNDER RESTORATION
4	DH5	105⁰11'924"	21⁰34'556"	INDUSTRIAL TEA TREE PLANTATION, WITH TERRACING AS EROSION CONTROL MEASURE
5	DH6	105⁰11'924"	21⁰34'556"	NATURAL REGENERATED FOREST LAND

Source: Thang, 2014

TABLE 19

AMOUNT OF FERTILIZER APPLIED ANNUALLY AT THE MONITORING SITES

VALUE	MANURE	N	P_2O_5	K_2O	NPK
	(tonnes/ha)	(kg/ha)			
AVERAGE	13.89	197.22	138.39	97.50	433.11
MIN	11.11	170.67	135.28	66.67	372.62
MAX	16.67	205.56	143.61	115.00	464.17

Source: Thang, 2014

area of the North Central Coast, as well as in the Central Coast. The remaining cassava areas are located on sloping land, characterized by serious erosion and degenerated, very poor soil.

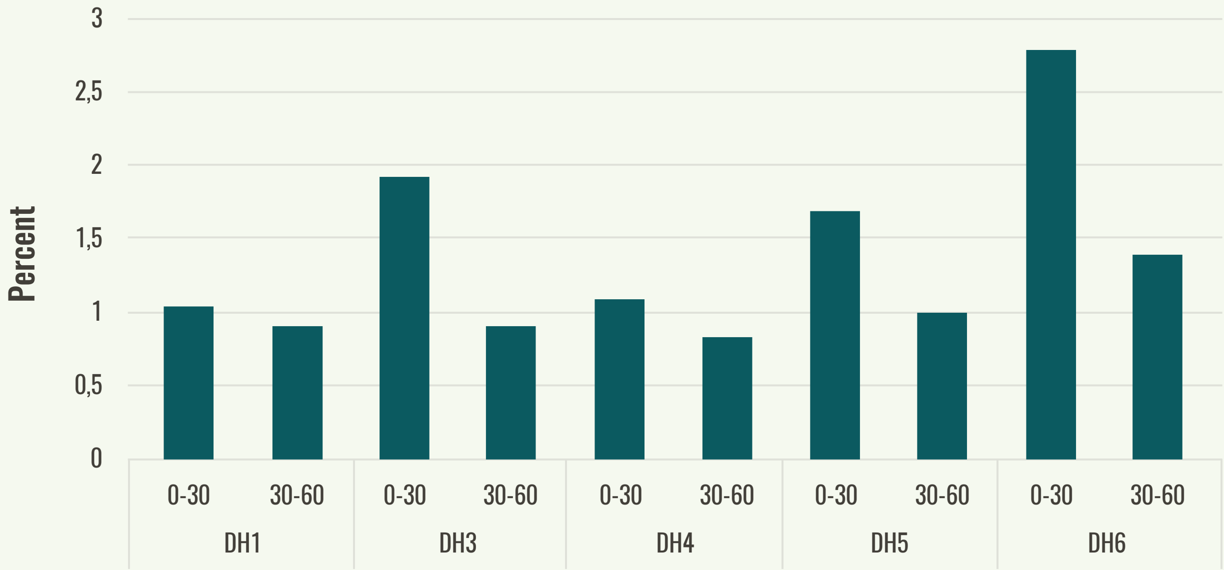
The SOC content of soils plays a major role in sustainable agricultural development in Viet Nam. Generally, the content of SOM in the uppermost soil horizons of most soil units in Viet Nam ranges between 0.5 and 3.0 percent. Sloping land typically has lower SOM content levels. Upland soils, 70 percent of which contain two percent or less SOM, are very vulnerable to soil erosion. Erosion rapidly removes organic matter from soils, and can arise as a result of poor application of organic inputs (e.g. manure, sewage sludge, crop residues) and farming techniques. Using green hedgerows along contour lines, intercropping with legume species and ensuring soil cover through mulching are management practices that can be used to control soil erosion and improve SOM content on sloping land. Green hedgerows significantly reduce soil and organic matter loss by 50 – 70 percent, compared to sloping land without hedgerows. Intercropping with legume species reduces soil loss by 40 – 50 percent, and can provide the soil with 2.5 – 12 tonnes of green manure per hectare annually. Maintaining the 30 percent of soil surface covered during the entire year, by the adoption of cover crops, crop rotation and/or soil mulching with crop residues, can reduce soil erosion by 50 percent (Dang and Klinnert, 2001).

▶ SOC in areas at risk of erosion in Doan Hung District (Phu Tho province) in 2014

Thang (2014) compared five soil areas located in the midland (e.g. Thach Son commune located in the Lam Thao District of the Phu Tho province) on relatively flat terrain under different land uses (See **Table 18**). Chemical characteristics, SOC and nutrient content of sampled soils were determined (See **Table 20**).

FIGURE 18

SOC IN AREA AT RISK OF EROSION IN THE DOAN HUNG DISTRICT OF THE PHU THO PROVINCE



Source: Thang, 2014

TABLE 20

SOIL QUALITY AND NUTRIENT CONTENT IN SLOPING AREAS AT RISK OF EROSION IN DOAN HUNG DISTRICT OF THE PHU THO PROVINCE, 2014

No	Sample	Depth	pH H2O	pH KCl	OC	N	P_2O_5	K_2O	CEC	Ca	Mg	K	Na	Cu	Zn
					percent	percent	percent	percent	(cmol/kg)					mg/kg	mg/kg
1	DH1	0-30	5.09	4.38	1.04	0.18	0.09	0.02	5.26	0.12	0.16	0.04	0.08	39.68	57.71
		30-60	4.74	3.81	0.85	0.08	0.07	0.02	9.35	0.09	0.12	0	0	47.97	56.53
2	DH3	0-30	4.17	3.57	1.9	0.18	0.00	0.07	11.01	0.51	0.39	0.35	0.08	50.81	56.57
		30-60	4.58	4.06	0.86	0.10	0.04	0.04	12.27	1.57	0.81	0.36	0.38	60.64	65.3
3	DH4	0-30	4.69	4.03	1.15	0.16	0.05	0.13	4.03	1.19	0.67	0.08	0.13	26	69.23
		30-60	4.68	4.1	0.82	0.09	0.04	0.17	4.87	1.35	0.45	0.15	0.07	33.52	112.97
4	DH5	0-30	4.12	3.7	1.68	0.15	0.05	0.03	5.48	0.8	0.64	0.3	0.14	77.09	94.55
		30-60	4.22	3.84	1.01	0.08	0.03	0.02	7.14	0.87	0.6	0.15	0.14	73.7	104.16
5	DH6	0-30	4.08	3.76	2.77	0.14	0.03	0.01	6.81	0.56	0.18	0.07	0.09	28.46	33.22
		30-60	4.27	4.06	1.4	0.08	0.04	0.01	8.91	0.61	0.19	0.04	0.05	29.65	33.8

Source: Thang, 2014

TABLE 21

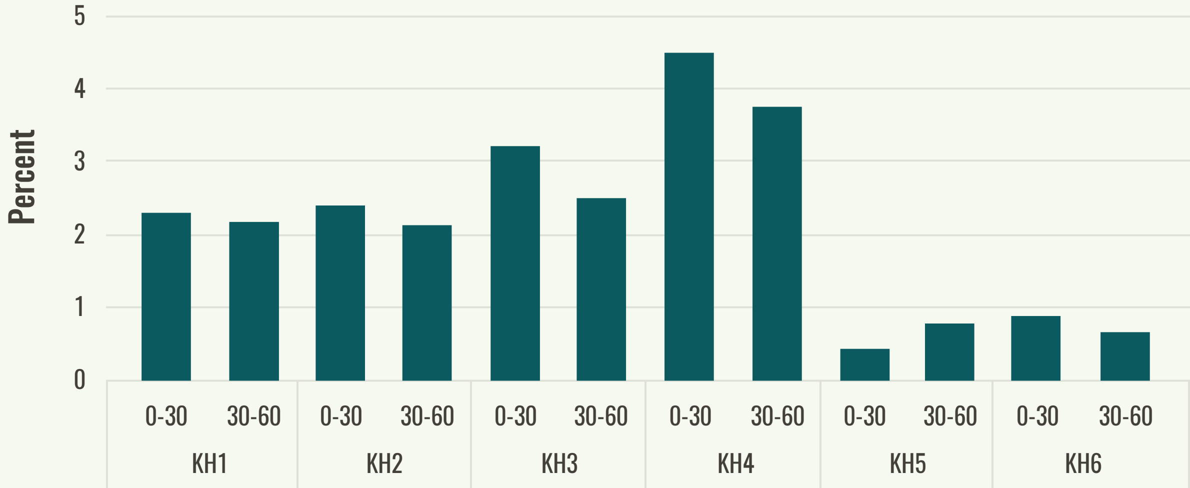
LOCATION, SOIL COVER AND AGRONOMICAL PRACTICES APPLIED IN CHL

NO	SYMBOL	COORDINATES		LOCATION	FARMING PRACTICES
		N	E		
1	KH1	14⁰39'44,3"	107⁰48'46,7"	TAN CANH COMMUNE IN DAK TO DISTRICT IN THE KON TUM PROVINCE	PLANTING CASSAVA ALTERNATIVELY WITH RUBBER
2	KH2	14⁰23'59,7"	107⁰56'25,0"	MO RAI COMMUNE, IN SA THAY DISTRICT, IN KON TUM PROVINCE	PLANTING CASSAVA ALTERNATIVELY WITH RUBBER
3	KH3	14⁰12'43,4"	107⁰8'04,8"	IA KHOUL COMMUNE IN CHU PAH DISTRICT IN THE GIA LAI PROVINCE	PLANTING CASSAVA AFTER ABANDONED
4	KH4	13⁰53'31,6"	108⁰00'11,0"	IA KENH COMMUNE IN PLEIKU DISTRICT, IN THE GIA LAI PROVINCE	FALLOW
5	KH5	13⁰02'22,8"	107⁰50'44,3"	CU MLAN COMMUNE, EA SUP DISTRICT, IN THE DAK LAK PROVINCE	FALLOW
6	KH6	12⁰52'18,4"	107⁰48'39,5"	KRONG ANA COMMUN, BUON DON DISTRICT IN THE DAK LAK PROVINCE	DIPTEROCARP FOREST, RECLAIMED LAND FOR PLANTING CASSAVA

Source: Lich, 2014

FIGURE 19

SOC CONTENT IN CHL



Source: Lich, 2014

Results of the study showed that in DH1 area, where cassava has been planted for around 20 years, the soil appeared discoloured, hardened and desertified. This soil depletion was attributed to a reduction in SOC due to cassava plantations.

- SOC in dry land in the Central Highlands (CHL) and South Central Coast (SCC) in 2014

In a study conducted by Lich (2014), the soil quality of six areas with different land uses and agricultural practices were compared. A brief description of climate conditions in these areas is reported below.

- Kon Tum province points (KH1, KH2, KH5, KH6): Altitude: 800 MASL. Average rainfall: 2 121 mm/year, with the highest rainfall (260 mm) taking place in August. Lowest rainfall: 1 234 mm /year.
- Gia Lai province points (KH3, KH4): Tropical monsoon tropical zone, with high humidity, characterized by heavy rainfall, no storms and no frost. Climate is divided into two distinct seasons: the rainy season starts in May and ends in October, and the dry season is from November to April of the following year.
- Dak Lak province points: Relatively flat plain

TABLE 22

SOIL CHARACTERISTICS IN CHL

NO	Sample	Depth	pH H2O	pH KCl	OC	N	P_2O_5	K_2O	Ca	Mg	CEC
					percent	percent	mg/100g soil		cmol/kg		
1	KH1	0-30	5.17	4.38	2.27	0.148	5 491	6.514	1	0.1	12.8
		30-60	5.39	4.92	2.2	0.129	2.594	3.024	2.2	0.4	12
2	KH2	0-30	4.62	4.21	2.33	0.123	5.491	3.024	0.8	0.5	16
		30-60	4.82	4.14	2.13	0.12	1.839	1.861	0.6	0.3	14
3	KH3	0-30	4.21	4.12	3.2	0.151	6.876	3.024	0.3	0	16
		30-60	4.52	4.24	2.47	0.171	1.713	1 861	0.3	0.1	11.2
4	KH4	0-30	4.57	4.25	4.53	0.146	11.536	5.35	0.4	0.1	16
		30-60	4.42	4.32	3.67	0.185	9.647	3.024	0.3	0.1	16.4
5	KH5	0-30	5.05	4.75	0.49	0.084	14.433	3.024	1.1	0.6	12.4
		30-60	6.5	4.91	0.62	0.09	5.491	6.514	1	0.8	12
6	KH6	0-30	5.05	4.61	0.86	0.101	9.6	3	2.8	0.6	12
		30-60	5.25	4.27	0.55	0.087	3.5	3	1.8	0.7	11.2

Source: Lich, 2014

FIGURE 20

LAND SAMPLING IN PHU THO AND TAY NINH PROVINCES

Source: Pham Quang Ha, 2018

with the lowest average height in the province. The climate is characterized by two distinct seasons every year: the rainy season runs from April to the end of October, concentrating 93.5 percent of the total rainfall of the year. Dry season begins in November and ends in March the next year, with little rainfall and often drought at the end of dry season.

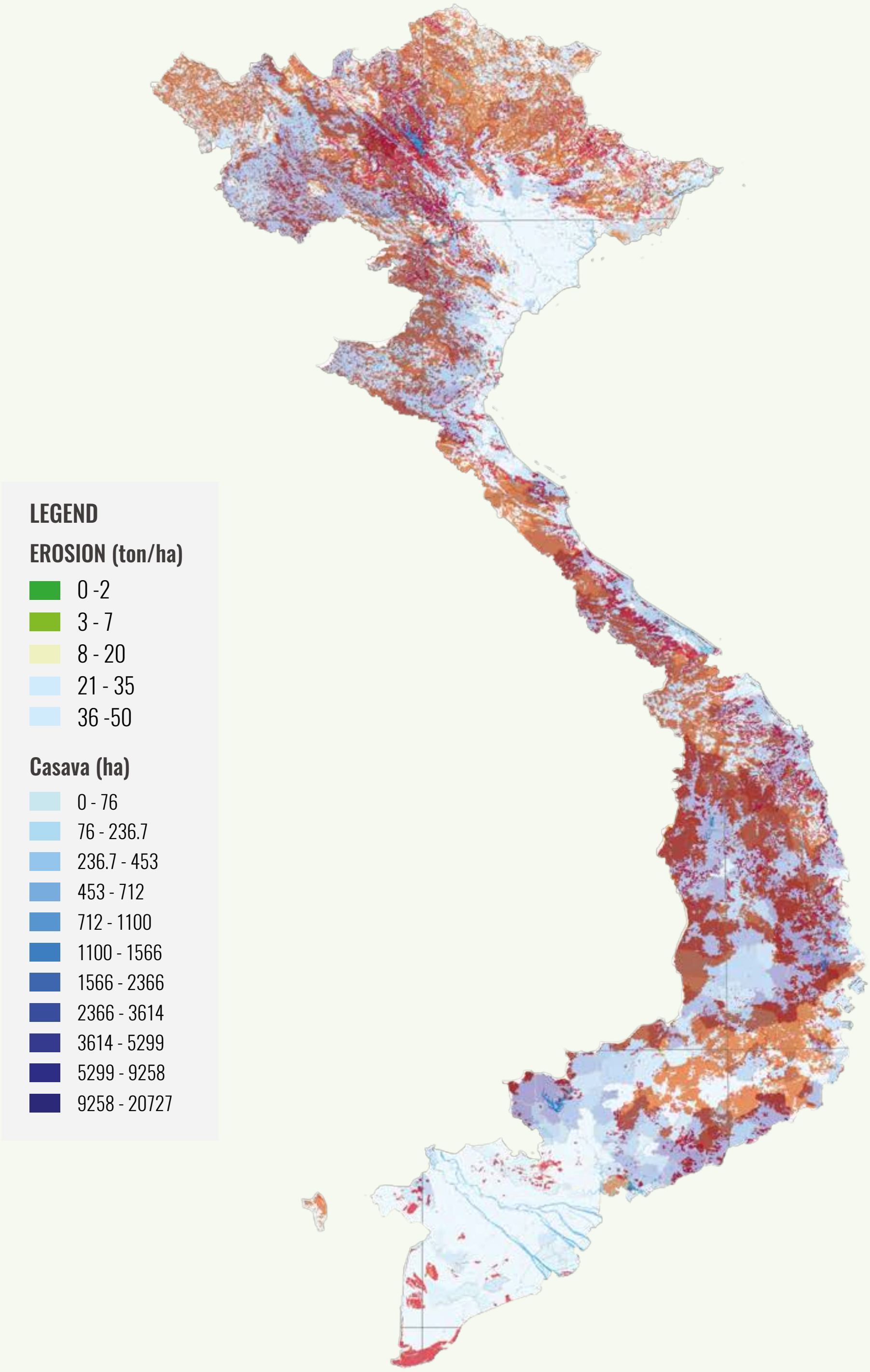
SOC content varies among the monitored sites and also depends on soil depth. In general it could be said that in the Central Highlands, the reddish brown soil (KH1, KH2, KH3, KH4) have higher SOC content compared to the grey soil (KH5, KH 6). The lowest SOC content was found in KH5 (0.49 percent) and the highest in KH4 (4.53 percent), both classified as fallow. Fallow is a type of land that is not cultivated and tended. In other word, it is unaffected by any human impact.

Soil erosion

Soil erosion is a naturally occurring process that affects all landforms. In agriculture, soil erosion refers to the wearing away of a field's topsoil due to the natural physical forces of water and wind or through forces associated with farming activities such as soil tillage.

FIGURE 21

MAP OF SOIL EROSION OVERLAID WITH CASSAVA CULTIVATION AREAS, 2016



Source: elaborated by IAE as part of this study

TABLE 23

AMOUNT OF ERODED SOIL IN CASSAVA CULTIVATED AREAS IN NMM

LOCATION		YEAR	AMOUNT OF ERODED SOIL (t/ha)
YEN BAI	YEN BINH	2008	75.3
	VAN YEN	2009	71.4

Source: Doanh ***et al.****, 2009*

All soils can suffer erosion but some are more vulnerable than others. Soil erosion removes the top layer of the soil which is the most valuable and productive portion of soil profile, thus affecting soil fertility and productivity. In fact, loss of the top soil results in lower yields and higher production costs. When top soil is gone, erosion can cause rills and gullies that make the cultivation of paddocks impossible.

Soil erosion on cropping lands causes:

- reduced quality of soil structure;
- reduced ability of the soil to store water and nutrients;
- poor physical and chemical properties;
- higher rates of runoff, shedding soil particles, water and nutrients otherwise used for crop growth;
- loss of newly planted crops; and
- deposits of silt in low-lying areas.

Understanding the type of soil and how prone it is to erosion phenomena can help to define the most appropriate soil management practices to be used to prevent soil erosion that could affect agricultural production, waterways and infrastructure.

Figure 21 shows the map of soil erosion in Viet Nam overlaid with the cassava cultivation areas. In the Northern Midlands and Mountain (NMM) areas, cassava area had increased by 42.75 percent in 2012 compared to 2000 (**Table 23**). The pace of cassava cultivated areas land was too rapid and farmers did not pay much attention in using sustainable farming practices. Many households cultivated even on sloping lands (over 25 percent), even though these area are recommended only for afforestation. This led to a serious decrease in soil quality in this area. Cassava cultivation on these areas caused erosion, accompanied by the decline of soil fertility, thus the upland fields became even more degraded.

In order to reduce the risk of soil erosion, many field trials have been conducted for testing different crop systems, with a particular focus on soil cover, realized through intercropping cassava with other species. One of these studies was conducted in Yen Bai province and has demonstrated that soil cover has a good erosion control effect; the amount of soil lost due to erosion decreased by increasing the cover material such as straw or dried leaves. In particular it has been demonstrated that soil cover could significantly reduce soil erosion from 71.4 to 42.6 tonnes/ha, with a decrease compared to the control of around 28.8 tonnes/ha, or 40.3 percent. In fact, soil cover helps to reduce the breakdown of soil surface caused by rain, as demonstrated by Lal *et al.* (2001).

Research results show that peanut and black bean are suitable species to be intercropped in cassava cultivation on sloping land. The use of intercropping species allows soil cover, erosion control, maintenance and improved yield. Field trials conducted in 2008 demonstrated that the use of terraces together with soil cover realized through organic residues and intercropping black bean was the most effective crop management practice for keeping drift.

b. Soil compaction

Soil compaction is the reduction of soil volume due to external factors. It is one of the main causes of soil depletion and induces a reduction of the agro-ecosystem's quality and productivity.

Soil compaction occurs when soil particles are pressed together, reducing pore space between them. It changes pore space size, distribution, and soil strength. Heavily compacted soils contain few large pores, leading to a reduced rate of both water infiltration and drainage. This occurs because large pores are the most effective in moving water through the soil when

TABLE 24

THE EFFECT OF CROP MANAGEMENT PRACTICES IN CONTROLLING SOIL EROSION IN YEN BAI PROVINCE

NO	LOCATION (DISTRICT)	CROP MANAGEMENT PRACTICES	YEAR	SOIL EROSION (tonnes/ha/year)	DECREASE COMPARED TO CONTROL	
					Tonnes/ha	percent
1	VAN YEN	NORMAL CASSAVA CULTIVATION WITHOUT SOIL COVER (CONTROL)	2009	71.4	-	-
		CASSAVA CULTIVATION WITH SOIL COVER		42.6	28.8	40.3
2	YEN BINH	NORMAL CASSAVA CULTIVATION WITHOUT GRASS (CONTROL)	2008	75.3	-	-
			2009	13.0	-	-
		INTERCROPPING CASSAVA WITH PEANUTS AND WITHOUT GRASS	2008	48.6	26.7	64.5
			2009	3.0	10	77
		INTERCROPPING CASSAVA WITH PEANUTS AND VETIVER GRASS	2008	44.5	30.8	59.1
			2009	2.5	10.5	81
		INTERCROPPING CASSAVA WITH PEANUTS AND POLYGONUM CUSPIDATUM SIEH. ZNCE	2008	46.5	28.8	61.8
			2009	3.0	10	77
		INTERCROPPING CASSAVA WITH PEANUTS AND PASPALUM GRASS	2008	45.1	30.2	59.9
			2009	2.9	10.1	71
3	VAN CHAN	NORMAL CASSAVA CULTIVATION (CONTROL)	2008	106.0	-	-
		TERRACES		40.3	65.7	61.9
		TERRACES + COVER ORGANIC MATTER		12.0	94.0	88.7
		TERRACES + COVER ORGANIC MATTER AND INTERCROP BLACK BEAN		6.7	99.3	93.7
4	YEN BINH	NORMAL CASSAVA CULTIVATION WITHOUT GRASS (CONTROL)	2014	7.97	-	-
		NORMAL CASSAVA CULTIVATION WITH GRASS		3.71	4.26	53.45
		INTERCROPPING CASSAVA WITH ONE ROW OF PEANUT		5.90	2.07	6.2
	YEN BINH	INTERCROPPING CASSAVA WITH TWO ROWS OF BLACK BEAN WITH GRASS		1.77	6.2	105.08

Source: Quyen et al*, 2015*

it is saturated. In addition, in compacted soils, the exchange of gases slows down, causing an increase in the likelihood of aeration-related problems. Finally, soil compaction increases soil strength – the ability of soil to resist being moved by an applied force – thus roots must exert greater force to penetrate the compacted layer.

One way to quantify soil compaction is by measuring its bulk density. Bulk density is the mass of a standard volume of soil after being oven-dried and is measured in grams per cubic centimetre (g/cm^3). The increase of bulk density means a decrease in soil porosity. Soils with a higher percentage of clay and silt, which naturally have more pore space, have a lower bulk density than sandier soils. Optimum bulk densities for soils depend on the soil texture. Whenever the bulk density exceeds a certain level, root growth is restricted.

c. Sustainable cassava farming practices for south east Viet Nam

Cassava is cultivated in several areas of Viet Nam and different soil management practices are adopted depending on soil characteristics and land slope.

On flat land, soil preparation is performed one to two months before planting; this includes the

TABLE 25

RECOMMENDED NUTRIENT RATES FOR CASSAVA CULTIVATION IN VIET NAM

SOIL TYPE	TIME	ORGANIC FERTILIZER (per ha)	LIME (kg/ha)	N (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)
GREY	BEFORE PLANTING	GREEN (5-7 TONNES) OR PEAT (500 kg)	150-200 (GRAYISH)		40	
	20-30 DAYS AFTER PLANTING			40		40
	50-60 DAYS AFTER PLANTING			40		40
RED	BEFORE PLANTING	GREEN 5-7 TONNES OR COMPOST (500 kg)			40	
	20-30 DAYS AFTER PLANTING			40		40
	50-60 DAYS AFTER PLANTING			40		40

Source: Hy ***et al.*** *2014*

removal of roots and residues, ploughing (one or two times), draining soil and levelling it.

On sloping land areas (> 30 percent) such as hilly land, vegetal residues are burned and ploughing is not performed. When cassava is planted on paddy rice paddies, after drainage and rice harvesting, it is necessary to prepare the soil early in order to make use of soil humidity, including the treatment of weeds and grass, levelling, ploughing right after the spring.

d. Plant nutrients

A survey was conducted within the present study (April 2017) in order to investigate the amount of organic and inorganic fertilizers actually applied to cassava-cultivated fields located in the provinces of Phu Tho and Thay Ninh provinces (IAE, 2017). Results showed that in the Phu Tho province, interviewed households apply a high rate of organic fertilizer (**Table 26**).

In fact, 100 percent of interviewed households declared use of manure as fertilizer, with an average amount of 14.1±1.4 tonnes/ha. Therein, seven out of nine households used composted manure, while two out of nine used fresh manure directly. According to data from the survey, the average amount of N, P_2O and K_2O applied per hectare to the soil were of 142.9 ± 64.5 kg, 81.5 ± 52 kg, 140.9 ± 115.6 kg, respectively. According to the recommendation of Institute of Agricultural Science for Southern Viet Nam (IASVN), N, P_2O_5 and K_2O requirement of cassava is in the range of 80-120 kg, 50-100 kg and 200-500 kg/ha, respectively. This data showed that, in some cases, the amount of N and K_2O applied with fertilizers by local householders exceed the recommendation of IASVN for cassava. However, there is a large fluctuation in the amount of fertilizer applied by households.

TABLE 26

FERTILIZER APPLICATION BY SURVEYED HOUSEHOLDS IN PHU THO PROVINCE

VALUE \ FERTILIZER APPLICATION	ORGANIC (Tonnes/ha)	N (Kg/ha)	P2O5 (Kg/ha)	K2O (Kg/ha)
AVERAGE	14.1	142.9	81.5	140.9
MAX	16.7	291.7	200	333.3
MIN	8.4	80.6	33.3	13.9
STANDARD DEVIATION	1.4	64.5	52.0	115.6

Source: IAE, 2017

The survey showed that, in Tay Ninh province, 52 percent of respondents use organic fertilizer in cassava cultivation. The amount of organic fertilizer applied by farmers is on average 4.9 tonnes/ha, thus lower than in Phu Tho province. According to local farmers, the livestock sector is not developed in the area, and this results in lack of manure for field application. The average amounts of N, P_2O and K_2O applied per hectare were 138.5±82.6 kg, 115.5±56.2 kg and 105.3±69.4 kg, respectively. The amount of N applied exceed the recommendation of IASVN, while the amount of K_2O applied is lower than the one recommended (**Table 27**).

The survey also showed that, in Tay Ninh province, 100 percent of surveyed households irrigated cassava during the dry season. This is due to the relatively accessible water source for irrigation. Water supplies come from the Dau Tieng lake, one of the largest artificial lakes in Viet Nam, and from groundwater resources, which are abundant in this area and distributed throughout. The farmers draw water from the around canals and use pumps to obtain groundwater. This is one reason why the yield of cassava in Tay Ninh province is much higher than the one in the province of Phu Tho.

TABLE 27

FERTILIZER APPLICATION BY SURVEYED HOUSEHOLDS IN TAY NINH PROVINCE

VALUE \ FERTILIZER APPLICATION	ORGANIC (Tonnes/ha)	N (Kg/ha)	P_2O_5 (Kg/ha)	K_2O (Kg/ha)
AVERAGE	4.9	138.5	115.5	105.3
MAX	25.0	430.0	275.0	425.0
MIN	1.0	48.0	31.0	35.5
STANDARD DEVIATION	6.0	82.6	56.2	69.4

Source: IAE, 2017

TABLE 28

TECHNIQUE FOR FERTILIZER APPLICATION FOR CASSAVA CULTIVATION IN NGHE AN PROVINCE

TIME	MANURE (tonnes/ha)	UREA (kg/ha)	PHOSPHOROUS (kg/ha)	CALCIUM (kg/ha)	NPK 8:8:3 (kg/ha)
TECHNIQUE 1					
BEFORE PLANTING 1-3 DAYS	8-10		200-240		
AFTER PLANTING 40-45 DAYS		60-80		30-40	
AFTER PLANTING 70-75 DAYS		60-70		70-80	
TECHNIQUE 2					
BEFORE PLANTING 1-3 DAYS	8-10				600
AFTER PLANTING 70 DAYS		50		80	

Source: Phu Yen crop production and plant protection sub-department, 2015.

Biogas

a. Manure application and its effects on soil physical properties

The addition of organic materials such as solid manure, deep litter or compost to a fine-textured soil can increase the SOM content, thus stabilizing soil aggregates and improving soil structure, finally augmenting soil quality and health. Humus is the dark organic matter that forms in the soil when plant and animal matter decays. It contains many useful nutrients, nitrogen being the most important of all. During the humification process of the added organic material, microbes secrete sticky gum-like mucilage that contributes to aggregate soil particles by holding particles together, thus allowing greater aeration of the soil. Improvement of the soil structure makes soil more friable (lower soil strength, desirable for cultivation and seedbed preparation), reduces soil compaction, while increasing the amount of pore space available for plant roots and the entry of water and air into the soil.

In coarse-textured sandy soils, an increasing in organic matter can significantly ameliorate the water-holding capacity of the soil, and provide exchange and adsorption sites for nutrients. Humus can hold the equivalent of its weight in moisture and therefore increases the soil's capacity to withstand drought conditions. Furthermore, diurnal variations in surface soil temperatures are reduced by mulches of solid manure (Dahiya ***et al.***, 2001) and they may therefore serve to modulate variations in soil temperatures, buffering from temperature extremes at the soil surface, which is beneficial for seed germination and early seedling growth. The addition of manure and other organic materials in soils of arid regions is particularly beneficial. In cooler climates, on the other hand, the dark colour of humus (usually black or dark brown) helps to warm up cold soils in the spring.

b. Digestate application and its effects on soil physical properties

With the proliferation of biogas plants in many countries, an increasing proportion of manure is applied to soil in form of biogas effluent (digestate). Digestate has a high potential Mineral Fertilizer Equivalent (MFE) value. It also brings potential benefits for N availability; the proportion of NH_4^+ is increased due to mineralization occurring during the digestion, while easily decomposable C in Volatile Fatty Acids (VFAs) is converted to biogas and hence is not stored in soil upon digestate application. However, the increased proportion of NH_4^+ in digested slurries does not guarantee improved use efficiencies of slurry N, since the pH of digestate is usually 0.5-1.5 units higher than that of the raw slurry and this fact favours the formation and the volatilization of ammonia. Therefore, digestate needs to be injected or incorporated rapidly into the soil in order to avoid ammonia volatilization and to obtain higher MFE values (Nyord ***et al.***, 2012). The available field data on actual N and P MFE of digestate from animal slurries show variable results, with small or inconsistent benefits compared with undigested slurries (Möller and Müller, 2012). However, in a review of 11 field trials with various types of digested animal slurries, Birkmose (2009) found that the MFE value increased on average by approximately 10 percent, compared to that of the raw slurry. A similar magnitude has been found by Schröder ***et al.*** (2007) and de Boer (2008).

There may be concerns that applying digestate with a reduced dry matter and C content compared to raw slurry will have an adverse effect on soil structure and fertility in the long term due to the lower organic matter input. However, the organic matter left after anaerobic digestion is in more stable compounds and could contribute more to medium-term carbon retention in soil. In the medium term, Thomsen ***et al.*** (2013) found that 48 and 78 percent of C applied in faeces and digested faeces, respectively, was retained in the soil after one to two years. However, in the long-term, C retention was found to be similar regardless of anaerobic digestion, at around 12-14 percent of the C initially present in the animal feed.

4.2.3 Main conclusions and recommendations

Approach used

This project studied the state of Vietnamese soils at national level, and collected primary data on soil quality and soil management practices in cassava plantations at local level as a proxy to describe soil quality in farmland where bioenergy feedstock is produced.

Results

Information found in literature highlighted the importance of erosion risk as a possible consequence of the adoption of inappropriate soil tillage practices and soil cover management where cassava is cultivated in sloping areas.

Generally, the content of SOM in most soil units in Viet Nam ranges from 0.5 to 3.0 percent in the uppermost soil horizons. Sloping land typically has lower SOM content levels. Erosion rapidly removes organic matter from soils, and can arise as a result of poor application of organic inputs (e.g. manure, sewage sludge, crop residues) and farming techniques. In Viet Nam, there has been a lot of field research and experiments to find the optimal solution to maintain or even improve the quality of soil cultivated with cassava, especially when cassava is cultivated on sloping land.

Practices and policies to improve sustainability

To improve the efficiency and sustainability of cassava production related to soil quality, studies need to accurately assess the effectiveness of land use patterns and planting practices. Existing global or national datasets on, for example, SOC content are unlikely to be useful as a baseline, but they may be very helpful as a basis for risk assessment and modelling.

The results of the analysis show that sloping land is at higher risk of erosion and that soil quality is lower. Specialised area planning should be used to ensure that increases in cassava area and productivity occur in appropriate locations across the country in order to minimise soil degradation in higher risk areas. Suitable farming practices should also be implemented; for example, peanut and black bean intercropping in cassava cultivation on sloping land have proven to be effective at controlling erosion while maintaining or even improving cassava yield.

Waste residues from the use of cassava pulp to produce alcohol in Viet Nam can cause serious environmental pollution to the soil. Therefore, prior to the construction of biofuel production plants, a complete waste treatment system should be put in place.

Future monitoring

The indicator has proven to be relevant in the Vietnamese context and the extensive literature review performed during its assessment has confirmed the scientific basis and the value of assessing soil quality parameters in order to inform about the sustainability of bioenergy feedstock production. With regard to the practicality of the tool, the scarcity of information on changes in soil quality parameters, particularly in terms of soil organic carbon, has limited the descriptive capacity of this study.

SOC-change databases are not common in many countries and this may require primary data campaigns in order to assess the percentage of land used for bioenergy feedstock production for which soil quality is maintained or improved. These analyses, however, are complex, and time and resource intensive as they involve a large number of samples to be mapped with extreme accuracy over a large surface in order to be representative. Furthermore, due to the fairly rapid and highly variable changes that can occur in topsoil as a result of land use and soil management practices, this indicator depends in principle on site-level measurements associated with individual bioenergy production areas that need to be repeated after at least 5-10 years in the same sampling point and using the same methodology. These requirements limit the practicality of the indicator and its methodology in a context such as Viet Nam.

In addition, the data and research on the impact on soil quality of biogas digestate compared to raw manure distribution is limited due to the low number of farmers applying digestate. Furthermore, this issue does not appear to be a priority of relevant agencies and research institutions.

In order to assess this key indicator, it would be useful to plan and implement an ad-hoc national monitoring program. The program would measure SOC content and bulk soil together in different areas throughout Viet Nam, and it would map the sampling sites by exactly geo-referencing each sampling point. Since SOC changes are appreciable after a minimum of 10 years (Chappell *et al.*, 2013), this interval should be chosen in order to perform the consequential sampling on the same sites. Stratifying the sampling and establishing standard protocols could reduce the burden of monitoring the indicator.

The level of soil erosion in agricultural production has only been studied in some localities, but there has not been a comprehensive evaluation of Viet Nam. Therefore, it is necessary to combine domestic and foreign projects to assess soil erosion in agricultural soil, for the whole country. Nevertheless, actual soil loss from erosion is difficult to measure, which is why reporting on established soil stabilization measures is suggested as a proxy indicator for erosion or avoidance of erosion.

REFERENCES

Birkmose, T.S., 2009. Nitrogen Recovery from Organic Manures: Improved Slurry Application Techniques and Treatment - the Danish Scenario. International Fertiliser Society.

Chappell, A., Webb, N.P., Butler, H.J., Strong, C.L., McTainsh, G.H. and Leys, J.F., Viscarra R.R.A., 2013. Soil organic carbon dust emission: an omitted global source of atmospheric CO_2. Global change ecology, Pages 3238–3244

De Boer H.C., 2008. Co-digestion of animal slurry can increase short-term nitrogen recovery by crops. J Environ Qual.; 37(5):1968-73. doi: 10.2134/jeq2007.0594.

Dahiya, R., Malik, R. S., Jhorar, B. S, Dahiya J.B., 2001. Organic mulch decomposition kinetics in semiarid environment at bare and crop field conditions. Arid Land Research and Management. Vol.15 (1): 49-60. http://doi.org/10.1080/15324980121163

Dang, N. D. and Klinnert, C., 2001. Problems with and local solutions for organic matter management in Vietnam. Nutrient Cycling in Agroecosystems 61 (1-2): 89 – 97. Available at: https://doi.org/10.1023/A:1013388816328

Doanh, L.Q., Tuan, H.D. and Chabanne, A., 2009. *Sustainable upland farming*. Agricultural publisher. Ha Noi.

FAO, 2011. The Global Bioenergy Partnership Sustainability Indicators for Bioenergy. First Edition. ISBN 978-92-5-107249-3. Available at: www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/Indicators/The_GBEP_Sustainability_Indicators_for_Bioenergy_FINAL.pdf

GSO website. Statistical data: Agriculture, Forestry and Fishery. Available at: www.gso.gov.vn/default_en.aspx?tabid=778. Accessed 24/01/2018

Hy, N.H., Nhan, P.T., Cuong, D.V., An, T.Q, Tuan, V.V. and Long, B.V., 2014. Fertilizer application for cassava on different soil types, available at: http://iasvn.org/chuyen-muc/Quy-trinh-canh-tac-san-ben-vung-cho-vung-dong-nam-bo-7681.html

IASVN website. Available at: http://iasvn.org/chuyen-muc/Quy-trinh-canh-tac-san-ben-vung-cho-vung-dong-nam-bo-7681.html

Institute of Agricultural Environment (IAE), 2017. Survey conducted within this study on April 2017 for the collection of primary data from local farmers. The survey was conducted in the provinces of Phu Tho and Tay Ninh.

Lal, R., 2001. Soil degradation by erosion. Land Degradation & Development, 12:519-539. doi:10.1002/ldr.472.

Lich, L.H., 2014. Results of monitoring and analysis of soil environment in the Central Highlands and South Central Coast. Dak Lak, 2014.

Möller, K. and Müller, T., 2012. Effects of anaerobic digestion on digestate nutrient availability and crop growth. Eng. Life Sci. 2012, 12, No. 3, 242–257

Nyord, T., Hansen, M.N., Birkmose, T.S., 2012. Ammonia volatilisation and crop yield following land application of solid–liquid separated, anaerobically digested, and soil injected animal, slurry to winter wheat. Agriculture, Ecosystems and Environment 160: 75-81

Phu Yen crop production and plant protection sub-department, 2015. Cassava growing technique, available at: http://bvtv.phuyen.gov.vn/ky-thuat-tham-canh-cay-san.html

Quyen, L.N., Hieu, D.T. and Toan, N.V., 2015. Using sloping land and livelihood of ethnic minorities in the Northern midland and mountainous areas. In Vietnam national land Conference - current usage and challenges. ***Agriculture publishing house. Hanoi, Vietnam***. Pp 138-148.

Schröder, J.J., Uenk, D., and Hilhorst, G.J., 2007. Long-term nitrogen fertilizer replacement value of cattle manures applied to cut grassland. Plant Soil 299:83-99

Thang, H.M., 2014. Results of monitoring and analysis of soil environment in the North Viet Nam. IAE, Ha Noi, 2014.

Thomsen, I. K., Olesen J. E., Moller H. B., Sorensen P., and Christensen B. T.. 2013. Carbon dynamics and retention in soil after anaerobic digestion of dairy cattle feed and faeces. Soil Biol. Biochem. 58:82-87.

4.3 INDICATOR 3: HARVEST LEVELS OF WOOD RESOURCES

Dam Trong Anh, Nguyen Ngoc Quynh, Pham Quang Ha
Institute for Agricultural Environment (IAE), Viet Nam Academy of Agricultural Sciences (VAAS)

DESCRIPTION:

Annual harvest of wood resources by volume and as a percentage of net growth or sustained yield, and the percentage of the annual harvest used for bioenergy.

MEASUREMENT UNIT(S):

m^3/ha/year, tonnes/ha/year, m^3/year or tonnes/year; percentage

4.3.1 Implementation of Indicator 3 in Viet Nam

For measuring indicator 3 in Viet Nam, secondary data on forest cover and forest productivity over the period 2007–2015 were compiled and analysed, together with data on annual harvest of wood resources and firewood specifically.

However, part of the indicator could not be measured, as data on net annual growth and sustained yield and on the exact share of wood resources used for bioenergy could not be found when the analysis was carried out.

Almost all data were collected from statistical books and web sources, such as the General Statistics Office (GSO website) of Viet Nam and FAOSTAT (FAO, 2017).

4.3.2 Key findings

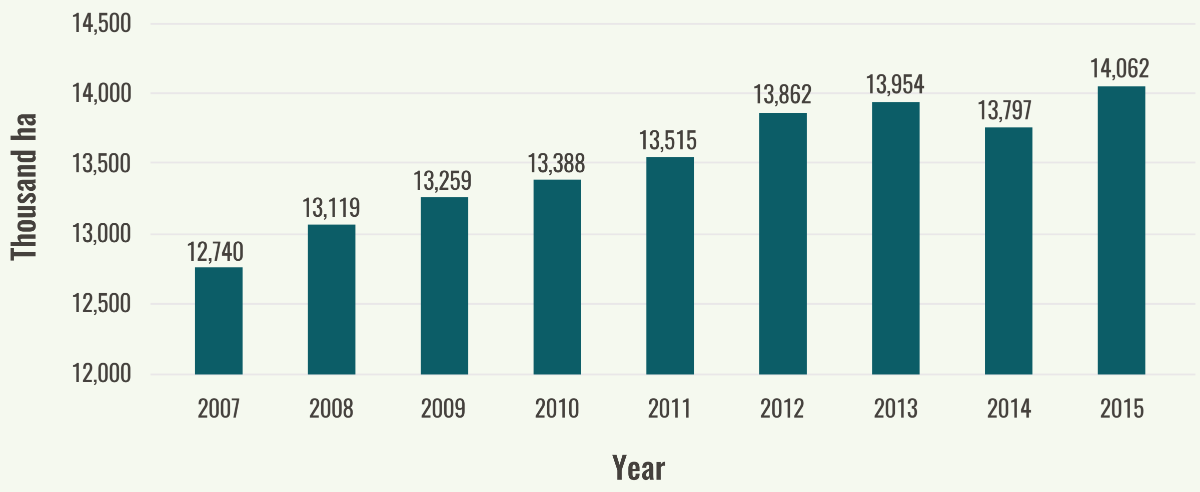
Forest areas

a. Forest cover by region

According to MARD (2016), forest ecosystems include populations of perennial timber trees, bamboos and palms of all kinds of a minimum height of five metres, minimum 10 percent tree cover and minimum area of 0.5 ha, together with wildlife, forest microorganisms, forest lands and other environmental components. The name "forest" can be used as a general term for all planted forests and natural forests under

FIGURE 22

FOREST COVER IN VIET NAM, 2007 - 2015



Source: GSO website

TABLE 29

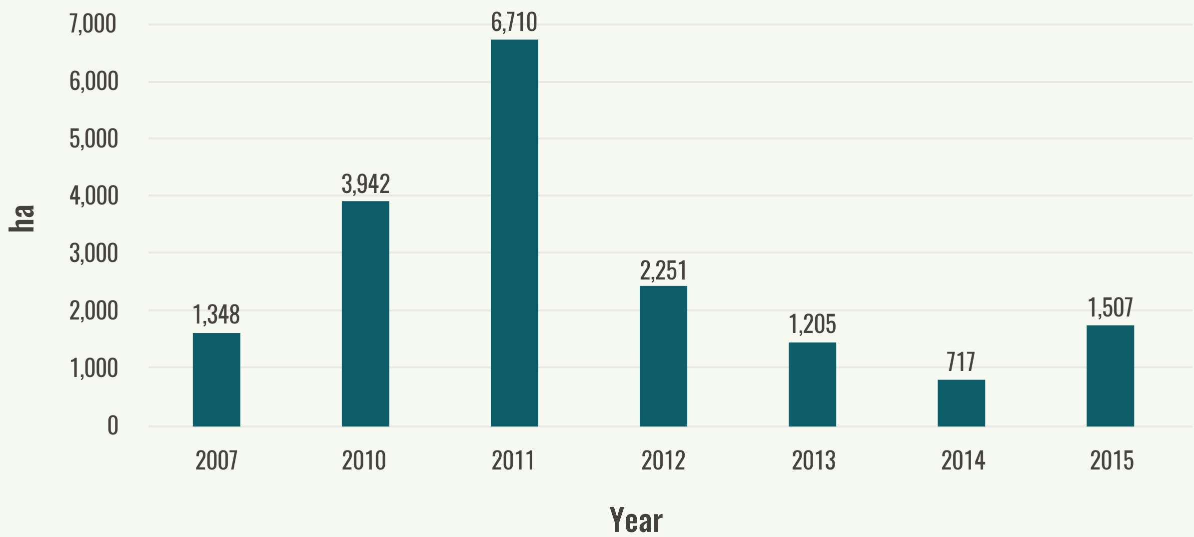
FOREST COVER BY REGION, 2007-2015

REGION	2007	2008	2009	2010	2011	2012	2013	2014	2015
RED RIVER DELTA (RRD)	123.1	416.4	428.9	434.9	440.8	447.7	466.0	482.9	491.6
NORTHERN MIDLANDS AND MOUNTAIN AREAS (NMM)	4 654.7	4 558.4	4 633.5	4 675.0	4 746.5	4 925.2	4 959.3	5 030.0	5 082.6
NORTH CENTRAL AND CENTRAL COASTAL AREAS (NCCC)	3 815.9	4 497.4	4 592.0	4 726.9	4 796.7	4 864.2	4 931.4	4 969.5	5 179.8
CENTRAL HIGHLAND (CHL)	2 926.6	2 928.7	2 925.2	2 874.4	2 848.0	2 903.9	2 848.7	2 567.1	2 562.0
SOUTH EAST (SE)	898.4	419.9	402.8	408.0	423.0	471.8	466.9	476.2	473.9
MEKONG RIVER DELTA (MRD)	320.9	298.5	276.3	268.9	260.1	249.2	282.1	270.8	272.0
WHOLE COUNTRY	12 739.6	13 118.8	13 258.7	13 388.1	13 515.1	13 862.0	13 954.4	13 796.5	14 061.9

Unit: Thousand ha
Source: GSO website

FIGURE 23

LOSS OF FOREST AREA DUE TO ANTHROPOGENIC ACTIVITIES, 2007-2015



Source: GSO website

production, forest land, protected forest land, and special-use forest land.

Total national forest areas in Viet Nam change continuously under the positive impacts of reforestation and afforestation policies started in the early 1990s, through a national program entitled ‘Greening the Barren Hills’ (Program 327) along with international support, and negative impacts of unsustainable exploitation and forest fires. Forest area has great significance for the development of forest ecosystems and their protection. **Figure 22** shows the change in forest cover from 2007 to 2015.

The forest area is mainly found in two regions of the country (i.e. the Northern Midlands and Mountain areas and the North Central and

TABLE 30

LOSS OF FOREST AREA DUE TO ANTHROPOGENIC ACTIVITIES BY REGION, 2007-2015

REGION	2007	2010	2011	2012	2013	2014	2015
RRD	3.2	1.8	1.6	134.4	0.7	52.8	2.2
NMM	229.0	319.5	541.2	267.5	118.3	131.6	279.3
NCCC	124.6	307.3	1 055.7	699.1	566.1	158.3	694.1
CHL	481.3	2 951.8	4 951.3	1 093.7	487.8	355.8	500.8
SE	483.9	361.6	153.5	55.8	27.1	12.2	18.0
MRD	26.1	..	7.0	0.5	4.5	5.8	12.3
WHOLE COUNTRY	**1 348.1**	**3 942.0**	**6 710.3**	**2 251.0**	**1 204.5**	**716.5**	**1 506.7**

Unit: Ha
Source: GSO website

FIGURE 24

SOME CASES OF CONFISCATED TIMBER

Timber illegally logged in Bac Kan province (Minh Anh, 2011)

Precious timber illegally logged in Phuoc Son, Quang Nam province (Quoc Do, 2010)

Central Coastal areas), which together account for 73 percent of total forest cover. In most regions, the forest cover tended to increase up to 2015, thanks to policies aiming to reduce the impacts of natural disasters, protect the ecological environment and respond to climate change, which together contribute to promoting reforestation and afforestation (**Table 29**).

One of these policies is the "5 million hectares Reforestation Programme (5MHRP)", which was launched in 1998 by the government, with the objective of establishing five million hectares of new forest and protecting 9.3 million hectares of existing forest, in order to increase national forest cover from 28 to 43 percent by 2010 (Huong, Zeller and Hoanh, 2014).

b. Forest area loss due to anthropogenic activities

In the period from 2007 to 2011, the area of forest cleared increased sharply from 1 348 ha per year in 2007 to 6 710 ha per year in 2011 (**Figure 23**).

Deforestation occurred mostly in the Central Highlands and in the North Central and Central Coastal Area (**Table 30**). Both of these regions are largely forested, and host many primary forests with high forest area. Forest is cut down by the loggers exploiting timber and by people who convert forest land to agricultural land (see indicators 7 and 8).

In the period from 2012 to 2015, the deforestation rate in the country decreased significantly up to 2014 (716 ha per year), but increased again in 2015 (1 507 ha per year). To avoid further deforestation, in September 2015 the Viet Nam government promulgated the Decree 75/2015/ND-CP on the mechanism and policy for the development of forests, related to the policy on sustainable and rapid poverty reduction and assistance to ethnic minorities for the period 2015-2020.

Forest is the key habitat for a high proportion of Viet Nam's globally threatened plant and animal species. However, these forests have been the focus of excessive commercial and non-commercial logging for decades, leading to reductions in both their extent and quality, with very few primary forests areas remaining.

Annually, the Forest Protection Department seizes tens of thousands of cubic meters of round and sawn timber, which is rare and precious. There are cases where loggers have blatantly carried out illegal exploitation of timber in core zones of national parks, which has caused anger among society.

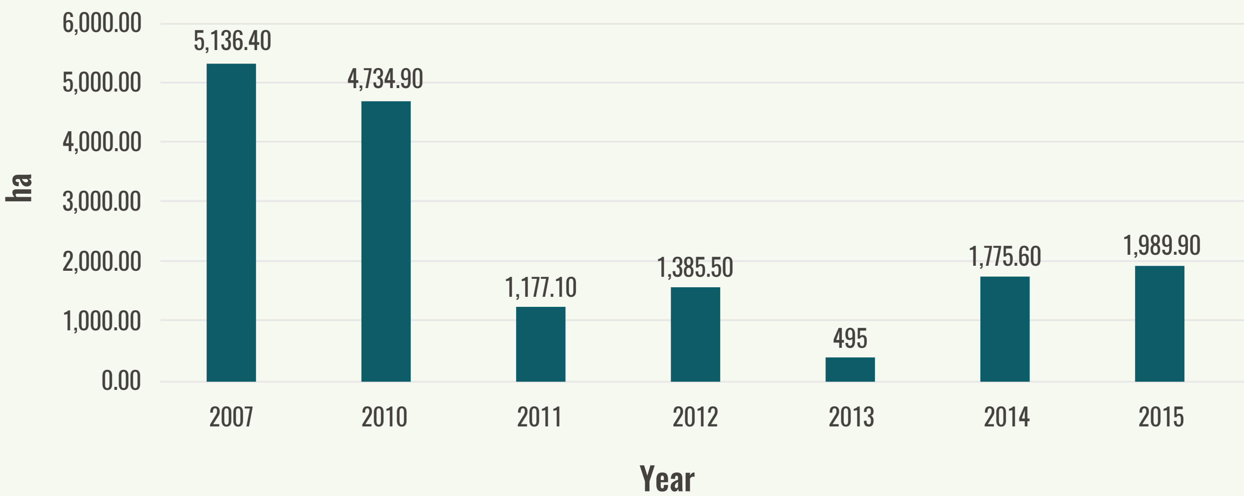
c. Amount of forest loss due to forest fires

In Viet Nam, every year hundreds of fires occur and destroy thousands of hectares of forests (see **Figure 25**). For example, just in the first eight months of 2011, 214 fires and 263 cases of violation of regulations on forest fire prevention and fighting were registered.

This can have a serious impact on the environment and biological communities in forest ecosystems and causing damage worth hundreds of billions of VND. For instance, the large forest fire occurring in Hoang Lien National Park (Lao Cai province) in February 2010 burned for 10 days and consumed 200 ha of forest and 700 ha of shrub land. Forest fires in Tram Chim National Park (Dong Thap province) in April 2010 destroyed 200 ha of forest, threatening the habitat of the Sarus crane (*Antigone antigone*) a species of bird classified as vulnerable on the International Union for Conservation of Nature (MONRE, 2016).

FIGURE 25

LOSS OF FOREST AREA DUE TO FOREST FIRES, 2007-2015



Source: GSO website

TABLE 31

LOSS OF FOREST AREA DUE TO FOREST FIRES BY REGION, 2007-2015

REGION	2007	2010	2011	2012	2013	2014	2015
RRD	979.2	28.8	33.7	79.2	72.6	61.9	50.4
NMM	3 059.0	2 418.4	458.7	915.3	159.9	483.5	677.6
NCCC	328.9	1 175.2	463.1	366.5	59.9	1 173.7	685.9
CH	420.7	238.4	214.5	3.1	196.5	40.5	363.4
SE	22.2	24.6	NA	0.0	3.8	15.3	29.9
MRD	326.4	849.5	7.1	21.4	2.3	0.7	182.7
WHOLE COUNTRY	5 136.4	4 734.9	1 177.1	1 385.5	495	1 775.6	1 989.9

Unit: ha

Source: GSO website

The high impact of forest fires in recent years show that there is a lack of modern facilities for fighting forest fires in Viet Nam, which makes fire control very difficult, especially in forests set on high mountains such as those in Hoang Lien National Park. Besides the need for more modern firefighting equipment to protect forests, it is also important to strengthen education and enhance the control of the activities of people entering forests for farming or resource exploitation.

Annual harvest of wood resources

a. Timber wood harvest by region

Forests in Viet Nam are property of the state and timber harvesting is regulated through the Forest Protection and Development Act passed by the National Assembly at its sixth session, Legislature XI, dated 3 December 2004 and implemented since 1 April 2005. The law states the rights and obligations of the parties in the exploitation, protection and development of forests. Cases of illegal exploitation of forest resources are punished according to the level of behaviour that the subject violates. The law is detrimental to individuals and organizations that intend to destroy forests.

The total volume of timber harvested per year throughout the country from 2007 to 2015 has seen a remarkable growth, with total production in 2007 of 3.46 million m^3, and 9.20 million m^3 in 2015 (**Figure 26**). Of these, the largest production is located in the North Central and Central Coastal areas and Northern Midlands and Mountain areas; the lowest amount of harvested timber wood was registered in the Red River Delta and South East regions (**Table 32**).

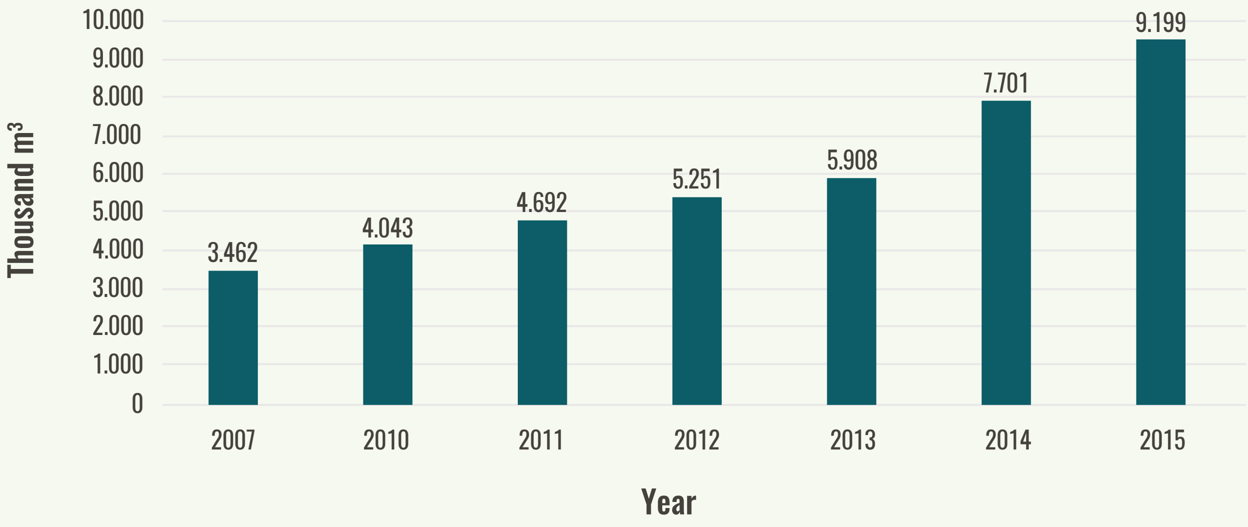
b. Firewood harvest by region

Total firewood harvested nationwide registered the highest value in 2013 with 29.4 million m^3 and the lowest value in 2014 with 21.8 million m^3 (**Figure 27**).

The areas in which the amount of harvested firewood registered the highest value were mostly concentrated in the Northern Midlands and Mountain areas (**Table 33**). This region has the largest forest area and forest cover available for wood harvest. Furthermore, due to the altitude, average temperatures are lower compared to other regions thus, because of the lack of other source of fuel (e.g. coal and LPG), people often use firewood for cooking and heating. The lowest amount of harvested firewood was registered in the South East (maximum 428.6 thousand m^3 in 2011) and Red River Delta (maximum 794.6 thousand m^3 in 2011), as these two areas have the lowest forest cover in the country. In these regions, other kinds of biomass (e.g. straw, rice husk) are available and commonly used as fuel for cooking at household level.

FIGURE 26

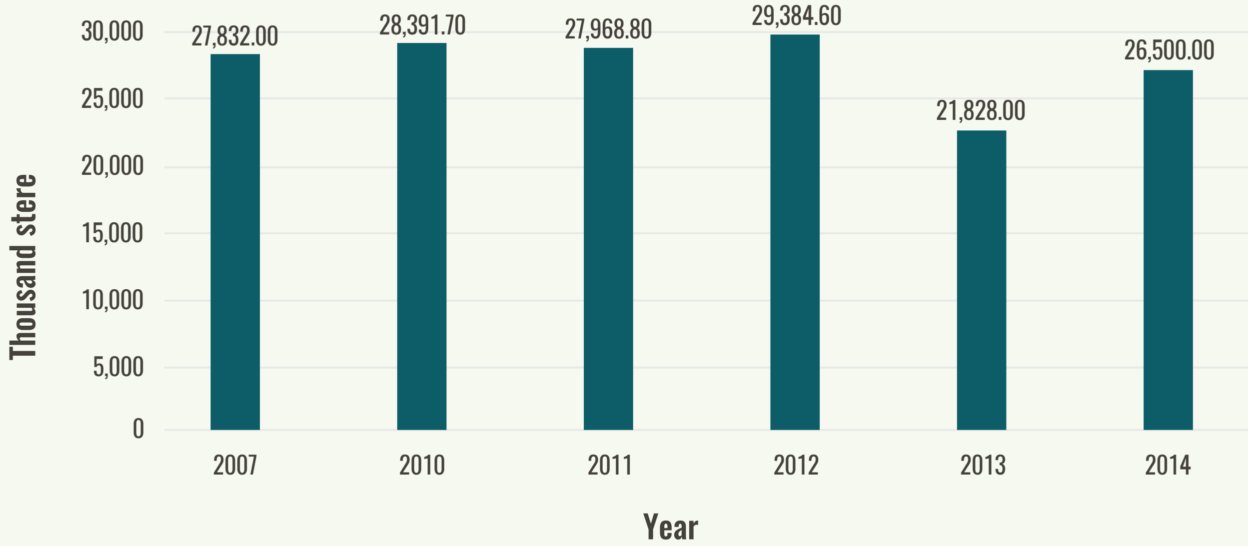
TIMBER WOOD HARVEST, 2007-2015



Source: GSO website

FIGURE 27

FIREWOOD HARVEST, 2007-2015



Source: GSO website

TABLE 32

TIMBER WOOD* HARVEST BY REGION, 2007-2015

REGION	2007	2010	2011	2012	2013	2014	2015
RRD	178.80	187.30	278.70	318.70	382.40	516.30	490.60
NMM	1 185.80	1 328.10	1 402.90	1 590.20	1 731.10	2 278.10	2 866.00
NCCC	991.10	1 237.70	1 443.50	1 717.30	2 349.90	3 474.30	4 388.00
CH	352.50	416.50	589.50	620.30	539.60	447.30	456.60
SE	127.40	262.80	324.60	323.00	323.60	320.80	323.80
MRD	626.20	610.10	652.80	681.50	581.40	664.60	674.20
WHOLE COUNTRY	3 461.80	4 042.60	4 692.00	5 251.00	5 908.00	7 701.40	9 199.209

Unit: thousand m3
Source: GSO website

* According to GSO of Viet Nam, 'harvested timber wood' includes round wood, wood for making paper, ships, boats and wood for making other products acquired from planted forest, natural forest and from separate planted trees.

TABLE 33

FIREWOOD HARVEST BY REGION, 2007-2015

REGION	2007	2011	2012	2013	2014	2015
RRD	NA	794.6	649.4	647.7	732.0	NA
NMM	NA	14 753.10	15 075.80	15 800.60	15 947.10	NA
NCCC	NA	7 365.20	7 205.40	7 768.50	7 683.9	NA
CH	NA	1 774.90	1 483.60	1 510.00	1 509.00	NA
SE	NA	428.6	395.2	400.8	395.9	NA
MRD	NA	3 275.30	3 159.40	3 257.00	3 244.00	NA
WHOLE COUNTRY	27 832.0	28 391.70	27 968.80	29 384.60	21 828.00	26 500.0

Unit: thousand m3
Source: GSO website

c. Share of wood production

According to FAO (2017), an increase in wood production was recorded in Viet Nam from 2007 to 2014/15. FAO (2017) reports data related to 'wood fuel (non-coniferous)'. This data is not consistent with those provided by the GSO website for 'firewood'. This might be due to inconsistent definitions, between the two sources, of the aforementioned terms, which might include different things.

According to FAO (2017), the production of charcoal increased significantly from 120 000 tonnes in 2007 to 414 000 tonnes in 2014. As demand for charcoal for restaurants as well as exports to Japan and South Korea increased, the amount of wood used for charcoal production increased sharply, as well the production of wood chips and particles (an increase of 1.39 million m^3 from 2012 to 2014) and the production of pellets (an increase of 1 million tonnes from 2007 to 2014). On the other hand, fibreboard production did not increase significantly (only 20.0 thousand m^3 from 2012 to 2014).

TABLE 34

SHARE OF WOOD PRODUCED, 2007-2015

SHARE OF WOOD*	UNIT	2007	2010	2011	2012	2013	2014	2015
ROUND WOOD	m^3	27 450 000	28 200 000	27 100 000	26 800 000	26 322 360	26 653 820	
WOOD FUEL (NON-CONIFEROUS)	m^3	22 000 000	21 500 000	20 400 000	20 000 000	20 000 000	20 000 000	20 000 000
SAW LOGS	m^3	2 150 000	2 850 000	2 750 000	2 750 000	2 363 400	2 618 400	
PULPWOOD, ROUND AND SPLIT	m^3	1 920 000	3 000 000	3 100 000	3 250 000	3 250 000	3 250 000	
WOOD CHARCOAL	tonnes	120 000	115 000	120 000	414 000	414 000	414 000	414 000
WOOD CHIPS AND PARTICLES	m^3	1 920 000	3 000 000	3 200 000	3 312 000	3 312 000	3 312 000	3 312 000
WOOD RESIDUES	m^3	320 000	330 000	350 000	350 000	350 000	350 000	350 000
WOOD PELLETS	tonnes				50 000	170 000	800 000	1 000 000
SAWN WOOD	m^3	4 500 000	5 800 000	5 800 000	6 200 000	6 000 000	6 000 000	
WOOD-BASED PANELS	m^3	554 000	680 000	809 000	1 037 000	1 432 000	1 950 000	
VENEER SHEETS	m^3	134 000	60 000	159 000	339 000	662 000	1 050 000	1 050 000
PLYWOOD	m^3	70 000	195 000	215 000	258 000	425 000	530 000	530 000
PARTICLE BOARD	m^3	180 000	240 000	245 000	250 000	250 000	250 000	
FIBERBOARD	m^3	170 000	185 000	190 000	190 000	190 000	190 000	

Source: FAO, 2017

* FAOSTAT – Forestry definition. Forest product statistics. Classification and standards. Available at: www.fao.org/forestry/statistics/80572/en/

4.3.3 Main conclusions and recommendations

Approach used

Secondary data were used for measuring Indicator 3 in Viet Nam. Only partial data could be found, mostly from the GSO website and FAO (2017). No data were available on the exact share of wood resources used for bioenergy.

Results

According to GSO, the amount of harvested firewood remained almost unchanged from 2007 to 2015. For the same period, FAO (2017) also reported a constant trend in harvest/production levels. However, different figures for wood fuel (non-coniferous) emerge, probably due (at least in part) to inconsistent definitions between the two sources.

This suggests that, during the considered period of time, modern bioenergy technologies and most notably biogas do not seem to have played a key role in displacing traditional uses of biomass in Viet Nam as the use of firewood remained constant. An explanation for this is that firewood is the primary source of fuel for heating in the colder Northern provinces (Northern Midlands and Mountain areas) where there is a large proportion of forest cover and limited alternative fuel sources. In these regions, the low temperature in winter does not allow for sufficient production of biogas to cover heating requirements and so it cannot be used as an alternative to firewood. In the regions where there is low forest cover (South East and Red River Delta), no firewood is required for heating and rice husk and straw are used for cooking.

Practices and policies to improve sustainability

Forest areas are the key habitats for a high proportion of Viet Nam's globally threatened plant and animal species. However, in the past decades forests have been the focus of excessive commercial and non-commercial logging, leading to reductions in both their extent and quality, with very few primary forests areas remaining. However, thanks to the issue of policies (e.g. Decree 75/2015/ND-CP) to prevent uncontrolled and unsustainable forest exploitation, the forest coverage has constantly and significantly increased from 2007 to 2015 with a final balance of +1.3 million ha over that period.

Future monitoring

In Viet Nam, official statistics are available on forest cover, and on the amount of timber wood and firewood harvested per year. Data on wood harvest/production for various uses, including 'wood fuel', is available from international sources as well (e.g. FAO 2017).

For Future monitoring, the inconsistencies highlighted above in the definitions should be addressed and possibly solved. Furthermore, accurate data should be collected and clearly presented (with transparent definitions) on all uses of wood for energy, including burning of forest residues. In addition, the net annual growth and/or sustained yield of forests in Viet Nam should be estimated.

REFERENCES

FAO. 2017. FAOSTAT. Available at: www.fao.org/faostat/en/#data [Accessed 24 Jan 2018]

GSO website. Statistical data (06.Agriculture, Forestry and Fishing). Available at: www.gso.gov.vn [Accessed 24 Jan. 2018]

Huong, T.T.T., Zeller, M. and Hoanh, C.T.2014. The 'Five Million Hectare Reforestation Program' in Vietnam: An Analysis of its Implementation and Transaction Costs. A Case Study in Hoa Binh Province. Quarterly Journal of International Agriculture 53 (4): 341-375.

Minh Anh. 2011. Gỗ rừng Bắc Kạn bị đốn trái phép chất đống chờ "về xuôi" (Bac Kan timber felled illegally piled up waiting for "downstream"). Available at: http://baophapluat.vn/thoi-su/go-rung-bac-kan-bi-don-trai-phep-chat-dong-cho-quotve-xuoiquot-152873.html [Accessed 21 Jan 2017]

Ministry of Agriculture and Rural Development (MARD) Viet Nam. 2016. Viet Nam's Submission on Reference Levels for REDD+ Results Based Payments under the UNFCCC. Available at: http://redd.unfccc.int/files/2016_submission_frel_viet_nam.pdf

Ministry of Natural Resources and Environment (MONRE). 2016. Vietnam National Biodiversity Strategy to 2020, vision to 2030. Hanoi, 2016.

Quoc Do. 2010. Phá rừng phòng hộ để khai thác vàng (Deforestation protective forest for exploit gold). Available at: http://dantri.com.vn/xa-hoi/pha-rung-phong-ho-de-khai-thac-vang-1276479662.htm [Accessed 21 Jan 2017].

4.4 INDICATOR 4: EMISSIONS OF NON-GHG AIR POLLUTANTS, INCLUDING AIR TOXICS

Nguyen Thi Anh Tuyet
Vietnam Japan International Institute for Science of Technology (VJIIST) at the Hanoi University of Science and Technology (HUST)

DESCRIPTION:

Emissions of non-GHG air pollutants, including air toxics, from
(4.1) bioenergy feedstock production,
(4.2) processing,
(4.3) transport of feedstocks, intermediate products and end products, and
(4.4) use;
and in comparison with other energy sources

MEASUREMENT UNIT(S):

Emissions of PM2.5, PM10, NOX, SO2 and other pollutants can be measured and reported in the following ways as is most relevant to the feedstock, mode of processing, transportation and use.
4.1 mg/ha, mg/MJ, and as a percentage
4.2 mg/m^3 or ppm
4.3 mg/MJ
4.4 mg/MJ

4.4.1 Implementation of Indicator 4 in Viet Nam

For the measurement of Indicator 4 (Emissions of non-GHG air pollutants, including air toxics), researchers performed a Lifecycle Assessment (LCA) for both pathways – Cassava-based ethanol and manure-based biogas[7].

For Cassava-based ethanol production, the following stages of the value chain were considered in the LCA: feedstock production, transformation and delivery to the ethanol plant; biomass processing into biofuels; and biofuel transportation, storage and distribution. The emissions associated with Cassava-based ethanol were compared with those of gasoline. In the case of biogas, the comparison was made with two other 'modern' fuels that could be used to displace traditional biomass use for cooking, i.e. LPG and natural gas.

The following types of non-GHG emissions were considered in this study: NH_3, NMVOC, CO, NO_x, PM_{10}, dust and SO_2. For the biofuel production and distribution phases, the amounts of non-GHG emissions were calculated by multiplying the Emission Factors (EF) from the GREET database (GREET, 2012) with the quantities of production inputs, including electricity, coal and diesel. The chemical inputs were ignored due to their expected insignificant amounts and the lack of data on their EFs. For the fuel combustion phase, the amounts of non-GHG emissions were derived from the official emission standards in Viet Nam, which are based on European emission standards for vehicles.

The emission sources for ethanol and biogas production are listed in **Table 35** and **Table 38**, respectively.

4.4.2 Key findings

Cassava-based ethanol production

A detailed description of the phases of cassava cultivation can be found in Chapter three. Regarding land use change and related emissions, input data based on the information included under indicator 8 (Land use and land-use change related to bioenergy feedstock production) were used.

Two different scenarios for cassava cultivation were considered in the analysis, reflecting the real situation in the country – cultivation in sloping and flat areas, with low and high input level, respectively. After harvest, cassava is manually sliced and dried in the sun before delivery to ethanol plants in the form of dried

[7] Biogas is produced from manure at both household and farm level in Viet Nam. At industrial level, cassava starch wastewater is the main feedstock; this could not be analysed here due to lack of data.

chips (final water content is about 14 percent, on average). The conversion ratio of fresh root to dried chips is 2.5 kg/kg (Indicator 18). Transport of the cassava occurs using 40 tonne trucks (full load), either from the cultivation areas or the main exporting port to the plants. For round trips, diesel consumption for the 40 tonne trucks is on average 0.28 litres/km.

There are four sub-processes to convert dried cassava chips to ethanol: 1) milling, 2) liquefaction, 3) saccharification and fermentation, and 4) distillation and dehydration. Besides ethanol, by-products include Dried Distillers Grains sold for animal feed production, biogas used as supplemental energy, and CO_2 collected for sale. The conversion ratio of dried chips to ethanol is on average 2.3 kg/litre (Indicator 18).

The ethanol product is sold to oil companies and delivered to blending stations by 30 m^3 trucks. For round trips, diesel consumption for the 30 m^3 trucks is on average 0.28 litre/km (Indicator 23). At the blending stations, three methods can be used: 1) in-tank recirculation; 2) static mixing; and 3) in-line blend. The first two methods require tanks for handling the ethanol fuel, while in the "in-line blend" method, gasoline and ethanol are blended directly in line before being transferred by truck and ship to the gasoline station. Therefore, most of the petroleum distribution companies choose the "in-line blend" method and several blending systems have been installed across the country.

The LCA input data of three ethanol plants was averaged and was multiplied by the corresponding non-GHG emission factors; this gave total non-GHG emissions from the ethanol production of 0.041 g SO_2, 0.092 g NO_x, 0.036 g CO, 0.009 g VOC, 0.085 g PM_{10}, 0.142 g NH_3 per MJ of product, of which the main contribution comes from burning solid fuels for steam production in the ethanol plants. Total non-GHG emissions from both the production and consumption phases were calculated as 0.041 g SO_2, 0.592 g NO_x, 0.216 g CO, 0.056 g VOC, 0.105 g PM_{10}, 0.142 g NH_3 per MJ of ethanol (**Table 36** and **Table 37**).

TABLE 35

LCA INPUT DATA FOR CASSAVA-BASED ETHANOL PRODUCTION IN VIET NAM

LAND USE CHANGE			
LAND USE CHANGE (LUC)	539		kg CO_{2eq} / ha/y
CULTIVATION			
	FLAT LAND	SLOPING LAND	
YIELD			
CASSAVA	25.00	14.75	tonnes/ ha/y
WATER CONTENT	65	65	percent
HARVEST RESIDUE	15.50	12.07	tonnes/ ha/y
FERTILIZER & PESTICIDES			
N-FERTILIZER	138.5	50.0	kg N / ha/y
MANURE	39.2	36.0	kg N / ha/y
P_2O_5-FERTILIZER	115.5	50.0	kg P_2O_5 / ha/y
K_2O-FERTILIZER	105.3	60.0	kg K_2O / ha/y
CAO- SOIL CONDITIONER (KG $CaCO_3$)	600	100	kg $CaCO_3$ / ha/y
STILLAGE	0	0	kg N / ha/y
PESTICIDES	2	0	kg / ha/y
SEEDS			
CASSAVA CUTTINGS	750	875	kg / ha/y
ENERGY			
DIESEL	22.5	0	litres / ha/y
EMISSIONS FROM DIESEL USAGE (AGRICULTURE)			
ELECTRICITY CONSUMPTION (FOR IRRIGATION)	45.0	0	kWh / ha/y
ELECTRICITY MIX	ELECTRICITY MIX VIET NAM		

TRANSPORT OF CASSAVA ROOTS		
TRANSPORT LOSSES	0.000	KG / KG CASSAVA
DISTANCE	10.0	KM
TRANSPORT VEHICLE	TRUCK (40 T) FOR DRY PRODUCTS	
FUEL	DIESEL	
CHIPPING MANUALLY PERFORMED		
YIELD	0.400	KG CHIPS / KG CASSAVA
DIESEL	0.00000	LITRES / KG CASSAVA
TRANSPORT OF CASSAVA CHIPS		
TRANSPORT LOSSES	0.000	KG / KG CASSAVA CHIPS
DISTANCE	288.96	KM
TRANSPORT VEHICLE	TRUCK (40 TONNE) FOR DRY PRODUCTS	
FUEL	DIESEL	
PROCESSING - ETHANOL PLANT		
ETHANOL	0.345	KG ETHANOL / KG CASSAVA CHIPS
CO-PRODUCTS		
CO_2	0.630	KG / KG ETHANOL
STILLAGE CAKE	0.075	KG / KG CASSAVA CHIPS
WATER CONTENT OF STILLAGE	20.0	PERCENT
BIOGAS (REUSED AS ENERGY SOURCE)		
CHEMICALS		
SULPHURIC ACID (H2SO4)	0.0031	KG / KG ETHANOL
ALPHA-AMYLASE	0.0019	KG / KG ETHANOL
AMMONIA (NH3)	0.0057	KG / KG ETHANOL
UREA	0.0047	KG / KG ETHANOL
SODIUM HYDROXIDE (NAOH)	0.0025	KG / KG ETHANOL
DAP	0.0034	KG / KG ETHANOL
ENERGY		
ELECTRICITY CONSUMPTION	0.274	KWH / KG ETHANOL
ELECTRICITY MIX	ELECTRICITY MIX VIET NAM	
METHANE FROM BIOGAS	1.008	MJ / KG ETHANOL
HARD COAL	8.160	MJ / KG ETHANOL
WOOD CHIPS	3.547	MJ / KG ETHANOL
ALLOCATION OVER MAIN- AND CO-PRODUCT		
HEATING VALUE PRODUCTS SUM	0.0	MJ
EMISSIONS ALLOCATED TO ETHANOL	78.3	PERCENT
TRANSPORT OF ETHANOL TO BLENDING/FILLING STATION		
TRANSPORT		
DISTANCE	522	KM
TRANSPORT VEHICLE	TRUCK (30 M3) FOR LIQUIDS	
FUEL	DIESEL	
BLENDING/FILLING STATION		
ELECTRICITY CONSUMPTION	0.005	KWH / KG ETHANOL
ELECTRICITY MIX	ELECTRICITY MIX VIET NAM	

TABLE 36

NON-GHG EMISSIONS FROM CASSAVA-BASED ETHANOL PRODUCTION (FLAT LAND)

		MAJOR AIR POLLUTANTS						
		g SO_2	g NO_x	g CO	g NMVOC	g PM_{10}	g Dust	g NH_3
CULTIVATION								
FERTILIZER & PESTICIDES								
N-FERTILIZER	PER HECTARE	132	254	107	49.3	23	28.3	0
P_2O_5-FERTILISER	PER HECTARE	436	411	103.2	20.85	21.83	51.2	0.071
K_2O-FERTILISER	PER HECTARE	19.2	151.6	52.8	7.46	0.759	6.39	0.008
CAO- SOIL CONDITIONER (KG $CaCO_3$)	PER HECTARE	54.9	87.9	12.33	0.410	3.49	4.79	0.033
PESTICIDES	PER HECTARE	80.8	184	42.5	5.73	3.83	19.3	0.021
NH3-EMISSION FROM N-MINERAL FERTILIZER	PER HECTARE							16818
EMISSIONS FROM FIELD BURNING OF RESIDUES	PER HECTARE	0	0	0	0	0	0	0
SEEDS								
CASSAVA CUTTINGS	PER HECTARE	0.000	0.00	0.000	0.0000	0.0000	0.000	0.0000000
ENERGY								
DIESEL	PER HECTARE	37	40	9.9	16.1	0.85	0.930	0.021
EMISSIONS FROM DIESEL USAGE (AGRICULTURE)	PER HECTARE	0.150	656	205	63	33	33	0.15
ELECTRICITY CONSUMPTION (FOR IRRIGATION)	PER HECTARE	35.0246	50.626	6.0715	2.3461	4.7199	6.1358	0.014
CULTIVATION SUM	**PER HECTARE**	**760**	**1784**	**532**	**163**	**86**	**143.4**	**16818**
CULTIVATION SUM	**PER KG OF CASSAVA**	**0.0304**	**0.071**	**0.021**	**0.0065**	**0.0034**	**0.0057**	**0.67**
TRANSPORT OF CASSAVA ROOTS								
DIESEL	PER KG OF CASSAVA	0.00037	0.0054	0.0009	0.00032	0.0001	0	0.000
TRANSPORT SUM	**PER KG OF CASSAVA**	**0.00037**	**0.0054**	**0.0009**	**0.00032**	**0.0001**	**0**	**0.000**
CHIPPING MANUALLY PERFORMED								
DIESEL	PER KG OF CASSAVA	0	0	0.0	0.0	0.00	0.000	0.000
CHIPPING SUM	**PER KG OF CASSAVA**	**0.000**	**0.000**	**0.0000**	**0**	**0.0000**	**0.0000**	**0.000**
TRANSPORT OF CASSAVA CHIPS								
DIESEL	PER KG OF CASSAVA CHIPS	0.01072	0.1554	0.0272	0.00923	0.0015	0	0.000

TRANSPORT SUM	**PER KG OF CASSAVA CHIPS**	**0.01072**	**0.1554**	**0.0272**	**0.00923**	**0.0015**	**0**	**0.000**
PROCESSING - ETHANOL PLANT								
CHEMICALS								
SULPHURIC ACID (H2SO4)	/KG ETHANOL	0.00104	0.0019	0.0004	0.00004	0.0001	0.0001	0.000
ALPHA-AMYLASE	/KG ETHANOL	0.00006	0.0029	0.0014	0.00022	0.0000	0.0000	0.000
AMMONIA (NH3)	/KG ETHANOL	0.00036	0.0097	0.0044	0.00113	0.0000	0.0003	0.000
UREA	/KG ETHANOL	0.00000	0.0000	0.0000	0.00000	0.0000	0.0000	0.000
SODIUM HYDROXIDE (NAOH)	/KG ETHANOL	0.00485	0.0064	0.0007	-0.00002	0.0003	0.0005	0.000
DAP	/KG ETHANOL	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.000
ENERGY								
ELECTRICITY CONSUMPTION	/KG ETHANOL	0.2136	0.3087	0.0370	0.0143	0.0288	0.0374	0.000
METHANE FROM BIOGAS	/KG ETHANOL	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.000
HARD COAL	/KG ETHANOL	0.7370	0.8790	0.1239	0.0388	0.2548	0.3105	0.001
WOOD CHIPS	/KG ETHANOL	0.1809	0.6136	0.7626	0.1561	2.6071	2.8377	0.000
ETHANOL PLANT SUM	**/KG ETHANOL**	**1.138**	**1.822**	**0.931**	**0.211**	**2.891**	**3.187**	**0.001**
CUMULATED EMISSIONS	**/KG ETHANOL**	**1.392**	**2.828**	**1.170**	**0.2868**	**2.9207**	**3.233**	**4.8726**
CUMULATED ALLOCATED EMISSIONS	**/KG ETHANOL**	**1.090**	**2.22**	**0.917**	**0.225**	**2.2880**	**2.5326**	**3.82**
TRANSPORT OF ETHANOL TO BLENDING/FILLING STATION								
TRANSPORT								
DISTANCE	/KG ETHANOL	0.02086	0.3023	0.0530	0.01795	0.0029	0.0030	0.000
BLENDING/FILLING STATION								
ELECTRICITY CONSUMPTION	/KG ETHANOL	0.0039	0.0057	0.0007	0.0003	0.0005	0.0007	0.000
ELECTRICITY MIX								
TRANSPORT & BLENDING/ FILLING STATION SUM	**/KG ETHANOL**	**0.0248**	**0.308**	**0.0537**	**0.0182**	**0.0035**	**0.0037**	**0.000**
FUEL USE								
EMISSIONS FROM ETHANOL USAGE	**PER MJ ETHANOL**	**0.0000**	**0.500**	**0.1800**	**0.0470**	**0.0200**	**0.0200**	**0.000**

TABLE 37

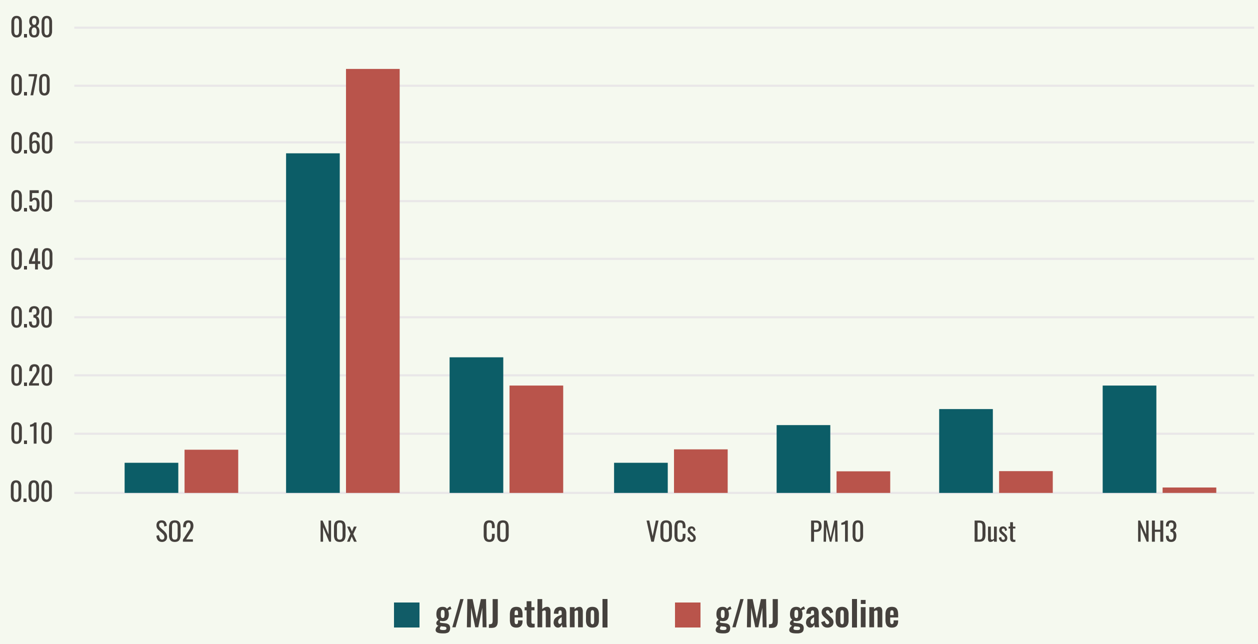
NON-GHG EMISSIONS FROM THE ENTIRE LIFE CYCLE: COMPARISON BETWEEN CASSAVA-BASED ETHANOL AND GASOLINE

	MAJOR AIR POLLUTANTS/MJ ETHANOL						
	G SO2	G NOX	G CO	G VOC	G PM10	G DUST	G NH3
CULTIVATION	0.0064	0.015	0.005	0.001	0.001	0.001	0.142
TRANSPORT	0.0017	0.023	0.004	0.001	0.000	0.000	0.000
PROCESSING	0.0332	0.053	0.027	0.006	0.084	0.093	0.000
FUEL USE	0.0000	0.500	0.180	0.047	0.020	0.020	0.000
TOTAL EMISSION/MJ ETHANOL	**0.041**	**0.592**	**0.216**	**0.056**	**0.105**	**0.115**	**0.142**
TOTAL EMISSION/MJ GASOLINE	**0.045**	**0.724**	**0.194**	**0.066**	**0.024**	**0.024**	**0**
SAVINGS (PERCENT)	**7**	**18**	**-11**	**16**	**-345**	**-383**	**-**

The comparison of the LCA for Cassava-based ethanol and gasoline shows that the emissions of SO_2, NO_x and VOCs from 1 MJ of biofuel are lightly smaller than the emissions of the corresponding non-GHG pollutants from 1 MJ of gasoline. On the contrary, the emissions of PM_{10}, dust and NH_3 from 1 MJ of ethanol are much larger than the emissions of the corresponding non-GHG pollutants from 1 MJ of gasoline (**Table 37** and **Figure 28**).

FIGURE 28

NON-GHG EMISSIONS FROM THE ENTIRE LIFE CYCLE: COMPARISON BETWEEN CASSAVA-BASED ETHANOL AND GASOLINE



Manure-based biogas pathway

Biogas is mostly produced in Viet Nam by anaerobic digestion of a feedlot manure. GHG emissions from the livestock raising process are entirely attributed to the main products (e.g. meat, milk) and not to manure, which is considered as a residue/waste. Therefore the GHG emissions from the livestock activities have not been taken into account in the assessment of the GHG emissions derived from the biogas pathway.

In Viet Nam, the digestion tanks, called anaerobic digesters (AD), are usually located nearby animal lodgings. The anaerobic digestion process produces biogas (methane and carbon dioxide) as the main product and digestate as the co-product.

According to the Biogas Program for the Animal Husbandry Sector in Viet Nam (MARD website), about 0.056 m^3 of biogas is produced from each kg of fresh manure, which has an average water content of 71.5 percent (in the range of 67 – 76 percent). The biogas is collected and then burned on-site, mostly in biogas stoves but also sometimes in small generators, to produce heat and power, respectively.

Digestate is the name assigned to the residue from the anaerobic digestion. It is a liquid product, rich in organic compounds and mineral nutrients that is generally used as a fertilizer and soil amendment. Once it is collected from the digester, the digestate must be stored before being applied to the fields. The anaerobic digestion process continues in the tank, therefore an additional amount of biogas is produced during the storage period. In Viet Nam, this biogas is recovered because the digestate is stored in a closed biogas tank.

TABLE 38

LCA INPUT DATA FOR PIG MANURE-BASED BIOGAS

MANURE		
MANURE	**1.00**	**kg / kg**
WATER CONTENT	71.5	percent
TRANSPORT OF MANURE		
DISTANCE	0.00	Km
TRANSPORT VEHICLE	N.A.	
FUEL	N.A.	
BIOGAS PLANT - ANAEROBIC FERMENTATION		
BIOGAS YIELD	0.603	MJ / kg manure
ENERGY		
	0.00813	kWh / MJ biogas
ELECTRICITY MIX	ELECTRICITY MIX VIET NAM	
ELECTRICITY FOR CHP FROM GRID	0.0100	MJ / MJ biogas
BIOGAS USE - COOKING OR LIGHTING		
HEAT TRANSFER IN BIOGAS STOVE (FOR COOKING)	32	percent
ELECTRICITY (BIOGAS-BASED) FOR LIGHTING	0	percent

The LCA shows that the emissions of SO_2 from 1 MJ of biogas is much greater than the emissions of SO_2 from 1 MJ of natural gas or LPG. On the contrary, the emissions of NO_x, CO and VOC from 1 MJ of biogas are much less than the emissions of the corresponding non-GHG pollutants from both 1 MJ of natural gas and 1 MJ of LPG. The emissions of PM_{10} and NH_3 are negligible in all three cases.

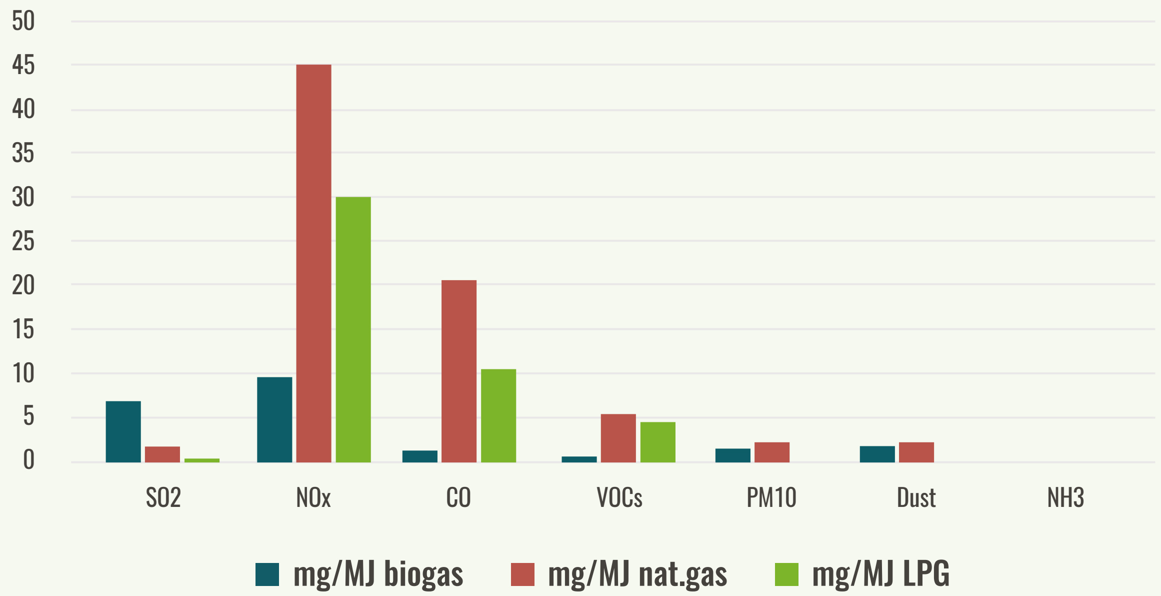
TABLE 39

NON-GHG EMISSIONS FROM PIG MANURE-BASED BIOGAS

	MAJOR AIR POLLUTANTS						
	mg SO_2	mg NO_x	mg CO	mg VOC	mg PM_{10}	mg Dust	mg NH_3
BIOGAS TANK - ANAEROBIC FERMENTATION *(G/MJ BIOGAS)*	3.931	5.681	0.681	0.263	0.530	0.689	0.002
BIOGAS USE *(G/MJ BIOGAS)*	2.162	3.125	0.375	0.145	0.291	0.379	0.001
TOTAL EMISSION/MJ BIOGAS	**6.093**	**8.806**	**1.056**	**0.408**	**0.821**	**1.067**	**0.003**
TOTAL EMISSION/MJ NAT. GAS	**1.675**	**44.979**	**20.739**	**5.277**	**1.281**	**1.281**	**0**
TOTAL EMISSION/MJ LPG	**0.400**	**30.000**	**10.000**	**4.000**	**0.003**	**0.020**	**0**

FIGURE 29

NON-GHG EMISSIONS: COMPARISON BETWEEN BIOGAS, NATURAL GAS AND LPG



4.4.3 Main conclusions and recommendations

Approach used

Regarding the cassava cultivation phase, two different scenarios (cultivation in sloping and flat areas, with low and high input level, respectively) reflecting the real situation in the country were considered in the analysis. Primary data were collected through surveys conducted in feedstock production areas in Phu Tho and Tay Ninh province, ethanol plants, transportation activities mapping (included vehicles for cassava chips, ethanol and biofuel transportation), and E5 stations (VJIIST, 2017). Secondary data included technical documents for ethanol production provided by ethanol plants, scientific publications, Emission Factors (EFs) of Viet Nam, IPCC guidelines (IPCC, 2006), and the BioGrace database.

In the case of biogas, the comparison was made with two other 'modern' fuels that could be used to displace traditional biomass use for cooking, i.e. LPG and natural gas.

The following types of non-GHG emissions were considered in this study: NH_3, NMVOC, CO, NO_x, PM_{10}, dust and SO_2.

Results

Non-GHG emissions produced from the ethanol pathway mainly come from the ethanol production plant. Therefore, in contrast with the GHG emissions, processing and using biofuel for transportation does not achieve significant SO_2, NO_x and VOC emissions reductions in comparison with gasoline. On the contrary, emissions of PM_{10}, dust and NH_3 are significantly higher in the case of ethanol (compared to gasoline).

In the case of manure-based biogas, the production and use of this fuel for cooking leads to NO_x, CO and VOC emission reductions in comparison with natural gas and LPG. The only exception is for SO_2 emissions from biogas production and use, which are higher compared to those of natural gas and LPG.

Practices and policies to improve sustainability

Based on the LCA of the Cassava-based ethanol pathway performed under this indicator, non-GHG emissions could be reduced mainly by:

- Technology improvements within the processing stage:
  - There were three plants taken into account in the analysis that have different characteristics. Plant A uses Chinese technology, plant B uses French technology and Plant C uses Indian technology. Energy consumption for ethanol processing in plant A is higher than that in plants B and C.
  - Approximately 30 percent of the power supply for the three plants is derived from biogas, with coal accounting for the remaining 70 percent. Reducing the share of this fossil fuel and replacing it with cleaner options such as biogas or other renewables, could significantly reduce non-GHG emissions from Cassava-based ethanol production.
- Improving the efficiency of blended fuel combustion.
- Improving the management of the feedstock provisioning network in order to reduce total distance of cassava transportation.

Based on the life cycle inventory of the manure-based biogas pathway, enhancing the efficiency of the anaerobic digestion process through improved technologies and management practices, would be key to reduce non-GHG emissions from biogas production.

Furthermore, if electricity was generated from biogas and supplied to the grid, there would be a reduction in non-GHG emissions through the displacement of fossil fuel based (and especially coal based) electricity.

Future monitoring of Indicator 4 in Viet Nam

The GBEP Common Methodological Framework (FAO, 2009) has proven to be a reliable tool for reporting the methodology applied in non-GHG LCA of bioenergy production and use. Its value could be further exploited by calculating LCA values using the major different methodologies of relevance to Viet Nam (in this study BioGrace was used) and comparing these methodologies using the Framework, step-by-step, to allow analysis of the effect of methodological differences on the LCA results.

Evaluation through the use of the GBEP General Framework also provides an opportunity to explore and describe the major types of raw material production and to gain in-depth information on the effectiveness of each production stage.

In order to fill data gaps (**Table 40**), Future monitoring of indicator 4 in Viet Nam should focus on:

- Developing non-GHG EFs for gasoline distribution;
- Developing non-GHG EFs for livestock waste pathways; and
- Strengthening human capacity for developing and updating LCA databases.

Besides cooking, converting biogas into electricity has a huge theoretical potential in the country. Further LCA analyses could be carried out on:

- Wastewater-based biogas (in cassava starch plants);
- Manure-based biogas on industrial-scale farms; and
- Biogas use for CHP.

TABLE 40

SUMMARY OF DATA GAPS TO FILL FOR BETTER LCA

DATA	SCALE/AREA	MEASUREMENT UNIT
ELECTRICITY USED FOR BIOGAS DIGESTERS	FARM/NATIONAL	kW/MJ of biogas
LEAKAGE RATIO OF BIOGAS DIGESTERS	FARM/NATIONAL	Percent
BACKGROUND DATA OF STILLAGE CAKE	NATIONAL OR EU	g/kg of stillage cake
ELECTRICITY CONSUMPTION OF WET MANURE COLLECTION, BIOGAS PRODUCTION OF PIG FARMS	FARM/NATIONAL	kW or kWh/m^3
FUEL CONSUMPTION OF WET MANURE COLLECTION, BIOGAS PRODUCTION OF PIG FARMS	FARM/NATIONAL	litres/m^3 or litres/d
ACTUAL TRANSPORTATION DISTANCES OF CHIPS AND ETHANOL	NATIONAL	km
AMOUNT OF BIOGAS USED FOR WASTEWATER TREATMENT AND BIOGAS PLANTS IN ETHANOL PLANTS	PLANTS	m^3 or percent

REFERENCES

BioGrace. Harmonised Calculations of Biofuel Greenhouse Gas Emissions in Europe. Utrecht (Netherlands), BioGrace project. Available online at www.biograce.net

FAO. 2011. The Global Bioenergy Partnership Sustainability Indicators for Bioenergy. First Edition. ISBN 978-92-5-107249-3. Available at: www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/Indicators/The_GBEP_Sustainability_Indicators_for_Bioenergy_FINAL.pdf

GREET. 2012. GREET Fleet Footprint Calculator. Available at: https://greet.es.anl.gov/fleet_footprint_calculator

IPCC. 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan. Available at: www.ipcc-nggip.iges.or.jp/public/2006gl/index.html

Ministry of Agriculture and rural development (MARD) website. Data bases on land uses and crop production, 2006-2015. Available at: www.mard.gov.vn/Pages/statistic

4.5 INDICATOR 5: WATER USE AND EFFICIENCY

Dinh Quang Hieu, Pham Quang Ha
Institute of Agricultural Environment (IAE), Viet Nam Academy of Agricultural Sciences (VAAS)

DESCRIPTION:

(5.1) Water withdrawn from nationally determined watershed(s) for the production and processing of bioenergy feedstocks, expressed (5.1a) as the percentage of Total Actual Renewable Water Resources (TARWR) and
(5.1b) as the percentage of Total Annual Water Withdrawals (TAWW), disaggregated into renewable and non-renewable water sources;
(5.2) Volume of water withdrawn from nationally determined watershed(s) used for the production and processing of bioenergy feedstocks per unit of bioenergy output, disaggregated into renewable and non-renewable water sources

MEASUREMENT UNIT(S):

(5.1a) Percentage
(5.1b) Percentage
(5.2) m^3/MJ or m^3/kWh

4.5.1 Implementation of Indicator 5 in Viet Nam

The implementation of indicator 5 in Viet Nam began with the study of the current situation related to water supply, demand and uses, and with the characterization of water basins in the country. Primary data were collected on water use efficiency in cassava cultivation areas and in Anaerobic Digesters (ADs).Water requirements and actual water withdrawn by cassava cultivation and for the operation of ADs were then estimated. The total volumes of water withdrawn for ethanol feedstock production and processing and for biogas production were then expressed in terms of unit of energy output and as a percentage of TARWR.

Due to lack of data on TAWW of Viet Nam in recent years (latest data from 2009, eight years ago and no longer reliable enough to be used), sub-indicator 5.1b could not be computed.

4.5.2 Key findings

Cassava-based ethanol production

According to FAO (2016), in Viet Nam the Total Actual Renewable Water Resources (TARWR) are 884.1 km^3/year. Total renewable surface water resources are an estimated 847.7 km^3/year and groundwater resources 71.42 km^3/year. Total exploitable water resources are an estimated 371.9 km^3/year. In 2005, the total annual water withdrawal for agriculture, industries and municipal purposes was an estimated 82.03 km^3. Irrigated agriculture uses the most water, accounting for 77.75 km^3 or 94.8 percent of total water withdrawals. Industrial and municipal sectors account for 3.07 km^3 (3.7 percent) and 1.21 km^3 (1.5 percent), respectively.

In Viet Nam, cassava cultivation is rain fed (Gerbens-Leenes ***et al.***, 2009); therefore, water consumption for cassava cultivation is mainly comprised of green water. Water withdrawal for cassava production was estimated by the evapotranspiration (ET) of cassava plantations. Due to lack of data on ET of cassava plantations in Viet Nam, data for Thailand were used because climate conditions in the two countries are similar.

According to Panjai and Pojanie (2006), the ET rate of cassava in the tropical region is higher in the daytime (08:00 to 17:00), with average values of 0.30 mm/hour for the Bowen Ratio (BR) method and 0.33 mm/hour for the Modified Penman-Monteith (MPM) method (recommended by FAO, 2006), and negligible or even negative during the night. A similar result for ET rate calculation for cassava plantations is reported by Attarod ***et al.*** (2009).

In Viet Nam, cassava cultivation (from planting to harvest) spans 10 - 12 months, depending on the region (330 days on average). Water consumption of cassava cultivated land is about 29.7 m^3/day per hectare or 9 801 m^3/year per hectare. This data confirmed the results of a review conducted by Kaenchan and Gheewala (2013) which estimated the water footprint of cassava and other key crops in Thailand.

As of 2015, with 566.5 thousand hectares of

FIGURE 30

WATER WITHDRAWAL BY SECTOR, 2005

Source: FAO, 2016

cassava, the total amount of water withdrawn by cassava cultivation was estimated at 5.55 km³. This amount was assumed to remain constant in 2016. Due to lack of data on actual ethanol production, we assumed that this was equal to domestic ethanol consumption, i.e. to 29 500 m³ in 2016 (MOIT, 2017). It is estimated that the production of this amount of ethanol requires 162 840 tonnes fresh cassava (1 litre of ethanol requires 5.52 kg of cassava fresh root). Assuming an average cassava yield of 18.8 tonnes/ha (see indicator 18), 8 662 ha of land under cassava cultivation (i.e. 1.53 percent of the total amount of such land) were used for ethanol feedstock production in 2016. The total water withdrawn for producing 29 500 m³ of ethanol was 0.0855 km³ (0.0849 km³ of water in feedstock production and 0.00066 km³ in the processing phase).

In case an E5 mandate had already been in place in 2016, total ethanol consumption in the country would have been 370 million litres (370 000 m³ - see indicator 24). To meet this ethanol demand, Viet Nam would have needed about 2.04 million tonnes of fresh cassava equivalent, requiring 108.6 thousand hectares (assuming a yield of 18.8 tonnes/ha), or 19.1 percent of the total area under cassava cultivation. Hence, water withdrawals by ethanol feedstock production would have amounted to 1.0648 km³.

Due to lack of data on the amount of water used in the processing of cassava into ethanol, information from previous studies conducted in Thailand were used for this stage of the supply chain as well. At the ethanol plant, water is used for the mixing, fermentation and distillation processes, and to dilute pollutants for wastewater treatment. Specifically, dry cassava based ethanol requires 8.30 – 18.97 litres water/litre ethanol and fresh cassava based ethanol requires 26.60 litres water/litre ethanol. Moreover, the wastewater treatment requires 7.8 – 9.9 litres water/litre ethanol.

Ethanol production in Viet Nam occurs mainly using dried cassava chips. On average, 1 litre ethanol requires 22.5 litres water in processing phase. In Thailand, the processing of 370 million litres of ethanol required 8.3 billion litres of water (Mangmeechai & Pavasant, 2013). Based on this data, in Viet Nam, 0.00066 km³ of water withdrawals would have been required for the processing of the ethanol needed to meet the domestic demand in 2016. In order to meet a hypothetical E5 mandate, water withdrawals for ethanol processing would have amounted to 0.00832 km³. These amounts are small in comparison with the amount of water used in the cassava cultivation phase. According to Mangmeechai and Pavasant (2013), the volume of water used for cassava processing utilised only 1 percent of the total amount of water used within the entire Cassava-based ethanol pathway which is in the range of 2 300-2 820 litres water/litre ethanol.

Considering both feedstock cultivation and processing, in 2016 total water withdrawals for Cassava-based ethanol production in Viet Nam amounted to 0.08556 km^3 (of which 0.0849 Km^3 in feedstock production and 0.00066 km^3 for processing), accounting for 0.0097 percent of TARWR. In case of a hypothetical E5 mandate in 2016, total water withdrawals for Cassava-based ethanol production would have been equal to 1.07312 km^3 (of which 1.0648 Km^3 in feedstock production and 0.00832 Km^3 for processing), accounting for 0.1214 percent of TARWR.

Heat released from burning 1 m^3 of ethanol is 21 100 MJ, thus the water withdrawn for cassava cultivation and processing for ethanol production is estimated at 0.137 m^3/MJ.

Due to lack of data on TAWW of Viet Nam in recent years (latest data from 2009, eight years ago and no longer reliable enough to be used), sub-indicator 5.1b was not calculated.

TABLE 41

WATER USE FOR ETHANOL PRODUCTION IN VIET NAM, 2016

PARAMETER	ACTUAL VALUE BASED ON ETHANOL CONSUMPTION IN 2016	ESTIMATED VALUE BASED ON HYPOTHETICAL E5 MANDATE IN 2016
TARWR IN VIET NAM (FAO, 2016)	884.1 km^3/year	884.1 km^3/year
WATER REQUIREMENT FOR CASSAVA CULTIVATION	9 801 m^3/ha/year	9 801 m^3/ha/year
WATER REQUIREMENT FOR CASSAVA CULTIVATION ADDRESSED TO ETHANOL PRODUCTION	0.0849 km^3/year	1.0648 km^3/year
WATER REQUIREMENT FOR CASSAVA PROCESSING INTO ETHANOL	0.00066 km^3/year	0.00832 km^3/year
TOTAL WATER WITHDRAWN FOR ETHANOL FEEDSTOCK PRODUCTION AND PROCESSING AS A PERCENTAGE OF TARWR (SUB-INDICATOR 5.1A)	0.0097 percent	0.1214 percent
WATER WITHDRAWN FOR ETHANOL FEEDSTOCK PRODUCTION AND PROCESSING PER UNIT OF ENERGY OUTPUT (SUB-INDICATOR 5.2)	0.137 m^3/MJ	0.137 m^3/MJ

Biogas

a. Biogas production at household scale

According to LCASP (2017), the total number of biogas digester at household (HH) scale is estimated to be 450 000, of which 90 percent (405 000 household bio-digesters) are in operation. All of the household scale ADs are used to contain and treat animal waste. The animal stalls are connected directly to ADs, which are fed with the wastewater, including urine, faeces, and fresh water that is used to clean the cages and bathe livestock. The wastewater flows down in the AD where, through a process of anaerobic fermentation, it produces biogas. The amount of available wastewater depends on season and region. For instance, the amount of water used during the summer is higher than in the winter (Thu *et al.*, 2012) and the amount available in mountainous area is lower than in the delta area (**Table 42**).

TABLE 42

VOLUME OF WATER USED IN A SMALL-SCALE BIOGAS PLANT (10 m³) IN DIFFERENT SEASONS

AMOUNT OF WATER USED (LITRES/DAY/HOUSEHOLD)		
SEASON	**HANOI**	**HUE**
SUMMER	380	220
WINTER	300	180

Source: Thu ***et al.****, 2012*

Using data collected by Thu *et al.* (2012) on small-scale ADs in Hanoi and Hue, the average water usage per household is 270 litres/day or 98 550 litres/year. The total amount of water used by all household ADs is estimated to be about **39.91 million m³/year**. The average household bio-digesters volume is 10 m³, and the related average biogas production is 3 m³/HH/day or 1 095 m³/HH/year (FAO, 2012). Based on this data, the total biogas production is estimated at about 443 475 000 m³/year. 0.0216 GJ or 5.96 kWh of thermal energy is generated from 1 m³ of biogas (FAO, 2012). In a year, total thermal energy generation from HH bio-digesters is equal to **9 579 060 GJ** (or 2 643.1 GWh). Therefore, in case of biogas production at HH level, the volume of water withdrawn per unit of energy output is **0.0042 m³/MJ**.

b. Biogas production at farm scale

According to MARD (2016), Viet Nam has 14 370 medium scale biogas plants, 90 percent of which (12 933) are in operation. By considering an annual average of about 15 days for repairing and maintaining biogas plants, a medium scale biogas plant (500 m³ volume) can produce 52 500 m³/year of biogas. In a year, total biogas production of medium scale biogas plants is 678 982 500 m³/year, generating 14 666 022 GJ/year or 4 046.7 GWh/year of thermal energy.

Besides, there are about 900 large scale biogas plants (2 000 m³ of volume) which can produce 189 000 000 m³ of biogas/year, equal to **4 082 400 GJ/year** or 1126.4 GWh/year of thermal energy. The total production of thermal energy by medium and large scale plants amounts to **18 748 422 GJ/year**.

The average size of a pig farm is 709 heads. On average, a pig produces about 15 l wastewater/day as a sum of cleaning water, bath for pig and pigs' urine. Thus, the total wastewater loaded into 13 833 farm-scale biogas plants is estimated to be **53 696 594 m³/y** and the volume of water withdrawn for biogas production per unit of energy output is **0.0029 m³/MJ**.

c. Biogas production at industrial scale

Further to wastewater from livestock farms, wastewater from cassava starch processing and ethanol production industries can be used for biogas production, as well. Results of the surveys carried out in the framework of the project showed that all five cassava starch processing factories interviewed in Phu Tho and Tay Ninh have an industrial scale biogas plant (VJIIST, 2017). There are currently 102 starch processing factories all over Viet Nam. These plants have the capacity to process 13 500–75 000 tonnes of cassava starch/year on average, which produces 243 000–1 500 000 m³ (with an average of 720 750 m³) of wastewater per year. Total water requirement is **73.52 million m³/year**. By calculation, 1 m³ of cassava starch wastewater can produce 3.06 m³ of biogas (see indicator 18), whose combustion can produce 21.6 MJ/m³ (FAO, 2012). Thus, in a year, an amount of 224 571 200 m³ of biogas could be potentially produced by these cassava starch processing plants. In terms of thermal energy, **4 859 378 GJ/year** or 1340.8 GWh/year equivalent could be potentially generated. Therefore, the volume of water withdrawn for biogas production (from cassava starch wastewater) on a per unit of energy output is **0.015 m³/MJ**.

d. Biogas sector as a whole

Compiling the above data, the potential amount of thermal energy produced by biogas plants at different scales is about 33 186 860 GJ/year or 9.157 GWh/year. Total amount of water used for biogas production is estimated to be about 167.12 million m^3. Therefore, the volume of water withdrawn for biogas production per unit of energy output is calculated at **0.005 m^3/MJ**. As mentioned above, sub-indicator 5.1b could not be calculated.

TABLE 43

WATER WITHDRAWALS ASSOCIATED WITH BIOGAS PRODUCTION IN VIET NAM

PARAMETER	VALUE
TARWR IN VIET NAM *	884.1 km^3/year
TOTAL WATER REQUIREMENTS FOR OPERATING ADS	0.167 km^3/year
TOTAL ENERGY PRODUCED FROM ADS	33.19 million GJ/year
TOTAL WATER WITHDRAWALS FOR OPERATING ADS AS A PERCENTAGE OF TARWR	0.019%
VOLUME OF WATER WITHDRAWN FOR BIOGAS PRODUCTION PER UNIT OF ENERGY OUTPUT	0.005 m^3/MJ

* *FAO, 2017*

4.5.3 Main conclusions and recommendations

Cassava-based ethanol production

a. Approach used

In Viet Nam, data on TARWR at the watershed level was not available and the analysis was done on the basis of water requirements per unit of planted surface and consequently inferred at the national level. The measurement was finalized by using secondary data such as area, yield and total production of cassava, total consumption of cassava based ethanol was assumed as total production of ethanol in the country. Secondary data were collected from GSO, MARD, MONRE, FAO, research institutes and peer-reviewed papers.

b. Results

As expected, the results confirmed that the bulk of the water withdrawals associated with bioenergy production are linked to the feedstock cultivation phase (9 801 m^3/ha/y). In fact, the water used for feedstock processing is one percent of that used for feedstock production. Total volume of water withdrawn for producing 1 MJ of ethanol is 0.137 m^3. Due to lack of data on water usage, an assessment of the share of renewable and non-renewable was not performed. Viet Nam ethanol production in 2015 required about 0.0097 percent of TARWR while if the ethanol E5 mandate had been applied in 2015 the ethanol production would have required 0.1214 percent of TARWR. Sub-indicator 5.1b was not calculated due to lack of data on TAWW of Viet Nam in recent years.

c. Practices and policies to improve sustainability

With the expected sharp increase in ethanol production following the recent adoption of the country-wide E5 mandate, monitoring of indicator 5 in key watersheds with significant levels of bioenergy feedstock cultivation and processing will be of crucial importance. At first glance, Viet Nam has apparently abundant water resources. However, this varies greatly between river basins and between the wet and dry seasons. Cassava is a strategic crop for the development of the country and the active irrigation of cassava will be unavoidable in the future to increase the yield. Currently, the management of water resources is not performed well, due to the low efficiency and productivity of cassava cultivation. This can cause water competition between cassava cultivation and other crops or decrease the availability of water for other activities. These conditions require an improvement in water resources management. The application of Climate-Smart Agriculture will be an important solution to decrease the pressures.

d. Future monitoring

Select a given watershed would have most likely been more informative of the real water balance of the cassava production areas. In fact, aggregating the results and presenting average national figures might not be a meaningful exercise, as these figures might not reveal potential situations of water stress, including severe ones, in specific watersheds where bioenergy feedstocks are cultivated and processed.

An issue that might affect the practicality of indicator 5 relates to the boundaries of the watershed, that in most cases do not coincide with those of the administrative units for which statistics on production of bioenergy feedstocks and products are available. Due to this issue, in some cases it might be difficult to determine the amount of water withdrawn in a specific watershed for bioenergy production.

Biogas

a. Results

The potential biogas production was estimated at national level by considering the different scales of ADs currently established at country level. The amount of water used by the Viet Nam biogas sector is equal to 0.019 percent of the country TARWR, as 0.005 m^3 of water are needed for each MJ of biogas produced. Sub-indicator ***5.1b*** was not calculated due to lack of data on TAWW of Viet Nam in recent years.

b. Practices and policies to improve sustainability

According to the 2015 ***Renewable Energy Development Strategy of Viet Nam to 2030, outlook up to 2050,*** the total volume of ADs will increase from 4 million m^3 in 2015 to 8 million m^3 in 2020, 60 million m^3 in 2030 and 100 million m^3 in 2050. However, since a small amount of water is used for operating ADs, the increase in their number should not put pressure on the water resources in future. Moreover, as explained in the previous section, biogas production uses wastewater from livestock activities or from cassava starch industries, which has no alternative use.

During animal husbandry, large amounts of water are used to clean cages and bathe animals, wasting large amounts of water and reducing the efficiency of anaerobic digestion. Therefore, it is necessary to improve skills and awareness of water saving techniques and the correct operation of ADs. The government should set the standards for the design of medium and large scale ADs, and continue improving the design of household level ADs to obtain the greatest possible efficiency.

REFERENCES

Attarod P., Komori D., K. Hayashi, M. Aoki, T. Ishida, K. Fukumura, S. Boonyawat, P. Polsan, P. Tongdeenok, P. Somboon and S. Punkngum. 2009. Seasonal change of evapotranspiration and crop coefficient in a rain fed paddy field, cassava plantation and teak plantation in Thailand. Available at: www.hyarc.nagoyau.ac.jp/game/6thconf/html/abs_html/pdfs/T5PA06Aug04163854.pdf [Accessed 7 Sep 2016].

FAO. 2006. Irrigation and Drainage Paper. No. 56: Crop Evapotranspiration (guidelines for computing crop water requirements). Available at: www.kimberly.uidaho.edu/water/fao56/fao56.pdf [Accessed 14 Feb 2018].

FAO. 2012. The low carbon agricultural support project (LCASP) in Viet Nam – Carbon balance appraisal with the ex-ante carbon balance tool. Available at: www.fao.org/fileadmin/templates/ex_act/pdf/case_studies/draft_aout2012-clear.pdf

FAO. 2016. AQUASTAT. Available at: www.fao.org/nr/water/aquastat/main/index.stm [Accessed 14 Feb 2018]

FAO. 2017. FAOSTAT. Available at: www.fao.org/faostat/en/#data [Accessed 14 Feb 2018]

Gerbens-Leenes, W., Hoekstra, A.Y. and van der Meer, T.H. 2009. The water footprint of bioenergy. PNAS 106 (25): 10219–10223.

GSO website. Statistical data: Agriculture, Forestry and Fishery. Available at: www.gso.gov.vn/default_en.aspx?tabid=778 [Accessed 24 Jan 2018].

Kaenchan, P. and Gheewala, S.H. 2013. A Review of the Water Footprint of Biofuel Crop Production in Thailand. Journal of Sustainable Energy & Environment 4: 45-52.

LCASP. 2017. Annual Report 2017. Available at: http://lcasp.org.vn/uploads/kien-thuc/2017_04/131326556632985253_lcasp-lic-annual-rep.pdf. [Accessed 15 Nov 2017].

Mangmeechai, A. and P. Pavasant. 2013. Water Footprints of Cassava- and Molasses-Based Ethanol Production in Thailand. Natural Resources Research 22 (4): 273 - 282.

MARD. 2016. Department of Livestock Production. Real situation and solutions for environmental treatment of livestock production

Ministry of Industry and Trade (MOIT). 2017. FAO Regional workshop Nov.16-17 "Sustainable Bioenergy Production and Use in Southeast Asia: Lessons Learnt and Future Opportunities, The orientation in the production and use of biofuels in Vietnam", Dr. Do Xuan Dong, Department of Science and Technology. Available at: www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/AG2/Viet_Nam_project/Final_Mettings/Dong_Do-Xuan.pdf

Ministry of Natural Resources and Environment (MONRE). 2016. Viet Nam national biodiversity strategy to 2020, vision to 2030. Synthesis of conversion of forest land in Viet Nam from 2007 to 2013, pp 40-176. Forest protection department website. Available at: www.kiemlam.org.vn [Accessed 9 Feb. 2017]

Saueprasearsit, P. and Khummongkol, P. 2006. "Comparison of method of determining evapotranspiration rate on a cassava plantation in tropical region". The 2nd Joint International Conference on sustainable energy and environment, Bangkok, Thailand. Available at: www.jgsee.kmutt.ac.th/see1/cd/file/E-078.pdf

Thu, C.T.T., Cuong P.H., Hang L.T., Chao N.V., Anh L.X., Trach N.X. and Sommer S.G. 2012. Manure management practices on biogas and non-biogas pig farms in developing countries – using livestock farms in Viet Nam as an example. Journal of Cleaner Production. 27 (2012): 64 – 71.

VJIIST. 2017. Surveys conducted within this study on April 2017 in feedstock production areas in Phu Tho, Tay Ninh province, ethanol plants, transportation activities mapping (including vehicles for cassava chips, ethanol and biofuel transportation) and E5 stations.

4.6 INDICATOR 6: WATER QUALITY

Dinh Quang Hieu, Pham Quang Ha
Institute of Agricultural Environment (IAE), Viet Nam Academy of Agricultural Sciences (VAAS)

DESCRIPTION:

(6.1) Pollutant loadings to waterways and bodies of water attributable to fertilizer and pesticide application for bioenergy feedstock production, and expressed as a percentage of pollutant loadings from total agricultural production in the watershed
(6.2) Pollutant loadings to waterways and bodies of water attributable to bioenergy processing effluents in the watershed

MEASUREMENT UNIT(S):

(6.1) Annual nitrogen (N) and phosphorus (P) loadings from fertilizer and pesticide active ingredient loading attributable to bioenergy feedstock production (per watershed area):
in kg of N, P and active ingredient per ha per year
(6.2) Pollutant loadings attributable to bioenergy processing effluent:
pollutant levels in bioenergy processing effluent in mg/litre

4.6.1 Implementation of Indicator 6 in Viet Nam

For the measurement of sub-indicator 6.1 for Cassava-based ethanol, 15 water samples were collected from waterways and bodies close to cassava plantation areas in the provinces of Phu Tho and Tay Ninh. Due to lack of data on pollutant loading to waterways and bodies of water from agricultural and ethanol processing effluents, indicator component 6.2 could not be measured.

For manure-based biogas, secondary evidence was collected from a literature search in order to present a qualitative assessment of indicator 6.

4.6.2 Key findings

Cassava-based ethanol

In order to measure this indicator, a water sampling campaign was carried out close to cassava plantation areas in the pronvinces of Phu Tho and Tay Ninh in April 2017. Fifteen water samples were collected from the waterways around these plantations (seven water samples in Phu Tho and eight water samples in Tay Ninh). A survey was also conducted with local farmers to determine the rate and timing of fertilizer use (IAE, 2017). According to this survey, the farmers in Phu Tho plant cassava in February or March. In cassava season, they apply fertilizer twice, once in February or March and again in May or June. In Tay Ninh, farmers plant cassava in April or May. They also apply fertilizer twice, once in April or May and then in June or July. Although chemical compounds persist in water, they are slowly diffused or diluted by the flow of water over time. By sampling in April, closely following initial fertilizer application, this ensured that chemical compounds were at their highest level, thus reflecting the most critical situation.

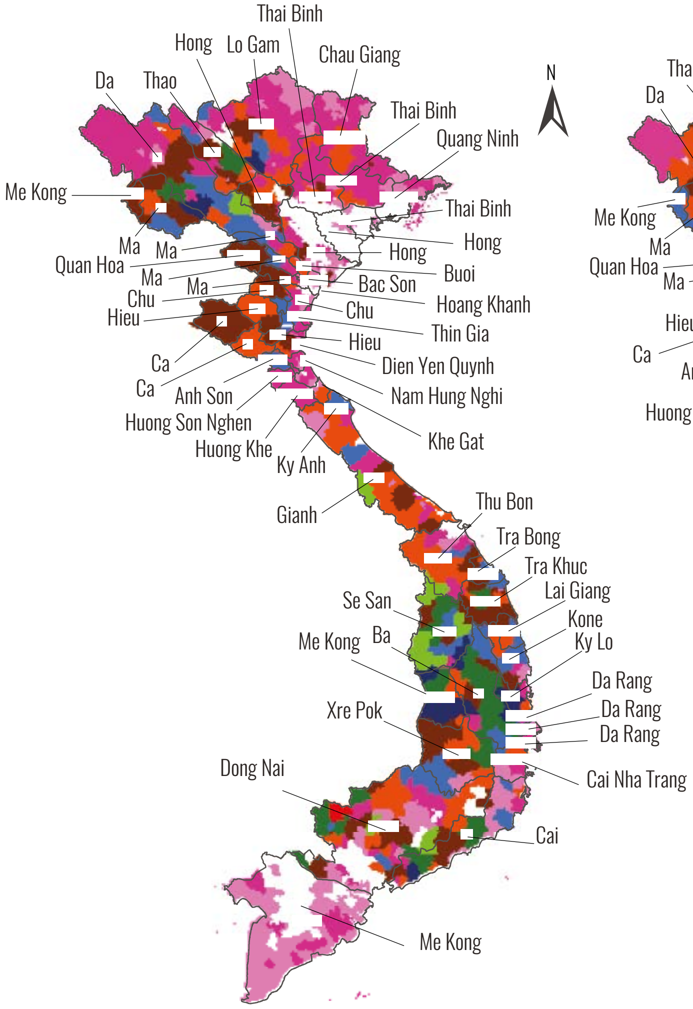
The laboratory analyses were performed by the Centre of Analysis and Environmental Technological Transfer, IAE. The main parameters analysed were the concentration of total nitrogen, phosphorus, BOD, COD and active compounds from pesticides. The result of the analysis was presented and compared with the Standard 08 of quality of surface water issued by the Ministry of Natural Resources and Environment in 2015 (QCVN 08: 2015/BTNMT) in **Table 44**.

The result showed that water bodies near cassava plantations are polluted, probably because of the high volume of fertilizers and pesticides applied by local farmers, as demonstrated by the survey conducted within this study, in Phu Tho and in Thay Ninh provinces.

The results of the survey submitted to nine households cultivating cassava in Phu Tho province showed that local households have a high application rate and volume of organic fertilizer use. All respondents declared that they use manure as fertilizer, with an average rate

FIGURE 31

MAP OF RIVER BASINS OF VIET NAM OVERLAID WITH CASSAVA CULTIVATION AREAS, 2007 AND 2016



Legend	
	boundary of provinces
Area (ha)	
	0
	0-100
	100-500
	500-1000
	1000-2000
	2000-3000
	3000-4000
	4000-5000
	5000-10000
	10000-21000

Legend

boundary of provinces

Area (ha)

0
0-100
100-500
500-1000
1000-2000
2000-3000
3000-4000
4000-5000
5000-10000
10000-21000

Source: elaborated by IAE as part of this study

of 14.1±1.4 tonnes/ha. Therein, seven out of nine households use composted manure, while the rest apply fresh manure directly. Data collected through the survey were elaborated and final results show that the average amounts of N, P2O and K2O applied to soils per hectare were 142.9 ± 64.5 kg, 81.5 ± 52 kg, 140.9 ± 115.6 kg, respectively. According to the recommendations of the Institute of Agricultural Science for Southern Viet Nam (IASVN), generally, N, P2O5 and K2O requirement of cassava is in the range of 80 -120 kg/ha, 50 - 100 kg/ha, and 200 - 500 kg/ha, respectively. Therefore, the amount of fertilizer applied by local farmers, despite our expectations, exceeds the IASVN recommendations. However, there is a large fluctuation in the amount of fertilizer applied by local households.

The rate and amount of pesticide applied during cassava cultivation were also investigated. Outcomes from the survey show that farmers cultivating cassava state that insect diseases are prevalent and that seven out of nine households apply pesticides for this scope. According to farmers, insects eat cassava roots, thus decreasing productivity. To control for this, local farmers use 50 kg/ha of Diazan H10 (the active compound is diazinon). The pesticide is administered once in the holes before planting. This amount exceeds the quantity recommended by the manufacturer (10-20 kg/ha). Furthermore, the farmers also used 300 ml/ha of Bestox 5EC (the active compound is alpha-cypermethrin) or 300 ml/ha of Ofatox 5C (the active compound is fenitrothion). All households interviewed within this study control the weeds by hand 3-4 times per year (IAE, 2017).

The results of the survey submitted to 36 cassava households in Tay Ninh showed that 52 percent of respondents use organic fertilizer in cassava cultivation, with an average amount of 4.9 tonnes per hectare. This is lower than in Phu Tho because the livestock sector in this area is not so developed, thus resulting in a lack of availability of manure for the field application. The average amounts of N, P_2O and K_2O applied to the cassava fields as manure per hectare is 138.5±82.6 kg, 115.5±56.2 kg and 105.3±69.4 kg, respectively.

Regarding pesticide application, 19 out of 36 households in Tay Ninh applied pesticide for controlling diseases caused by spiders, aphids, worms and weeds. The most popular pesticide applied contains active compounds belonging to the carbamate group. Chemicals are applied following the recommendations of the local agricultural extension centre. However, the farmers still use the herbicide containing 2,4-Dicholorophenoxyacetic acid, banned by MARD.

Regarding the processing stage, a survey was carried out among three ethanol plants to identify the amount of chemicals used in the production of ethanol (**Table 45**).

TABLE 44

POLLUTANT LOADINGS IN WATERWAYS AROUND CASSAVA PLANTATIONS

SITE OF SAMPLE COLLECTION	pH	COD (mg/l)	BOD_5 (mg/l)	N_{tt} (mg/l)	P_{tt} (mg/l)	Cypermethrin	2,4-D
TAM NONG -PHU THO (SURFACE WATER)	6.36 ± 0.14	138 ± 4	83.9 ± 4.1	32.2 ± 0.8	0.22 ± 0.03	ND	
THANH SON- PHU THO (SURFACE WATER)	6.92 ± 0.07	118.2 ± 2.4	72.4 ± 2.7	23.5 ± 1.2	4.6 ± 0.13	ND	
TAN CHAU - TAY NINH (SURFACE WATER)	6.84 ± 0.21	224.7 ± 12.1	117.4 ± 3.6	74.6 ± 1.3	52.9 ± 0.84		ND
CHÂU THANH - TAY NINH (SURFACE WATER)	6.56 ± 0.21	363.3 ± 21.6	213 ± 6.4	88.1 ± 2.3	1.58 ± 0.22		ND
TAN BIEN - TAY NINH (GROUNDWATER)	4.75 ± 0.14	114 ± 1	63.9 ± 3.2	30.4± 1.4	0.172 ± 0.03		ND
QCVN 08-MT: 2015/BTNMT	5.5-9	50	25	16	0.5		
QCVN 09-MT: 2015/BTNMT	5.5-8.5	-	-	17	-		

"ND": not detectable
"-": No regulations
QCVN 08-MT: 2015/BTNMT: National technical regulation on surface water quality
QCVN 09-MT: 2015/BTNMT: National technical regulation on ground water quality

TABLE 45

AMOUNT OF CHEMICALS IN ETHANOL PROCESSING

TYPE OF INPUT	AVERAGE AMOUNT OF INPUT USED* (MG/LITRE ETHANOL)	RESIDUAL CONTENT OF THE COMPONENT IN THE WASTEWATER** (MG/LITRE WATER)
ENZYME	1 310	58.2
SULPHUR ACID	2 450	108.9
AMMONIA	4 500	200.0
UREA	3 735	166.0
DAP	2 650	117.8
NaOH	2 020	89.8

(*) Source VJIIST, 2017

(**) According to indicator 5, 1 litre of ethanol requires, on average, 22.5 litres of water during the processing phase. The residual content of chemical in the wastewater is therefore calculated by dividing the amount of inputs for producing 1 litre of ethanol by 22.5.

Due to lack of data on the quality of wastewater after treatment in ethanol plants, sub-indicator 6.2 could not be measured. However, information on the quality of wastewater produced from cassava starch processing plants was collected. All of the plants combine anaerobic with aerobic treatment technologies for treating wastewater (**Table 46**). The quality of wastewater is monitored daily or monthly until it reaches the quality level that allows it to be discharged into the environment according to Vietnamese standard 40 issued by MONRE in 2011 (QCVN 40: 2011/BTNMT). The monitoring of wastewater quality involves the participation of government departments.

Biogas

According to the report on the status of national environmental quality in the period 2011-2015 (MONRE, 2016), on average, husbandry released 85-90 million tonnes of manure, 36 million tonnes of urine and tens of million tonnes of clean water per year. Only 40 percent of the waste was treated, while the residual was directly discharged into the environment (e.g. into lakes, canals, rivers, soil). In Viet Nam, livestock wastewater is classified as industrial wastewater and its quality must comply with Vietnamese standard 40 issued by MONRE in 2011 (QCVN 40: 2011/BTNMT). Biodigesters can be used to treat livestock wastewater but the

TABLE 46

WASTEWATER TREATMENT PROCESS IN CASSAVA STARCH PLANTS

COMPANY	ANAEROBIC TREATMENT METHOD			AEROBIC TREATMENT METHOD		
	BIO-DIGESTER			AERO TANK (YES/NO)	COAGULATION & FLOCCULATION (YES/NO)	OXIDATION LAKES/DITCHES (YES/NO)
	(YES/NO)	TYPE	VOLUME (m^3)			
PHU DAI DONG	YES	COVERED LAGOON BY HDPE	80 000	YES	YES	YES
HUNG DUY	YES	COVERED LAGOON BY HDPE	100 000	YES	YES	YES
QUOC DUNG	YES	COVERED LAGOON BY HDPE	140 000	NO	NO	YES
THANH BINH	YES	COVERED LAGOON BY HDPE	50 000	YES	NO	YES

Source: IAE, 201

TABLE 47

RESULTS OF BIOGAS EFFLUENT SAMPLING CAMPAIGN CONDUCTED IN 10 PROVINCES OF VIET NAM, 2014-2015

PARAMETER	UNIT	AMOUNT FOUND IN SAMPLED WASTEWATER OF DIFFERENT TYPES OF ANAEROBIC-DIGESTER			THRESHOLD VALUES ESTABLISHED BY QCVN 40: 2011/BTNMT
		KT1	KT2	COMPOSITE	
N_{tt}	mg/litre	265.62	218.55	188.40	50
P_{tt}	mg/litre	74.73	84.95	69.27	150
TSS	mg/litre	4 639.84	3 690.85	3 223.11	100
COD	mg/litre	1 083.83	875.14	726.70	10
BOD_5	mg/litre	565.42	429.99	385.36	40
FAECAL COLIFORM	MPN/100 ml	1 948	2 814	4 331	5 000

Source: Sampling campaign conducted by IAE, 2015

quality of wastewater after anaerobic digestion is not improved sufficiently to reach the quality standards required to be discharged into the environment. Many studies have been conducted to evaluate the quality of biogas effluents in Viet Nam.

From 2014 to 2015, the Institute of Agricultural Environment (IAE, 2015) implemented a large-scale project to investigate the status of biogas effluent quality. During the survey period, the project collected 300 samples of wastewater in 10 provinces of Viet Nam. The wastewater samples were collected from the main types of ADs in Viet Nam, including KT1, KT2 and composite. The analysis showed that all the collected samples of biogas effluent were highly polluted. The average concentrations of P, N, suspended solids, COD and BOD_5 in the effluent samples were 7, 15, 28, 5 and 8 times higher, respectively, than the threshold established within QCVN 40: 2011/ BTNMT (see **Table 47**).

According to Hong and Lieu (2012), the use of AD for the treatment of the pig wastewater significantly reduces the concentration of pollutants compared to the direct discharge of this wastewater into the environment. On average, the reductions were 84.7 percent for COD, 76.3 percent for BOD_5, 86.1 percent for SS, 11.8 percent for total N, 7.0 percent for total P and 51.2 percent for faecal coliform. However, the concentration of nutrients in the effluent remained quite high, giving rise to the risk of eutrophication. In biogas effluents, the concentration of many pathogens such as *Escherichia coli, Salmonella* spp. and parasite eggs remains high (Huong ***et al.***, 2014; Le-Thi T. ***et al.***, 2016).

It is very important to analyse the differences between farms with and without biogas production, especially in terms of manure management practices. Vu ***et al.*** (2012) conducted a field survey on 12 pig farms with biogas and 12 farms without biogas in Quoc Oai district, Ha Noi city. There were no significant differences in the average numbers of piglets, fattening pigs and sows between the biogas and non-biogas farms surveyed. There was also no significant difference between the total amount of manure produced in the biogas and non-biogas farms. The non-biogas pig farms used on average 3.8 tonnes/ha of compost and 3.1 tonnes/ha of fresh solid manure per crop for each of the three crops typically grown per year on their land. Furthermore, they discharged on average 16 percent of the total manure produced into the environment, in liquid form, through the public sewage system. On the biogas farms, the use of fresh solid manure for fertilizing cultivated soils and the amount of liquid manure discharged into the environment was lower compared to the non-biogas farms, since manure is used as feedstock to produce biogas. On the non-biogas farms, 50 percent of fresh solid manure was composted before being used as a crop fertilizer, while 21 percent and 13 percent of fresh solid manure were applied directly to fish pond and crops, respectively. On biogas farms, 50 percent of the residues from the AD (digestate) was discharged into the environment instead of being used for fertilizing crops. Outcomes from the survey showed that a large number of non-biogas farms do not discharge manure, while almost all biogas farms indicated discharge of digestate into the environment. To allow for a comparison between the two systems, data were averaged across farms within the biogas and non-biogas farm groups and nutrient flows were expressed in relative values of the total nutrient content. The total nutrient content excreted annually (in solid and liquid manure) per pig farm was: 101 kg N, 51 kg P and 22 kg K on non-biogas farms, and 116 kg N, 59 kg P and 22 kg N on biogas farms. The amount of nutrients discharged into the aquatic environment was 16 kg N (15.8 percent), 8 kg P (15.7 percent) and 4 kg K (18.2 percent) on non-biogas farms, and 43 (37.1 percent) kg N, 19 (32.2 percent) kg P and 12 kg K (54.5 percent) on biogas farms. Therefore, the nutrients discharged into the environment is on average higher for farms with biogas than for those without it, suggesting that discharge of digestate into the environment significantly increases the risk and level of water pollution from biogas plants.

Thu *et al.* (2012) carried out an investigation of manure management practices on biogas and non-biogas pig farms in Viet Nam. The results showed that the digestate is transported to fields by barrels on rudimentary vehicles, such as hand-pulled carts or motorbike. Farmers identified the lack of adequate manure transportation vehicles, the transport distance and high labour input as the main barriers to digestate utilization; hence, instead of using digestate for crops, farmers discharged it into the environment. 56 out of 96 households (58.3 percent) in Ha Noi and 30 out of 50 households (60 percent) in Hue responded that they discharge digestate into the environment. On non-biogas farms in Ha Noi, 65 percent of the manure was separated into a dry-matter-rich and a liquid fraction. The dry-matter-rich fraction is normally composted in a corner of the garden or in the field and after around three to four months, or longer, it is applied to crops as organic fertilizer (55 farms out of 85). The liquid fraction, urine and cleaning water are stored in uncovered containers and also used to fertilize the crop in the growing season. When the container reaches the maximum capacity, the excess is discharged into the environment. On 62 non-biogas farms, the liquid was discharged during periods when the container could not accommodate the liquid manure produced. This is a source of water pollution. On 16 out of 25 farms where both untreated manure and compost is produced, the

TABLE 48

MANURE MANAGEMENT METHODS ON BIOGAS AND NON-BIOGAS FARMS IN HA NOI AND HUE PROVINCES

MANURE MANAGEMENT*	HANOI (N=181)				HUE (N=100)			
	BIOGAS (N=96)		NON-BIOGAS (N=85)		BIOGAS (N=50)		NON-BIOGAS (N=50)	
	N	PERCENT	N	PERCENT	N	PERCENT	N	PERCENT
NO TREATMENT	0	0.0	30	35.3	0	0	45	90.0
COMPOSTED	0	0.0	30	35.3	0	0.0	0	0
NO TREATMENT + COMPOSTED	0	0.0	25	29.4	0	0.0	5	10.0
FERMENTED	82	85.4	0	0.0	50	100.0	0	0.0
FERMENTED + NO TREATMENT	8	8.3	0	0.0	0	0.0	0	0.0
FERMENTED + COMPOSTED	6	6.3	0	0.0	0	0.0	0	0.0
DISCHARGE	56	58.3	62	72.9	30	60.0	22	44.0

N: Number of households Source: Thu ***et al.****, 2012*

(*) Manure management method:

- ***No treatment*** *means unfermented manure.*
- ***Composted manure*** *is the solid fraction from separation of manure that has been stored in heaps for a minimum of two months before use.*
- ***Fermented manure*** *means manure that has been fermented in an AD (may also be called digestate).*
- ***Discharge*** *is manure that is discharged to the environment (ditches, canals, lakes, rivers, etc.). On biogas farms, discharged manure is fermented liquid manure, and on non-biogas farms discharge is usually washing water and urine.*

untreated manure is applied to fish ponds on the farm. It is notable that on two farms the fish died because the farmer used too much manure to nourish the fish pond. Vu *et al.* (2012) and Thu *et al.* (2012) found that a high rate of digestate is discharged directly into environment because the farmers attribute a low nutrient value to digestate since it is derived from the dilution of manure, and also because they do not have suitable means for transporting the large volumes of digestate over long distances.

There are not yet any official reports on the pollution status of recipient water bodies caused by biogas wastewater. However, there have been articles reflecting the opinion of local people that report that pollution from biogas wastewater has impacted harmfully on their life.

The nutrient content remains very high in the biogas effluent mainly due to incomplete digestion of organic matter due to inadequate storage time in AD system. According to a field survey of pig farms (Vu *et al.*, 2012), excessive use of washing water resulted in very dilute slurry (solid manure: water ratio 1:11) entering the AD. At highly diluted organic matter concentration, degradation activity of microorganisms can be significantly reduced. The result also showed that the retention time in the AD is below the optimum range of 35-55 days recommended (SNV, 2012) leading to low biogas production rates and high level of pollution in biogas effluents. This suggests that the biogas effluents still have a high polluting potential and further treating methods are required to ensure environmental quality. Making sure that there is widespread knowledge and training for farmers about effective AD operation is also very important.

One of the solutions to minimize the negative environmental impact from poorly operated biogas plants is to utilize the by-products from the digester (digestate). Digestate is composed of the wastewater and slurry after anaerobic processing in an AD. Digestate is still rich in nutrients and instead of being discharged directly into the environment, should be used as a nutrient source for farms. 1 m^3 of bio-slurry/digestate contains 0.8 m^3 of liquid slurry and 0.2 m^3 of solid slurry. The content of N, P and K in the digestate differs according to feeding materials. On average, 1 m^3 of digestate contains 0.16-2.4 kg N, 0.5-2.7 kg P_2O_5 and 0.9-4.0 kg K_2O (Xuan, 2006).

TABLE 49

N, P, K CONCENTRATION IN DIGESTATE

INDICATOR		N_{TOTAL}	NH_4^+	P_2O_5 TOTAL	K_2O TOTAL	pH
LIQUID SLURRY	mg/litre	170-2 240	130-930	56-320	100-434	1.7-8.5
	Percent	0.017-0.22	0.013-0.093	0.0056-0.032	0.01-0.043	
SOLID SLURRY	mg/litre	140-3 800	30.8-261.7	246-620	434-3 100	7.0-8.6
	Percent	0.07-1.9	0.015-0.13	0.123-0.31	0.217-1.55	

Source: Xuan, 2006

According to Xuan (2006), out of 8 512 households surveyed, 3 720 use bio-slurry/digestate for their farming activities including cultivation and animal production. 1 238 households built slurry pits. Out of 20 provinces surveyed, some provinces have a very high rate of bio-slurry use, namely Thanh Hoa (100 percent), Thai Nguyen (91 percent), Hai Duong (89 percent), whilst other provinces such as Yen Bai, Binh Dinh, Dak Lak and Hoa Binh have high rate of 70-76 percent. Most people know the benefits of digestate but do not use it due to a lack of land for cultivation or high costs for transportation.

In 2004, the National Institute for Soils and Fertilizers (NISF) carried out research on the application of liquid bio-slurry on cabbage with a ratio of slurry to water of 1:1 and 1:2. The results showed that the use 60 m^3 of liquid bio-slurry for cabbage as additional fertilizer helps increase yields by 24 percent. In addition, digestate can replace chemical fertilizers thus reducing cultivation costs. Savings obtained by applying digestate are 28 kg/ha urea, 10.8 kg/ha phosphate fertilizer and 27 kg/ha potassium fertilizers. Moreover, the pesticide amount needed for controlling leaf-damaging insects is reduced by 50 percent.

Within the biogas project (BP) for the animal husbandry sector in Viet Nam, field trials and demonstration plots on the use of bio-slurry for crops fertilizer were carried out. Demonstration plots were set up nation-wide in 24 provinces. The results showed that digestate application affects positively both crops yield and the quality of products. In particular crop yield increase as follows: vegetable 2-14 percent, secondary crop 15-20 percent, fruit 20-30 percent, industrial crop 5-14 percent, and paddy rice 7 percent. Cabbage fertilized with bio-slurry will roll tighter and french beans are more uniform and fresher. In the province of Tien Giang, liquid bio-slurry is used for watering a garden in Malpighia glabra. This practice has replaced 100 percent of the chemical fertilizer, and bigger fruits and lighter fruit colour were recorded (Xuan, 2006).

TABLE 50

IMPACTS ON CROP YIELD AND FERTILIZER USE FROM THE USE OF BIO-SLURRY

CROPS	INCREASED YIELD (Percent)	SAVED FERTILIZERS
MAIZE	25.8	
KOHLRABI	13.7	
CABBAGE	24.0	4.6 KG UREA, 3.6 KG PHOSPHATE AND 3.6 KG POTASSIUM PER "SAO" (360 M^2)
BUCK WHEAT	8.2	
PEANUT	8.5	21.7-43.4 KG UREA; 3.8-7.6 KG PHOSPHATE AND 5.6-11.2 KG POTASSIUM PER HECTARE
PADDY RICE	8.5	32.6-130.4 KG UREA, 59.4-238.2 KG PHOSPHATE AND 3.2-12.7 KG POTASSIUM PER HECTARE

Source: Xuan, 2006

4.6.3 Main conclusions and recommendations

Cassava based ethanol

a. Results

The results of this study show that large quantities of pollutants, mainly N and P, can be found into surface and groundwater bodies near cassava plantations. Although a nationwide assessment was not possible due to the lack of large-scale surveys and/or accurate modelling of pollutant discharge and flow, a preliminary analysis of the state of pollutants in the waterways and water bodies close to cassava cultivated areas was performed.

Table 44 shows the results of the measures of some quality parameters (COD, BOD_5, N_{tt} and P_{tt}) in water bodies near cassava plantations and demonstrates that all measured values exceed the respective thresholds set by law. This could be caused by high application rate of fertilizer and disregard for application methods that limit leaching. However, no active compounds from pesticide applied in cassava cultivation are detected in the surrounding water bodies.

b. Practices and policies to improve sustainability

The main issues identified in testing indicator 6 in Viet Nam relate to the limited extent of ongoing monitoring and analysis of water quality in the country, specifically, of the impacts of agriculture and bioenergy on the state of water bodies.

For improving water quality in the future, a good starting point could be to identify the main sources of water pollutants in biofuel lifecycles, identify a range of options for reducing the pollutant loadings associated with these sources, and assess and compare the impacts of implementing these options. For cassava, the main source of water pollution would seem to be fertilizer application. Good practices that reduce fertilizer application without undermining productivity exist, such as Integrated Plant Nutrient Management and low-input agro-ecological approaches. Checking and limiting water pollution would bring multiple benefits from both an environmental and an economic point of view. One option would be to start with regular and widespread monitoring of N and P balances, concentration of nutrients and pesticides in ground and surface waters.

c. Future monitoring

Investigating the impact of biofuel production on water quality does not seem to be among the highest priorities in Viet Nam. This may in part be due to the lack of information related to these impacts. However, certain measures that would lead to good performance against this indicator, such as more efficient use of fertilizers and pesticides, are relevant to Vietnamese stakeholders, particularly because of their relationships with GHG emissions (from fertilizer production and application) and implications for biodiversity in the landscape.

This indicator relies on local data and analysis and therefore has intensive measurement requirements. However, very useful information could be obtained by relatively practical measurements of N and P balances, complemented by monitoring of concentrations of these nutrients and key pesticides in ground and surface waters.

The GBEP methodological approach could perhaps be further enhanced by adding more details on how to practically make use of information on the implementation of good practices relating to major pollutant risks, including but not limited to fertilizer and pesticide application.

Biogas

a. Approach used

Secondary data were collected to present an overview of the nutrient loadings of biogas effluent and the impacts on surrounding waterbodies. Due to lack of data, a full assessment of the indicator could not be conducted.

b. Results

The results of this Indicator showed that there is a high level of pollution in effluents from ADs. Although the pollution parameters exceed many times the Vietnamese standard 40 of quality of livestock wastewater (IAE, 2015), some studies demonstrate that the concentration of pollutants are lowered compared to the direct discharge of this wastewater into the environment (Hong and Lieu, 2012). However, when farm practices are taken into consideration, the nutrients discharged into the environment is on average higher for farms with biogas than for those without it, suggesting that discharge of digestate into the environment significantly increases the risk and level of water pollution from biogas plants (Vu ***et al.***, 2012).

Digestate (or bioslurry) produced as a by-product of the AD can be used as a nutrient source on farms and has been shown to positively affect both crops yield and the quality of products, whilst reducing the need for chemical pesticides (Xuan, 2006).

c. Practices and policies to improve sustainability

The AD is a useful technology for boosting sustainable development if it is operated correctly. It can help reduce the level of pollution from livestock wastewater, whilst reducing the use of fossil fuels and fertilizer. However, its incorrect use could have relevant impact on water and air pollution.

Studies show that the nutrient content in the biogas effluent remains very high mainly due to incomplete digestion of organic matter due to inadequate storage time in AD system and over-diluted biogas feedstock (Vu ***et al.***, 2012). Therefore, it is extremely important to better train biogas users to ensure that they are aware of the optimum retention times and dilution values.

Digestate can be an important nutrient source for farms but it is currently underutilised. Certain studies identify the lack of adequate transport for digestate as a barrier to its proper use. Given that farmers only have access to rudimentary vehicles, and they underestimate the nutrient value of the digestate, they are more likely to discard the digestate rather than transporting large volumes of it over large distances to the fields (Vu *et al.*, *2012*; Thu *et al.*, 2012). Awareness raising could help to improve this situation, by demonstrating the benefits of biogas in terms of productivity.

d. Future monitoring

One recommendation that derives from this study is that it will be key to monitor the water quality of waterways and bodies receiving effluents from bio-digesters. Currently, limited information is available on the impact of digestate on receiving waterways and bodies. We only know that these effluents are still polluted, but we do not know the amount to which they influence the environment and what are the consequences of their impact. Only when these assessments are done can the full environmental impact of the biogas pathway on water quality can be determined.

REFERENCES

Hong, T.H and Lieu, P.H. 2012. Evaluation of the effluent treatment of pig waste from household bio-digester in Hue. *Academic Journal of Hue University* 73 (4): 83-91.

Huong, L.Q., Madsen, H., Anh, L.X., Ngoc, P.T and Dalsgaard, A. 2014. Hygienic aspects of livestock manure management and biogas systems operated by small-scale pig farmers in Viet Nam. *Science of the Total Environment* 470: 53-57.

Institute of Agricultural Environment (IAE). 2015. Investigation of current status the construction and installation of the environmental quality of the biogas (Biogas) small, medium and large scale – Propose a comprehensive management solution for livestock waste.

Institute of Agricultural Environment (IAE). 2017. Survey conducted within this study on April 2017 for the collection of primary data from local farmers. The survey was conducted in the provinces of Phu Tho and Tay Ninh.

Le-Thi, T., Pham-Duc, P., Zurbrugg, C., Luu-Quoc, T., Nguyen-Mai, H., Vu-Van, T., Nguyen-Viet H. 2016. Diarrhea risks by exposure to livestock waste in Viet Nam using quantitative microbial risk assessment. *Int. J. Public Health*. Springer. DOI 10.1007/s00038-016-0917-6

MONRE. 2016. Report on the status of national environment quality 2011-2015. Chapter 3: Emission and treatment of solid waste. Available at: http://cem.gov.vn/Portals/0/2016/TinBai/Chuong%203.pdf

SNV. 2012. Biogas program for animal husbandry sector in Vietnam. Program supported by Netherlands Development Organisation. www.biogas.org.vn/

Thu, C.T.T., Cuong, P.H., Hang, L.T., Chao, N.V., Anh, L.X., Trach, N.X. and Sommer, S.G. 2012. Manure management practices on biogas and non-biogas pig farms in developing countries – using livestock farms in Viet Nam as an example. Journal of Cleaner Production 27 (2012): 64 – 71. https://doi.org/10.1016/j.jclepro.2012.01.006.

Xuan, T.L.T. 2006. Country report on Bio-slurry utilization in Vietnam. The biogas program for the animal husbandry sector of Vietnam. Available at: www.biogas.org.vn [Accessed: 15 Mar 2017].

VJIIST. 2017. Surveys conducted within this study on April 2017 in feedstock production areas in Phu Tho, Tay Ninh province, ethanol plants, transportation activities mapping (including vehicles for cassava chips, ethanol and biofuel transportation) and E5 stations.

Vu, Q.D., Tran, T.M., Nguyen, P.D., Cuong, C.V., Vu, V.T.K and Jensen, L.S. 2012. Effect of biogas technology on nutrient flows for small- and medium-scale pig farms in Viet Nam. *Nutr. Cycl. Agroecosyst* 94: 1-13.

4.7 INDICATOR 7: BIOLOGICAL DIVERSITY IN THE LANDSCAPE

Nguyen Dinh Trang, Pham Quang Ha
Institute of Agricultural Environment (IAE), Viet Nam Academy of Agricultural Sciences (VAAS)

DESCRIPTION:

(7.1) Area and percentage of nationally recognized areas of high biodiversity value or critical ecosystems converted to cassava production;
(7.2) Area and percentage of the land used for bioenergy production where nationally recognized invasive species, by risk category, are cultivated;
(7.3) Area and percentage of the land used for bioenergy production where nationally recognized conservation methods are used.

MEASUREMENT UNITS(S):

Absolute areas in hectares or km^2 for each component and for total area used for bioenergy production. Percentages of bioenergy production area can be calculated from these, and given either separately for each relevant category (i.e. different types of priority areas for 7.1 and specific methods for 7.3) or as a combined total across such categories.

4.7.1 Implementation of Indicator 7 in Viet Nam

Indicator 7 was assessed at national level, based on secondary data from relevant ministries (e.g. MARD and MONRE), from international organizations (e.g. UNEP/WCMC), extension centres of provinces and localities, and from the authors' own case studies.

In Viet Nam, no data is available on the share of forest conversion to agricultural land attributable to cassava (sub-indicator 7.1). Furthermore, while information exists about conservation methods used in the cultivation of cassava (even though not 'nationally recognized'), the level of adoption of such methods among cassava producers is not known.

4.7.2 Key findings

Sub-indicator 7.1

Since 1991, Viet Nam has a relatively complete legal framework related to biodiversity conservation. Many important laws in the field of natural resource management have been enacted, such as: the Forest Protection and Development Law 1991 (revised in 2004); the Land Use Law, 1993 (revised in 1998, 2003 and 2013); the Environmental Protection Law, 1993 (amended in 2005 and 2014); the Water Resources Law, 1998 (revised in 2012); and the Fisheries Law, 2003. In particular, the Biodiversity Law (2008) has identified principles and priorities of biodiversity conservation at all levels, from national to local levels; thus creating the legal basis for local community involvement in the conservation of natural resources through new mechanisms of co-management and benefit sharing (MONRE, 2016).

For measuring sub-indicator 7.1, two different data sources were used: Ministry of Natural Resources and Environment (MONRE, 2016), for data related to Special Use Forests (SUF); and United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC, 2017), for data related to national protected areas and coverage. A list of conservation areas in Viet Nam is provided in **Table 51**.

According to UNEP-WCMC (2017), in Viet Nam there are 210 protected areas. These include 188 terrestrial Protected Areas (PAs), covering 7.58 percent of the country's total land area, and 22 Marine Protected Areas (MPAs) covering 0.56 percent of Viet Nam's total marine area. MONRE (2016) recognises 164 SUFs with total area of 2 198 744 ha.

TABLE 51

LIST OF CONSERVATION AREAS IN VIET NAM

TYPE OF PROTECTED AREA	NUMBER		AREA (ha)
	MONRE	UNEP-WCMC	
NATIONAL PROTECTED AREAS			
NATIONAL PARKS	30	32	1 077 236
NATURE RESERVES	58	90	1 060 959
SPECIES/HABITAT CONSERVATION AREAS (SHCA)	11		38 777
LANDSCAPE PROTECTION AREAS (LPA)	45		78 129
EXPERIMENTAL AND SCIENTIFIC RESEARCH AREAS (ESRA)	20	20	10 653
TOTAL SPECIAL USE FORESTS (SUFs)*	**164**		**2 198 744**
CULTURAL AND HISTORICAL SITES		42	
NATIONAL PARKS – BUFFER ZONES		2	
WETLAND PROTECTED AREAS		1	
SPECIAL USE FORESTS*		1	
MARINE PROTECTED AREAS (INCLUDING 104 098 ha OF MARINE AREA)		**22**	**172 577**
INTERNATIONALLY RECOGNIZED CONSERVATION AREAS			
RAMSAR WETLANDS OF INTERNATIONAL IMPORTANCE		8	84 982
UNESCO BIOSPHERE RESERVES		8	
UNESCO NATURAL WORLD HERITAGE SITES		3	
ASEAN HERITAGE PARKS	4		
IMPORTANT BIRD AREAS	62		1 641 920

Adapted from MONRE, 2016 and UNEP-WCMC, 2017

(*) Special Use Forests (SUFs) are defined differently by the two data sources: SUF is used by MONRE (2016) for all national forest protected areas.

Figure 32 shows the protected areas and internationally recognized conservation areas of Viet Nam. These areas include: National Parks; Nature Reserves; Species/Habitat Conservation Areas; Landscape Protection Areas; Experimental and Scientific Research Areas; Cultural and Historical Sites; National Parks – Buffer Zones; Special Use Forests; Ramsar Wetlands of International Importance; UNESCO Biosphere Reserves; UNESCO Natural World Heritage Sites; ASEAN Heritage Parks; and Important Bird Areas.

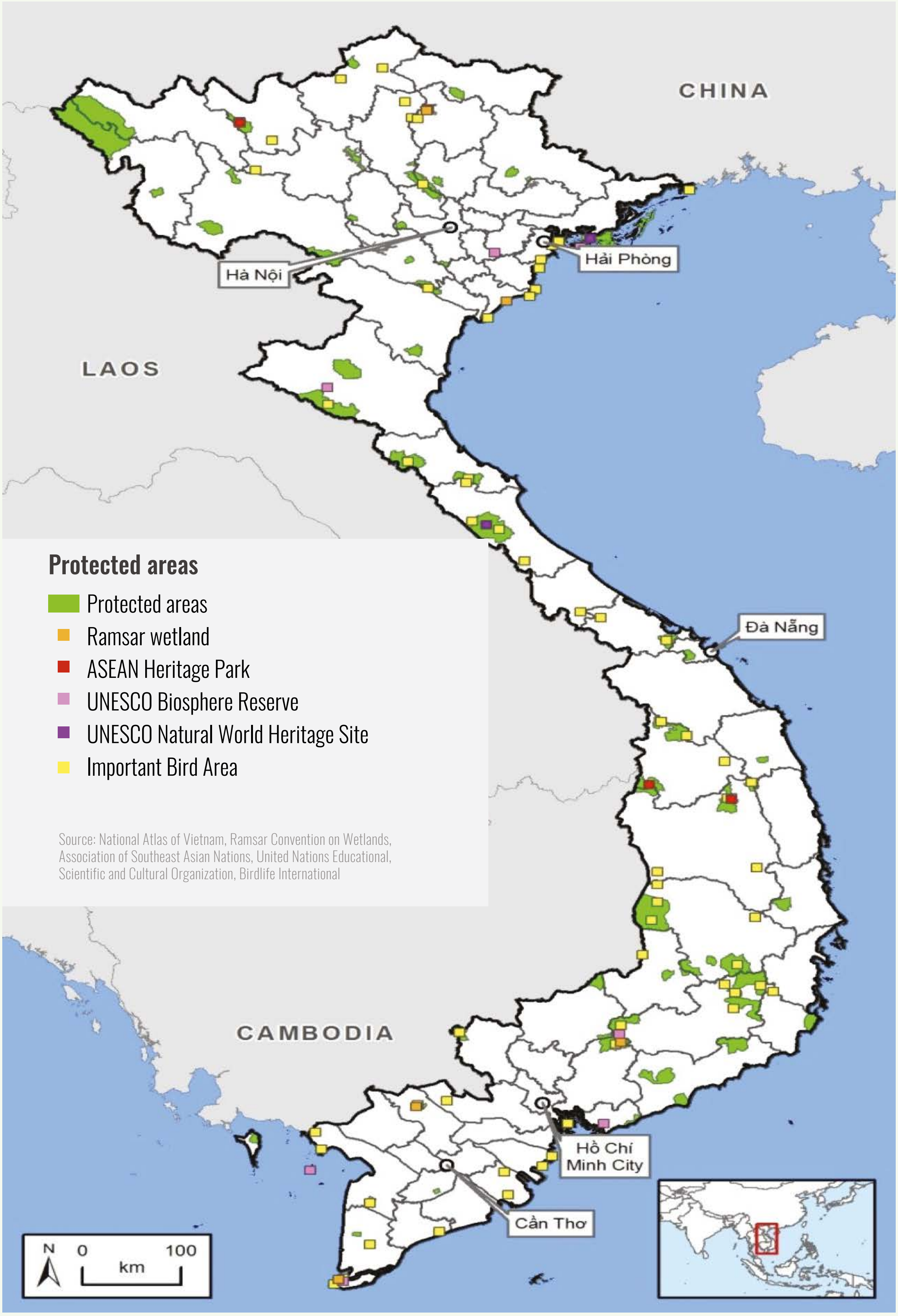
According to the literature currently available, the causes of biodiversity losses in those areas are very complex. The main causes of such losses include: illegal and excessive exploitation of biological resources, shifting to crop cultivation, fire and hydro-power reservoirs.

Figure 33 shows the levels of biodiversity across Viet Nam overlaid with the cassava cultivation areas and Protected Areas. As can be seen from the map, areas of widespread cassava cultivation are sometimes alongside Protected Areas. However, no specific data are currently available on land use change due to the shift in these areas to cassava cultivation. Therefore, it was not possible to retrieve data concerning the change in natural vegetation affecting the mapped protected areas due to ethanol feedstock production and sub-indicator 7.1 could not be calculated.

It is worth noting, however, that the nationally recognised protected areas with high biodiversity value in Viet Nam, which total 164 SUFs with 2 198 744 ha, are very well protected and legal cultivation of cassava in these areas would be unfeasible.

FIGURE 32

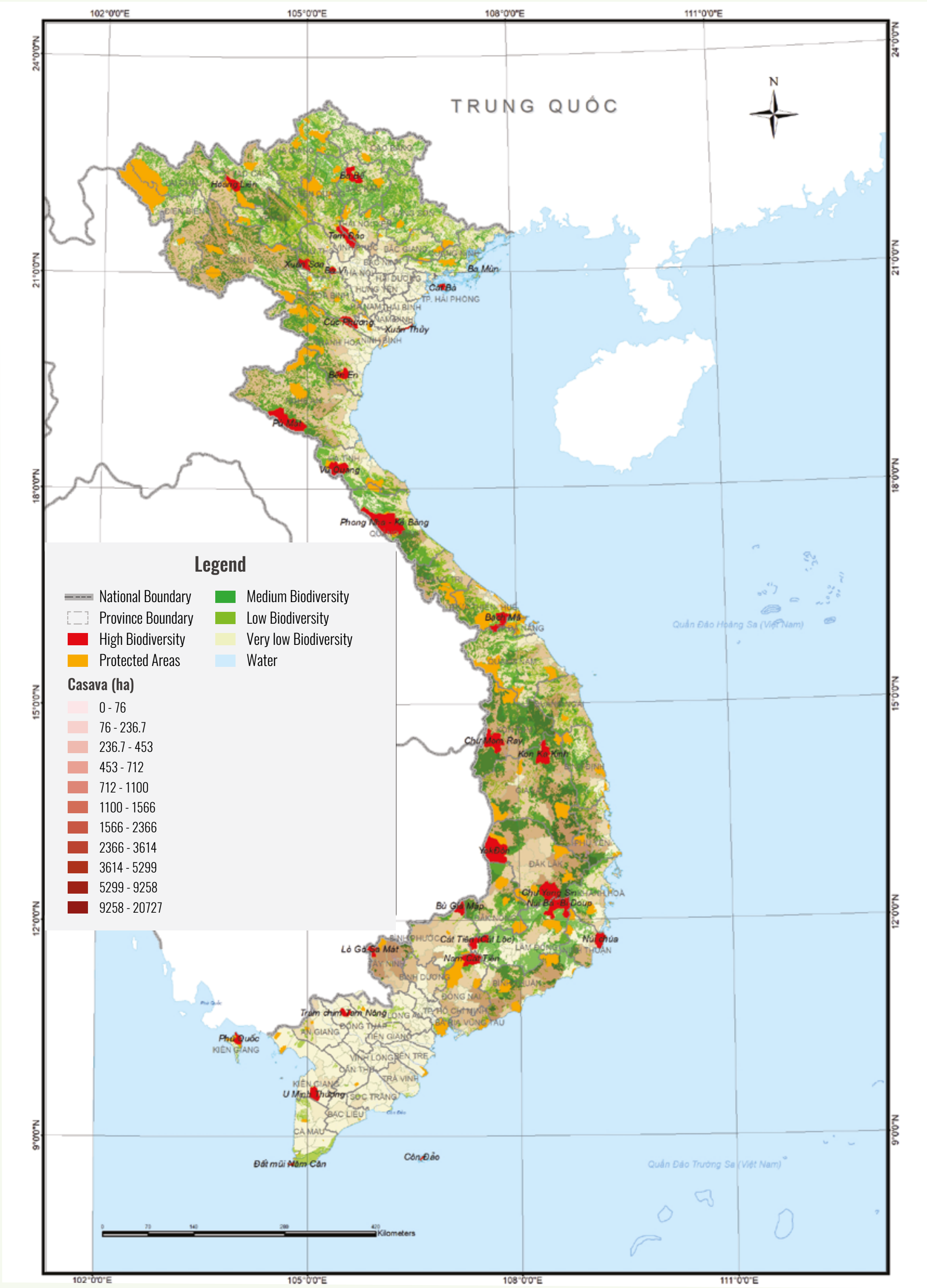
MAP OF PROTECTED AREAS (AS CLASSIFIED BY THE VIET NAM BIODIVERSITY LAW, 2008)



Source: *De Queiroz* ***et al.***, *2013*

FIGURE 33

BIODIVERSITY MAP AND CASSAVA CULTIVATION AREAS IN VIET NAM



Source: FAO, 2016

Conversion of forest areas to agricultural land

Viet Nam's forest ecosystems are highly biodiverse, containing the majority of the country's species of wild plants and animals. Since 1990, thanks to the reforestation program, the forest cover has increased continuously, growing from 27.8 percent (proportion of forest coverage in comparison with total land area of Viet Nam) in 1990, to 38.7 percent in 2007 and 42.4 percent in 2015 (see indicator 8). Increases in forest cover have resulted from the expansion of forest plantations and regeneration forests, which typically have much lower levels of biodiversity than primary forests.

Although forest cover in Viet Nam has been increasing thanks to reforestation, for the period 2007-2013, 225 000 ha of forest were converted to other land uses. Of this, 88 percent (199 293 ha) were converted to agricultural land (**Table 52**). The most critical year in terms of forest conversion was 2012 when the forest area converted to agricultural land increased by 394 percent in comparison with the year 2011. Deforestation due to shifting cultivation is actually one of the direct drivers of forest biodiversity loss and forest degradation. Forest conversion to annual crops and commercial perennial plantations at household scale by local people has often been claimed as the major direct driver of deforestation in Viet Nam. In the Northern mountainous region of Viet Nam, local people mainly shift to agriculture to grow crops like corn, cassava and upland rice for household consumption and some additional cash.

In the Central Highlands (CHL) and the Southern provinces of Viet Nam, upland cultivation activities are more market-oriented. In these regions, individual households establish tree plantations with fast-growing monoculture timber species (mainly Acacia and Eucalyptus species) for wood chips, pulp and paper, and timber production. When the price of cash crops (e.g. rubber, coffee, cassava) increases, timber plantations may be reconverted to cash crops and other commercial plantations.

Conversion of forest land to agricultural production may be a direct cause of biodiversity loss.

TABLE 52

CONVERSION OF FOREST LAND, 2007-2013

YEAR	CONVERTED FORESTRY LAND (ha)	NON- AGRICULTURAL PURPOSE (ha)	AGRICULTURAL PURPOSE (ha)	ANNUAL CHANGE IN FORESTRY LAND CONVERTED FOR AGRICULTURAL PURPOSE (percentage)
2007	16 200	580.32	15 620	-
2008	29 200	5 830.76	23 369	49.6
2009	38 600	164.19	38 436	64.5
2010	46 500	7 115.08	39 385	2.47
2011	24 100	12 157.08	11 943	-69.7
2012	59 200	89.34	59 111	394.9
2013	11 500	70.52	11 429	-80.7
TOTAL	**225 300**	**26 007**	**199 293**	

Source: MONRE, 2016

Unfortunately, it is impossible to have data on how much forest land was converted specifically to cassava production. Nevertheless it should be taken into account that cassava is planted in marginal and infertile land, while high fertility land is usually allocated to higher value food and feed crops.

Sub-indicator 7.2

Manihot esculenta (cassava) is not classified as an invasive species in Viet Nam. Thus, whilst further investigation to determine definitively if other invasive species are used or introduced along the Cassava-based ethanol pathway, the value for sub-indicator 7.2 for ethanol production in Viet Nam is zero.

Sub-indicator 7.3

Cassava is an annual crop with low cash and nutritive value. Therefore, in Viet Nam it is commonly cultivated in poor soil (e.g. sandy soils) on sloping or marginal land, whilst good soil is usually allocated to the cultivation of other food crops or high value cash crops.

Numerous studies have been conducted on soil conservation measures applied to cassava plantations, especially for preventing soil erosion. Special attention has been paid to the planting of cassava on sloping land such as in the North Mountainous Region, since in these areas soil is particularly prone to erosion.

The Vietnamese Government and provincial authorities have issued guidance and advice on advanced techniques to be applied in upland cropping in general and for cassava plantation on sloping land in particular. Most of the studies on sloping soil management were carried out before 2000, within national and international programmes. Many of these studies warned that cassava cultivation on slopes may cause more severe erosion than other annual crops due to its wide plant spacing and slow initial growth at the beginning of the rainy season (April). In order to enhance the sustainability of cassava production, several good practices were identified and implemented especially in Northern Viet Nam, such as minimum tillage, contour planting, tree or grass erosion control hedgerows and intercropping with leguminous plants, together with integrated pest management and nutrient management practices (Loan, 2007; Dieu, 2015; Phuong *et al.*, 2016; VNCA, 2012).

The use of conservation methods, such as minimum or no-tillage practices, in cassava cultivation has been encouraged by the extension centres of provinces and localities, and have become common in cassava cultivation on sloping land. Especially for the Northern mountainous provinces (where over 70 percent of the agricultural land area has a slope of more than 8 percent, for example in some provinces such as Lao Cai, Son La, Lai Chau and Hoa Binh), cassava planting does not foresee the use of ploughing but is instead directly planted by holing.

In addition to minimum or even no-tillage practices, other conservation methods used on sloping land include intercropping cassava with grass or trees, and using erosion-resistant hedgerows, which consist of a contour of green barriers. Given that the hedgerows follow the contours of the land, the distance between hedgerows depends on the slope: with an 8-15 percent slope, the distance between the runways (cassava planting) is 8-10 m, whereas with a greater slope of 15-20 percent, the distance is slightly smaller at 6-8 m. On each contour, two rows of hedgerows are planted, with a width of 0.5 m. Hedgerow species used include ***Tephrosia candida***, ***Vetivena zizannoides***, ***Pennisetum purpureum***, ***Crotalaria***, and ***Ananas comosus***. Annually, the biomass of the hedgerow is from 3.5 to 6.8 tonnes ha^{-1} and provides nutrients in the soil of 21-50 kg N, 3-5 kg P_2O_5, and 20-40 kg K_2O ha^{-1} (Thai ***et al.***, 2002). At the same time, the fences of the hedgerows are effective in reducing soil and nutrients losses by 50-60 percent per year. Periodically, hedgerows can be trimmed to lower than 0.8 m to ensure adequate light and the cut leaves can be put into the soil as green manure. These measures have been recently implemented in a project by the Center for Seed Testing and Crop Production called "Sustainable Cassava Development for Northern Mountainous Provinces" (2014), in the Son La, Hoa Binh, Phu Tho, Vinh Phuc, Thai Nguyen and Lao Cai provinces. The project successfully cultivated cassava on sloping land by using conservation methods in combination with planting grass and erosion-resistant hedgerows.

The conservation methods described above are not mandatory, so their application depends very much on farmers' willingness. Furthermore, no statistical data are available on how many farmers have actually adopted conservation practices so far. According to a recent study (not-published) of the Tuber Research Centre under VAAS, about 70 percent of cassava cultivation on sloping soils occurs with the use of conservation methods.

Regarding the adoption of integrated nutrient management practices and intercropping for cultivating cassava, Kim *et al.* (2010) conducted experimental trials, established at the pilot sites in Dong Nai, Yen Bai and Thua Thien Hue provinces, to determine:

(i) The agronomic potential of intercropping systems that include cassava with sweet sorghum, maize or groundnut;
(ii) The best management practices for these cropping systems, with particular reference to integrated soil fertility management and soil erosion control; and
(iii) The most productive varieties of sweet sorghum, maize and groundnut to intercrop with cassava.

The results of the trials indicated that, with intercropping, the productivity of cassava increased and soil erosion was reduced. Further experimental trials were carried out by Trung *et al.* (2013), who conducted three experiments in Dong Mau commune, Van Yen district and Yen Bai province to enhance sustainable cassava production. The results indicated that intercropping of cassava with a hedgerow of peanut, *Tephrosia candida,* was effective in reducing soil erosion, and resulted in a higher cassava yield, higher harvest index and higher starch content compared to the control.

4.7.3 Main conclusions and recommendations

Approach used

Indicator 7 was assessed at national level, based on secondary data from relevant ministries (e.g. MARD and MONRE), from international organizations (e.g. UNEP/WCMC), extension centres of provinces and localities, and from the authors' own case studies.

As explained above, no data was available on the share of forest conversion to agricultural land attributable to cassava (sub-indicator 7.1) and on the level of adoption of conservation methods among cassava producers. Finally, regarding sub-indicator 7.2, cassava is not classified as an invasive species in Viet Nam.

Results

With regard to sub-indicator 7.1, although forest cover in Viet Nam has been increasing thanks to reforestation, for the period 2007-2013, 225 000 ha of forest were converted to other land uses. Of this, 88 percent (199 293 ha) were converted to agricultural land. However, no information is available on the share of this expansion attributable to cassava cultivation (including for ethanol production).

With regard to sub-indicator component 7.2, cassava is not classified as an invasive species in Viet Nam; therefore sub-Indicator 7.2 is equal to zero.

Finally, concerning sub- indicator 7.3, soil conservation practices on sloping land are well-known in Viet Nam and highly recommended by researchers and by the extension community, nevertheless they are not mandatory and their application depends on farmers' willingness. No official/statistical data are available at national scale on the application of conservation methods, data available come from experts' own experiences only. To be able to determine if sustainable agricultural practices are actually implemented, the data on the application of conservation methods should be registered or surveyed.

Practices and policies to improve sustainability

Impacts on biodiversity of cassava feedstock production for ethanol could be negative or positive. The expansion of feedstock production has been based on land-use change or management intensification, which can occur in relatively undisturbed ecosystems, crop or managed forest lands, or degraded lands. Direct loss of biodiversity occurs if there is a concurrent loss of wildlife habitat and this is greatest where feedstock for biofuels is planted in protected areas, and biodiversity losses exceed positive impacts of biofuels production on biodiversity. However, benefits to biodiversity can occur where feedstock is planted on degraded land. For example, the use of perennial grasses intercropped with cassava cultivation for ethanol production, along with other conservation methods used on sloping land, can enhance bird species richness and abundance relative to bird diversity of normal cassava fields.

With regard to practices and policies in Viet Nam, there are several measures for avoiding or reducing environmental impacts of cassava expansion for ethanol production. First, land-use planning with clearly defined agricultural production zoning can limit the expansion of cassava into protected areas. Spatial planning based on systematic conservation planning principles can establish networks of sustainable protected areas. Secondly, wildlife friendly agricultural and forestry practices can be employed, as promoted by the work of MARD, extension centre of provinces and localities, and the Forest Protection Department. These approaches complement public policy and market demands. However, both strategies depend on the implementation of long-term monitoring activities by a network of relevant organisations.

Future monitoring

This indicator can play a key role in shedding light on the sustainability of ethanol feedstock production, by assessing its impacts on biodiversity, and identifying and evaluating good management practices in cassava cultivation.

In the case of Viet Nam, data is available on the quantity and area of national and internationally recognized high biodiversity value and conservation areas, which include National Parks, Nature Reserves, Species/Habitat Conservation Areas, Landscape Protection Areas, Experimental and Scientific Research Areas, Cultural and Historical Sites, National Park Buffer Zones, Special Use Forests, Ramsar Wetlands of International Importance, UNESCO Biosphere Reserves, UNESCO Natural World Heritage Sites, ASEAN Heritage Parks, and Important Bird Areas. However, it was not possible to determine the area and percentage of nationally recognized areas of high biodiversity value or critical ecosystems converted to cassava production. In order to estimate this, it would be necessary to agree on a single official definition of what is considered a nationally recognized area of high biodiversity value or critical ecosystem, at least for the purposes of bioenergy feedstock expansion. Furthermore, data on land use change and particularly on the conversion of areas of high biodiversity value to cassava cultivation (including for ethanol) need to be collected and related maps developed by relevant organizations such as MONRE or the Forest Protection Department.

As described above, conservation methods are applied in Viet Nam, including in cassava cultivation. Nevertheless, the area and percentage of land used for cassava production where a nationally recognized conservation method is applied could not be determined. Hence, in order to measure sub-indicator 7.3, a nationally recognized set of conservation methods should be developed, and surveys should be conducted in order to determine the level of adoption of such methods among cassava producers.

REFERENCES

De Queiroz, J.S., Griswold, D., Nguyen, D.T. and Hall, P. 2013. Vietnam Tropical Forest and Biodiversity Assessment. Sun Mountain International and the Cadmus Group, Inc. & The Global Environmental Management Support Project (GEMS). August/2013.

Dieu, H.K. 2015. Study on growth, development and main technical method for new cassava varieties in some provinces of the Northern Mountain Viet Nam. PhD Thesis in Agriculture. Thai Nguyen University.

Kim, H., Bo, N.V., Phuong, N., Long, H., Khanh, T.C., Hien, N.T., Ceballos, H., Lefroy, R., Fahrney, K., Howeler R. and Aye, T.M. 2010. Current situation of cassava in Viet Nam and the breeding of improved cultivars. 21pp. Available at: www..hcmuaf.edu.vn/contents.php?ids=5380&ur=hoangkim

Loan, T.T.P. 2007. Result studied on cassava cultivar selection and sustainable cassava cropping in North Viet Nam. Journal of Science and Technology N3 (4).

Ministry of Agriculture and Rural Development (MARD). 2006. A Review for Planning Special Use Forest System in Vietnam. Reported in 'Viet Nam fifth National report to the United Nations Convention on biological diversity'

Ministry of Natural Resources and Environment (MONRE). 2016. Viet Nam national biodiversity strategy to 2020, vision to 2030. Synthesis of conversion of forest land in Viet Nam from 2007 to 2013, pp 40-176. Forest protection department website. Available at: www.kiemlam.org.vn [Accessed 9 Feb. 2017]

Phương, N.T., Công, H.S., Hải, N.Q., Anh, N.T. and Dương, N.V. 2016. Research techniques for integrated farming cassava towards efficient and sustainable in sand and hill for coastal area of the southern Vietnam central. VAAS. 2016**.**

Thai, P., Huy, B.H. and Acton, D. 2002. Sustainable land management in Viet Nam: assessment of hedgerow farming system on sloping land. Available at: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.9.5732&rep=rep1&type=pdf

Trung, N.T., Nakasathien, S. and Vichukit, V. 2013. Enhancing sustainable cassava production in hilly areas of Van Yen, Yen Bai province, Viet Nam. *Kasertsart Journal (National Science)* 47: 492-505.

United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC). 2017. Protected area profile for Viet Nam from the World database of protected areas, November 2017. Available at: www.protectedplanet.net

Vietnam Cassava Association (VNCA). 2012. Sustainable cassava cropping on sloping land in Yen Bai Province (in Vietnamese). (Video clip). Available at: http://hiephoisanvietnam.org.vn/ Accessed 16/01/2018.

4.8 INDICATOR 8: LAND USE AND LAND-USE CHANGE RELATED TO BIOENERGY FEEDSTOCK PRODUCTION

Dinh Viet Hung, Pham Quang Ha
Institute of Agricultural Environment (IAE), Viet Nam Academy of Agricultural Sciences (VAAS)

DESCRIPTION:

(8.1) Total area of land for bioenergy feedstock production, and as compared to total national surface and (8.2) agricultural land and managed forest area
(8.3) Percentages of bioenergy from:

- (8.3a) yield increases,
- (8.3b) residues,
- (8.3c) wastes,
- (8.3d) degraded or contaminated land

(8.4) Net annual rates of conversion between land-use types caused directly by bioenergy feedstock production, including the following (amongst others):

- Arable land and permanent crops, permanent meadows and pastures, and managed forests
- Natural forests and grasslands (including savannah, excluding natural permanent meadow and pastures), peatlands, and wetlands

MEASUREMENT UNITS:

(8.1-2) hectares and percentages
(8.3) percentages
(8.4) hectares per year

4.8.1 Implementation of Indicator 8 in Viet Nam

Viet Nam can be divided in six, seven or eight agro-ecological regions according to different purposes. The classification of the agro-ecological regions in Viet Nam has changed during the past years and depends on the sources of information, as statistical data is only reported by provinces and some provinces have been re-organized administratively by the government, and some have even shifted from one region to another (GSO website; MARD, 2017). For the scope of this work, it was assumed that Viet Nam is classified in six different regions as listed by the national GSO.

The year 2007 was used as a baseline for this study as it represents the year in which the Government issued the first policy to support bioenergy development. Data related to 2015 were used for discussing and computing indicator 8 in terms of percentage, while data related to 2007, and the period 2010 to 2015 were listed to understand the evolution of Land Use Change over time.

4.8.2 Key findings

Evolution of agricultural land by region

The maps in **Figure 34** show the change in land use across Viet Nam between 2007 and 2016, including a widespread increase in agricultural crop land. This is emphasised in **Table 53**, which shows that agricultural land in Viet Nam increased by about 706 thousand ha in the three years from 2007 to 2010 and by about 1.4 million ha from 2010 to 2015. At the national level, the total increase was almost 2 million ha in eight years. The agricultural land expansion occurred as part of a food security and cash crop diversification program to increase agricultural production. Between 2007 and 2015, agricultural land increased in almost all regions of Viet Nam, except for the Red River Delta (RRD), where it remained almost stable. The major increases were registered especially in Central High Lands (CHL), Northern Midlands & Mountainous areas (NMM), North Central and Central Coastal areas (NCCC), and the South East (SE). To understand where this expansion of agricultural land came from, it is important to analyse the evolution of forestry areas in the same period.

FIGURE 34

MAP OF LAND USE IN VIET NAM, 2007 AND 2016

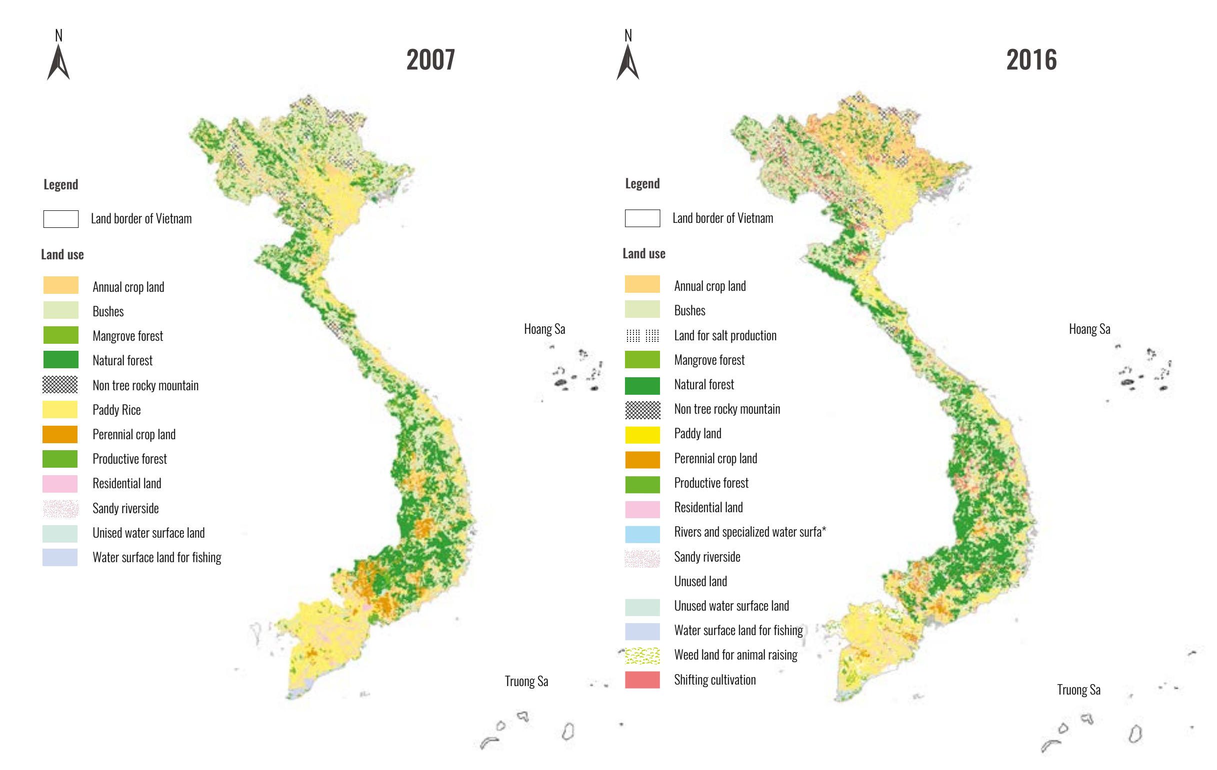


TABLE 53

AGRICULTURAL LAND BY REGION

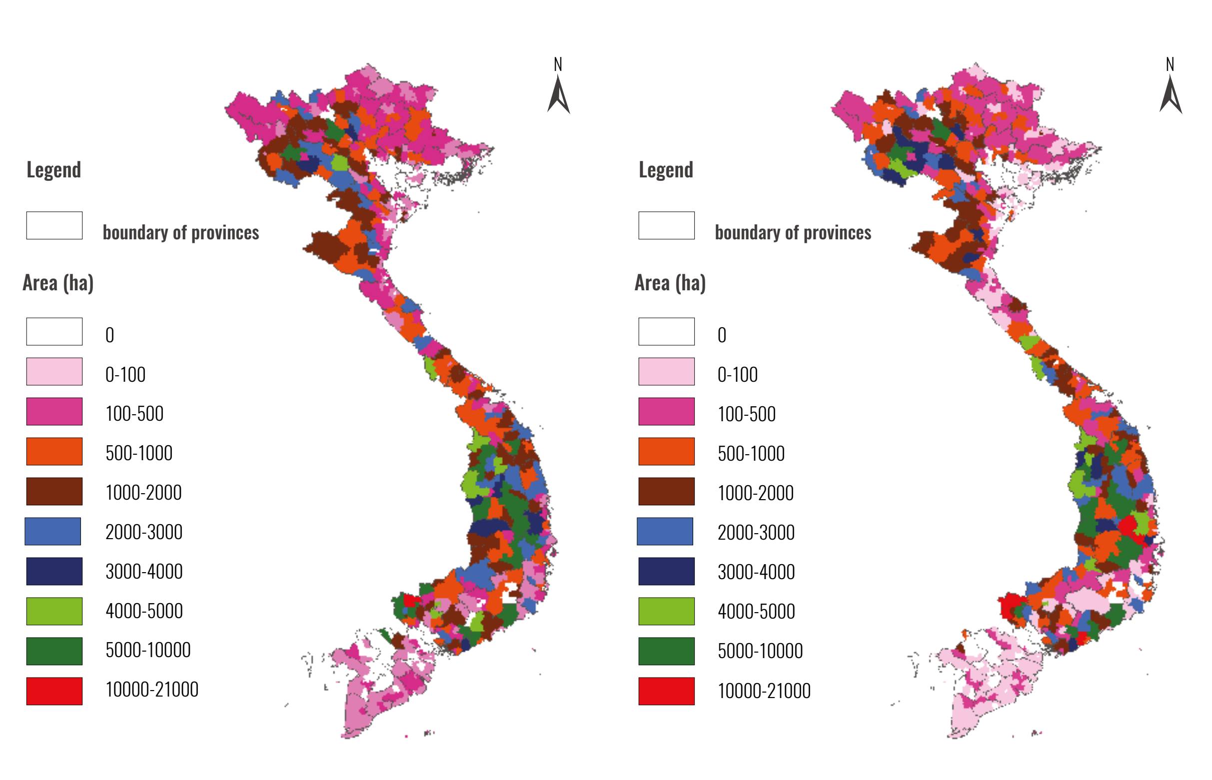
	REGION	2007	2010/11	2012	2013	2014	2015
1	RED RIVER DELTA (RRD)	802.6	779.8	775.2	770.8	769.3	799.0
2	NORTHERN MIDLANDS AND MOUNTAIN AREAS (NMM)	1 423.2	1 570.6	1 571.1	1.596.3	1 597.7	2116.7
3	NORTH CENTRAL AND CENTRAL COASTAL AREAS (NCCC)	1 758.3	1 851.7	1 863.8	1 881.6	1 902.1	2205.5
4	CENTRAL HIGHLAND (CHL)	1 626.9	1 952.8	1 958.2	2 000.4	2 001.6	2420.6
5	SOUTH EAST (SE)	1 248.7	1 354.7	1 355.5	1 355.2	1 353.9	1 363.4
6	MEKONG RIVER DELTA (MRD)	2 560.6	2 616.5	2 600.3	2 606.5	2 607.1	2 623.9
	WHOLE COUNTRY	9 420.3	10 126.1	10 151.1	10 210.8	10 231.7	11 530.2

Unit: thousand ha

Source: Elaborated from GSO website & MARD website

FIGURE 35

CASSAVA HARVESTED AREA IN VIET NAM, 2007 AND 2016



Source: elaborated by IAE as part of this study

TABLE 54

CASSAVA HARVESTED AREA, YIELD AND PRODUCTION IN VIET NAM, 2007-2015

YEAR	HARVEST AREA (thousand ha)	YIELD (tonnes/ha)	PRODUCTION (thousand tonnes)	ANNUAL CHANGE IN AREA (percent)	ANNUAL CHANGE IN YIELD (percent)
2007	495.5	16.5	8 192.8		
2008	554.0	16.8	9 309.9	11.81	1.81
2009	507.8	16.8	8 530.5	-8.34	0
2010	498.0	17.3	8 595.6	-1.93	2.98
2011	558.4	17.7	9 897.9	12.13	2.31
2012	551.9	17.6	9 735.4	-1.16	-0.56
2013	543.9	17.9	9 757.3	-1.45	1.70
2014	552.8	18.5	10 209.9	1.64	3.35
2015	566.5	18.8	10 739.9	2.48	1.62
AVERAGE					1.65

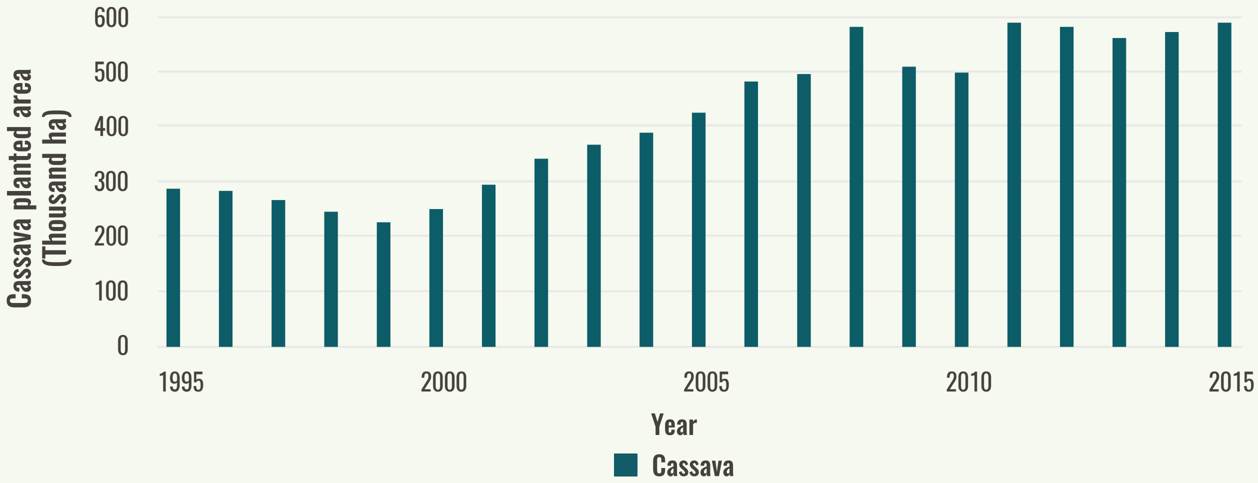
Source: GSO website

Cassava harvested area, yield and production in Viet Nam

Cassava harvested areas in 2007 and 2015 were respectively 495 500 ha and 566 500 ha, with an average annual increase of about 1.89 percent, for a total expansion of 14.33 percent in eight years (**Table 54**). The area increased quite rapidly between 2007 and 2008 (+11.8 percent) but decreased sharply in 2009 (–8.34 percent on the previous year). It increased again in 2011 (+12.1 percent) and then decreased slowly in 2012 (–1.16 percent) and 2013 (–1.45 percent). The areas increased again in 2014 (+1.63 percent) and 2015 (+2.48 percent). As shown in **Table 54**, there was also an average increase in yield over the same period of about 1.65 percent per year.

FIGURE 36

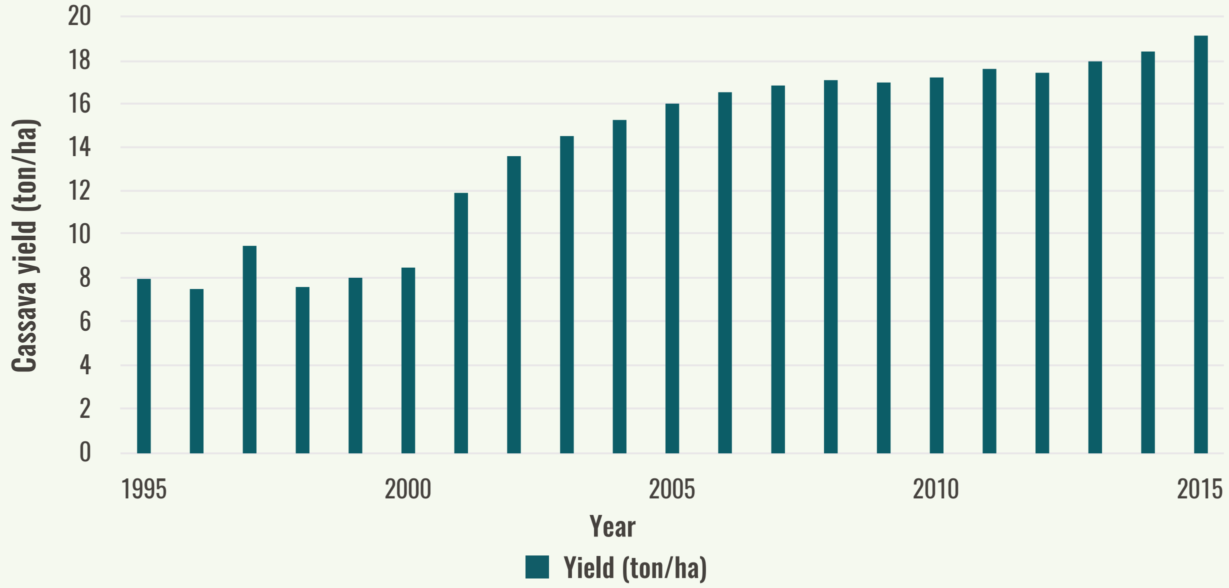
CASSAVA AREA IN VIET NAM, 1995-2015



Source: GSO website

FIGURE 37

EVOLUTION OF ANNUAL CASSAVA YIELD, 1995-2015



Source: GSO website

The average cassava yield from 1995 up to 2015 is reported in **Figure 37**. In Viet Nam, cassava yield rapidly increased in the last 20 year period, passing from 8 tonnes/ha in 1995 to 15.8 tonnes/ha in 2005 and reaching 18.8 tonnes/ha in 2015.

Cassava yield depends on different factors, among which the variety of the crop, the soil type and the fertilization input. Currently, cassava yield varies from 10 to 40 tonnes/ha (Hoang, 2015) and in some cases, such as in very high intensive plantations with high productive varieties, it can exceed 60 tonnes/ha (Hi, 2016). Data coming from the survey and the literature review conducted within this study show that Tay Ninh, a province in the SE region, has the highest cassava yield in the country that varied, on average, between 29 and 32 tonnes/ha from 2007 to 2015 (**Table 55**; Indicator 18).

TABLE 55

CASSAVA HARVESTED AREA, YIELD AND PRODUCTION IN TAY NINH PROVINCE, 2011-2015

PROVINCE	YEAR	AREA (thousand ha)	YIELD (tonnes/ha)	PRODUCTION (thousand tonnes)	YIELD COMPARED TO THE NATIONAL AVERAGE (percent)
TAY NINH	2011	45.7	29.01	1325.9	163.7
	2012	45.4	29.02	1317.3	164.5
	2013	45.7	29.47	1347.0	164.3
	2014	50.5	31.75	1603.4	171.9
	2015	57.6	32.44	1868.3	172.2

Source: GSO website

The increase in both area and yields means that total cassava production in Viet Nam increased significantly, passing from 8.2 million tonnes in 2007 to 10.7 million tonnes in 2015 (see **Table 54**). In the reference period, cassava yield increased by 2.3 tonnes/ha or 13.94 percent, while the cassava harvested area increased by 14.33 percent.

According to the most updated information, more than 90 percent of cassava produced in Viet Nam is exported as cassava chips and starch. On the other hand, about one million tonnes of fresh cassava and 600 000 tonnes of dry cassava chips are imported from Cambodia (providing 1 million tonnes of dried cassava chips). About 1.3 million tonnes of dry cassava chips are consumed domestically, mainly for starch production (Viet Nam Finance, 2017). Cassava has, in fact, many uses in industrial processing, for example, production of monosodium glutamate (MSG), alcohol, instant noodles, glucose, syrup, candy, cookies, barley sugar, adhesives (glue paste for fabric, wood), food additives, pharmaceutical additives, biofuel and ethanol.

Since the first ethanol support policy was introduced in 2007, only a very limited amount of ethanol has been actually produced and consumed in Viet Nam. In 2016, ethanol consumption in the country amounted to 29 000 m^3 (MOIT, 2017). The consumption of dry cassava chips for producing this amount of ethanol was equal to 67 850 tonnes and the cassava area used for producing this amount of cassava chips was 8 662 ha (assuming a yield of 18.8 tonnes/ha), equal to 1.53 percent of the total harvested area in the country. These figures suggest that the expansion in the cassava harvested area registered in the period 2007-2015 (+71 000 ha) was not driven primarily by the demand for ethanol.

If a country-wide E5 mandate for RON92 gasoline had already been in place in 2016 (as per Prime Minister's Decision No. 53/2012/QD-TTg, dated 22 November 2012), total ethanol consumption in the country would have amounted to 370 000 m^3. The production of this amount of ethanol would have required about 2.04 million tonnes of fresh cassava equivalent. The cassava area addressed to ethanol production would have been equal to 108 640 hectares (assuming a yield of 18.8 tonnes/ha), or 19.1 percent of the total harvested area of this crop in the country.

The figures presented above seem to suggest that the increase in the harvested area of cassava that has been recorded in recent years (i.e. + 71 000 ha between 2007 and 2015) has not been driven primarily by the demand for ethanol. As a matter of fact, as explained in the next section, the expansion in the harvested area of cassava was much more significant during the years prior to the introduction of the first ethanol support policy in 2007, and in 2016 only 8 662 ha were used to cultivate cassava for ethanol production.

Cassava area as compared with national surface area and with agricultural land

a. Percentage of cassava area compared with national surface area

The cassava harvested area accounted for 1.49 percent and 1.71 percent of the total national surface (33 123 100 ha) in 2007 and in 2015, respectively (**Table 56**).

TABLE 56

PERCENTAGE OF CASSAVA AREA COMPARED WITH NATIONAL SURFACE

YEAR	CASSAVA HARVEST AREA (thousand ha)	SHARE OF NATIONAL SURFACE	ANNUAL CHANGE (percent)
2007	495.5	1.49	-
2008	554.0	1.67	12.10
2009	507.8	1.53	-8.38
2010	498.0	1.50	-1.96
2011	558.4	1.68	12.00
2012	551.9	1.67	-0.59
2013	543.9	1.64	-1.79
2014	552.8	1.67	1.82
2015	566.5	1.71	2.39

Source: GSO website

The total area of land for ethanol feedstock production in 2016 was estimated at 8 662 thousand hectares, equal to 0.026 percent of the total national surface. If the E5 mandate had already been in place in 2016, the production of cassava addressed to ethanol production would have required 108 640 hectares, accounting for 0.33 percent of the total national surface.

b. Percentage of cassava area compared with agricultural land

Agricultural land includes arable land, permanent crops, and permanent meadows and pastures (FAO, 2011). Cassava is considered as an annual crop, with only one season per year.

As shown in **Table 57**, the cassava harvested area accounted for the following shares of total agricultural land: 6.03 percent in 2007, 4.92 percent in 2010 and 4.91 percent in 2015. This is due to the fact that, in line with the figures presented above, between 2007 and 2015, the area under agricultural land increased at a faster rate than the area under cassava cultivation.

In 2016, the area used for ethanol feedstock production accounted for 0.075 percent of total agricultural land. If the E5 mandate had been in place in 2016, the share of agricultural land used for ethanol feedstock production would have been equal to 0.94 percent.

Evolution of cassava area in the different regions of Viet Nam

Table 58 shows how the harvested area of cassava changed in different regions of the country between 2000 and 2015.

TABLE 57

PERCENTAGE OF CASSAVA AREA COMPARED WITH AGRICULTURAL LAND

YEAR	CASSAVA HARVESTED AREA (thousand ha)	AGRICULTURAL LAND (thousand ha)	SHARE OF CASSAVA HARVESTED AREA OUT OF AGRICULTURAL LAND (percent)	ANNUAL CHANGE (percent)
2007	495.5	8 218.3	6.03	-
2008	554.0	9 420.3	5.88	-2.46
2009	507.8	9 598.8	5.29	-10.04
2010	498.0	10 118.1	4.92	-6.96
2011	558.4	10 126.1	5.51	12.04
2012	551.9	10 151.1	5.43	-1.41
2013	543.9	10 210.8	5.32	-2.03
2014	552.8	10 231.7	5.40	1.43
2015	566.5	11 530.2	4.91	-9.06

Source: GSO website

TABLE 58

EVOLUTION OF CASSAVA HARVESTED AREAS BY REGION, 2000-2015

	REGION	2000	2005	2007	2010	2014	2015
1	RRD	8.3	7.3	8.8	7.3	6.3	6.2
2	NMM	83.7	90.6	96.5	104.6	118.5	117.1
3	NCCC	75.5	112.7	151.2	155.5	170.1	171.2
4	CHL	38.0	89.0	129.9	133.2	152.2	155.6
5	SE	24.4	119.1	102.9	90.1	97.7	104.4
6	MRD	7.7	6.4	6.2	6.0	6.3	6.3

Unit: thousand ha

Source: adapted from GSO website & MARD website

Except for RRD and MRD, in the period from 2000 to 2007, the cassava harvested area sharply increased in most regions and especially in NCCC, where it doubled, CHL, where it tripled, and SE, were it almost quadrupled. From 2007 to 2015, the cassava harvested area continued to increase but at much slower rate, in all regions of Viet Nam, with the exception of RRD.
As of 2015, the largest cassava harvested areas were found in NCCC, with more than 171 000 ha, followed immediately by CHL with more than 155 000 ha and NMM with around 117 000 ha. SE was the fourth largest area of cassava production in 2015, with over 104 000 ha. However, in the two deltas of Viet Nam, RRD and MRD, the production of cassava was quite limited, and only 6 200 and 6 300 ha were planted in these areas, respectively.

Share of cassava areas out of total surface and total agricultural land in the different regions of Viet Nam

As shown in **Table 59**, SE and CHL were the regions with the highest share of surface dedicated to cassava cultivation, with 4.44 percent and 2.85 percent of the total, respectively. These regions, together with NCCC, also had the highest share of cassava harvested area out of total agricultural area. On the other hand, MRD and RRD had the lowest shares of total surface and agricultural area devoted to cassava cultivation.

TABLE 59

TOTAL SURFACE, AGRICULTURAL LAND AND CASSAVA HARVESTED AREA BY REGION, 2015

	REGION	TOTAL SURFACE (thousand ha)	AGRICULTURAL LAND (thousand ha)	CASSAVA HARVESTED AREA (thousand ha)	CASSAVA HARVESTED AREA AS COMPARED TO TOTAL SURFACE (percent)	CASSAVA HARVESTED AREA AS COMPARED TO AGRICULTURAL LAND (percent)
1	RRD	2 126.0	799.0	6.2	0.29	0.78
2	NMM	9 520.0	2 116.7	117.1	1.23	5.53
3	NCCC	9 564.9	2 205.5	171.2	1.79	7.76
4	CHL	5 450.8	2 420.6	155.6	2.85	6.43
5	SE	2 351.9	1 363.4	104.4	4.44	7.66
6	MRD	4 081.6	2 623.9	6.3	0.15	0.24

Source: adapted from GSO website and MARD website

Evolution of forest area in the different regions of Viet Nam

Different data sources were used for the scope, most notably MARD and GSO, which presented some slight differences between them due to inconsistent definitions of forest area and forestry land. MARD defines the former as the area that is considered as forested at the time of accounting, while forestry land (FL) is defined as the land allocated to forestry. Forestry land, as defined by the GSO, includes natural forest (often considered as protected areas), productive forest and new planted forest. New planted forest represents the area reforested in the year of accounting. Productive forests are defined as the forests that could be harvested at a convenient time. No data on productive forests were available at the time of this study.

The evolution of the forest area in the period 2007 - 2015 (**Table 60**) confirms the positive growing tendency of forest cover in Viet Nam. The increase in forest cover was most notable in NCCC, NMM, RRD and SE. However, between 2007 and 2015, the forest area decreased in MRD (-32.5 thousand ha) and in CHL (-275 thousand ha). In MRD, the decrease in forest area was not due to an increase in the cassava harvested area as this remained constant during the same time period. However, in the case of CHL, where the harvested area of cassava increased sharply in the same period (+25.7 thousand ha), it is reasonable to assume that forest was replaced by agricultural land, including cassava cultivation.

Similarly, for the period 2007–2015, the GSO reported a decrease of lands allocated to forest in MRD and in CHL, but also in the SE region that is reported as increasing by MARD (**Table 61**).

The GSO website and MARD website report net changes in forest cover. This may mask details where, for example, deforestation in one area is obscured by afforestation in a different area of the same region. Looking at net changes over time makes it difficult to determine where and why deforestation may be occurring. More detailed data on the conversion of forested land specifically to agricultural land can be found in Indicator 7.

TABLE 60

EVOLUTION OF FOREST AREA BY REGION, 2007-2015

	REGION	2007	2008	2009	2011	2012	2013	2014	2015
1	**RRD**	412.8	416.4	428.9	440.9	447.8	466.0	482.9	491.6
2	**NMM**	4 453.1	4 558.4	4 633.5	4 746.5	4 959.2	4 959.3	5 030.0	5 082.6
3	**NCCC**	4 423.8	4 497.4	4 592.0	4 796.7	4 864.6	4 931.4	4 969.5	5 179.8
4	**CHL**	2 836.9	2 993.2	2 925.2	2 848.0	2 903.8	2 847.7	2 567.1	2 562.0
5	**SE**	406.3	419.9	402.8	423.0	471.6	466.9	476.2	473.9
6	**MRD**	304.5	298.5	276.3	260.0	249.1	282.1	270.8	272.0
	WHOLE COUNTRY	**12 837.3**	**13 118.8**	**13 258.7**	**13 515.1**	**13 862**	**13 954**	**13 796**	**14 061.9**
	COVERAGE (PERCENT)	38.7	38.7	39.1	39.6	41.9	42.1	41.7	42.45

Unit: thousand ha
Source: MARD website

TABLE 61

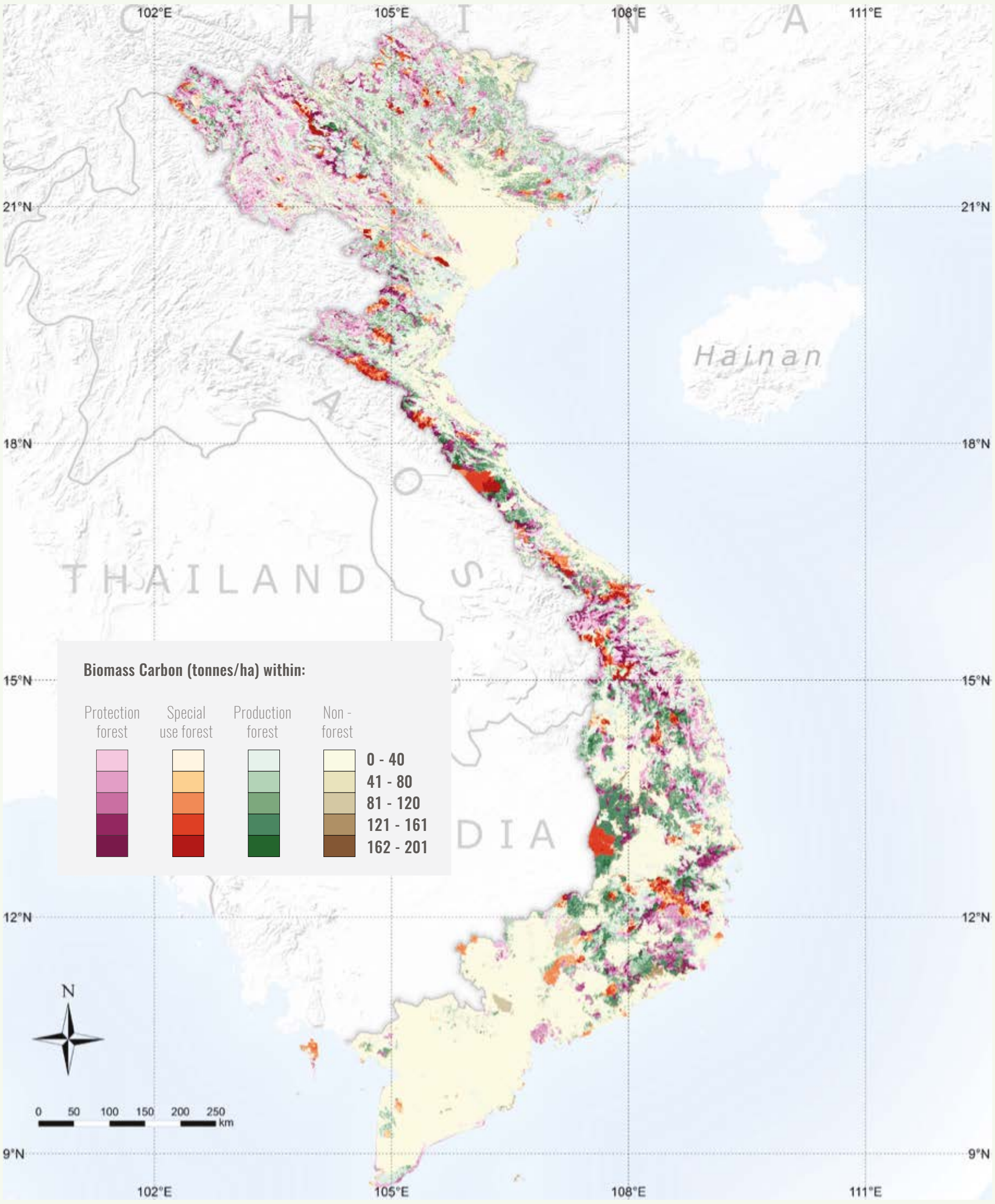
EVOLUTION OF FORESTRY LAND BY REGION, 2007-2015

	REGION	2007	2010/11	2012	2013	2014/15
1	RRD	445.4	519.4	518.4	N/A*	519.8
2	NMM	5 173.7	5 662.7	5 708.0	N/A	6 098.5
3	NCCC	5 069.7	5 496.7	5 500.3	N/A	5 602.3
4	CHL	3 122.5	2 864.1	2 830.3	N/A	2 811.3
5	SE	668.4	512.8	511.4	N/A	511.2
6	MRD	336.8	310.8	304.7	N/A	302.1
	WHOLE COUNTRY	**14 816.6**	**15 366.5**	**15 373.1**	**15 405.8**	**15 845.2**

Unit: thousand ha
Source: GSO website
* Data for this year was not available.

FIGURE 38

TYPES OF FOREST MANAGEMENT



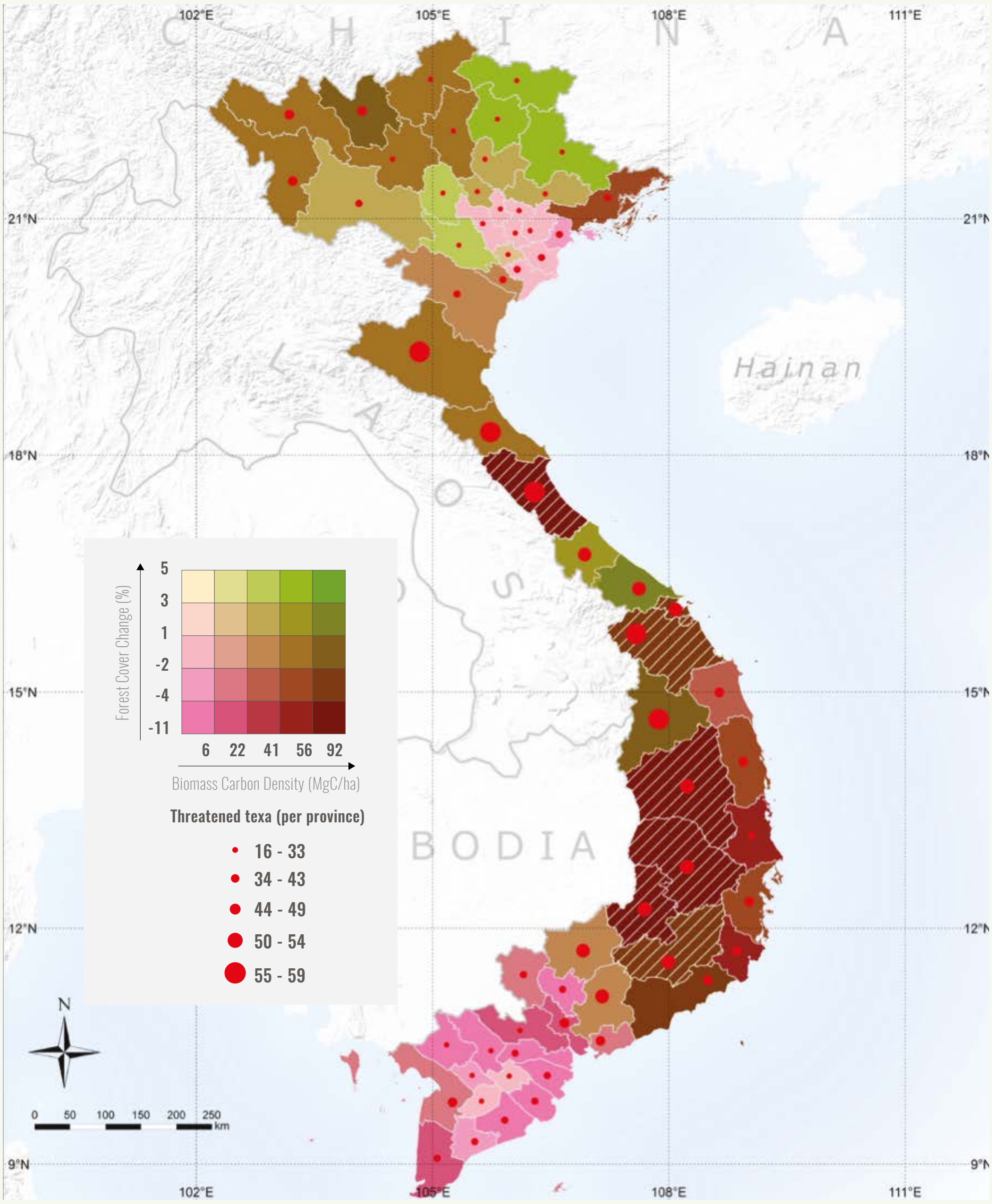
Source: Mant, et al, 2013

Figure 38 shows forest biomass carbon density as distributed over three types of management categories regulated by the State in Viet Nam: production, protection and special-use.

Figure 39 attempts to visualize four attributes – carbon, loss of carbon, biodiversity and conservation value. Areas of past deforestation can be an indicator of where future deforestation may occur, forest carbon biomass can indicate likely emissions from deforestation and the number of threatened species is an indicator of the biodiversity conservation value of an area.

FIGURE 39

FOREST BIOMASS CARBON, FOREST COVER CHANGE AND THREATENED SPECIES RICHNESS



Source: *Mant, et al, 2013*

4.8.3 Main conclusions and recommendations

Approach used

For the implementation of indicator 8 in Viet Nam, data was retrieved from both national statistics, specifically from the GSO (GSO website), and from ministerial statistics, such as those of MARD (MARD website). Additionally, primary data were collected through surveys conducted in April 2017 in Phu Tho and Tay Ninh provinces (IAE, 2017). Data from FAOSTAT and from peer-reviewed papers and theses were consulted for discussion and reflection.

Results

Between 2007 and 2015, cassava production increased from 8.2 to 10.7 million tonnes, thanks to an expansion in the harvested area and to a yield increase, both in the order of around 14 percent. The ethanol demand does not appear to have been a key driver of this increase. As a matter of fact, both the expansion in the harvested area of cassava and the yield increase were much more significant during the years prior to the introduction of the first ethanol support policy in 2007, and in 2016 only 8 662 ha (or 0.0751 percent of the total agricultural land) were used to cultivate cassava for ethanol production. In case an E5 mandate had already been in place in 2016, 108 638 ha (or 0.9422 percent of the total agricultural land) would have been used for ethanol feedstock production.

Results from the surveys carried out within this study and from the analysis of secondary data do not reveal the use of cassava residues and/or by-products in Viet Nam for ethanol production; neither official data on the cultivation of cassava in degraded/contaminated land were available (Sub-Indicator 8.3). In some regions, cassava is planted on previously unused lands, such as marginal land of coastal areas or in mountainous areas.

Regarding Sub-Indicator 8.4, the total forest area increased in the period 2007 – 2015, especially in NCCC, NMM, RRD and SE. However, a decrease in forest area was reported in MRD (-32.5 thousand ha) and in CHL (-275 thousand ha). In this latter region, the harvested area of cassava increased sharply in the same period (+25.7 thousand ha), suggesting that at least part of this cassava might have happened at the expense of forest.

Practices and policies to improve sustainability

To minimize direct and indirect impacts of cassava cultivation for ethanol production, policies and incentives should be issued to promote a more efficient land use. Higher production efficiency could be achieved by: promoting the adoption of new and improved crop varieties; sustaining productivity (e.g. through the use of higher nutrient inputs and irrigation); and adopting more sustainable agricultural practices (e.g. crop rotation, intercropping). However, land use should be intensified in a sustainable way by ensuring the absence of negative environmental consequences in terms of soil and water quality parameters (e.g. yield improvement should not lead to water scarcity downstream), including through the adoption of the aforementioned good practices. The environmental, agricultural and genetics research centres and institutes can play a key role in enhancing land use efficiency. For this reason, local government should support related research and the continuous monitoring, in the long term, of the impacts of biofuel feedstock production systems on land use.

Future monitoring

Following the recent adoption of a country-wide E5 mandate for RON92 gasoline (as per Directive No 11/CT-BCT, promulgated by MOIT on 22 September 2017), the need to carefully monitor land use changes for the sustainability of bioenergy will also grow. To understand the detailed effects of bioenergy policies on land use change, it will be important in the future to collect regional-level data. Particular

TABLE 62

SUMMARY OF RESULTS FOR SUB-INDICATORS 8.1 AND 8.2

PARAMETER	BASED ON ETHANOL CONSUMPTION IN 2016	BASED ON A HYPOTHETICAL E5 MANDATE IN 2016
(8.1A) TOTAL AREA OF LAND FOR BIOENERGY FEEDSTOCK PRODUCTION (HA)	8 662	108 638
(8.1B) TOTAL AREA OF LAND FOR BIOENERGY FEEDSTOCK PRODUCTION AS COMPARED TO TOTAL NATIONAL SURFACE	0.0262 PERCENT	0.3280 PERCENT
(8.2A) TOTAL AREA OF LAND FOR BIOENERGY FEEDSTOCK PRODUCTION, AS COMPARED TO AGRICULTURAL LAND	0.0751 PERCENT	0.9422 PERCENT

attention should be paid to regions such as SE and especially CHL, where deforestation during the 2007-2015 period was accompanied by an expansion in the harvested area of cassava. The possible causal relationship between these two processes should be further assessed and analysed.

REFERENCE

FAO. 2011. The Global Bioenergy Partnership Sustainability Indicators for Bioenergy. First Edition. ISBN 978-92-5-107249-3. Available at: www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/Indicators/The_GBEP_Sustainability_Indicators_for_Bioenergy_FINAL.pdf

GSO website. Statistical data: Agriculture, Forestry and Fishery. Available at: www.gso.gov.vn/default_en.aspx?tabid=778 [Accessed: Apr 2017]

Hi, N.H. 2016. Vietnam cassava, status and development (translated from Vietnamese). Available at: www.vaas.org.vn/cay-san-viet-nam-hien-trang-va-phat-trien-a15438.html

Hoang, K.D. 2015. Study on growth, development and main technical method for new cassava varieties in some provinces of the Northern Mountain Viet Nam. PhD Thesis in Agriculture. Thai Nguyen University. 2015.

Institute of Agricultural Environment (IAE). 2017. Survey conducted within this study on April 2017 for the collection of primary data from local farmers. The survey was conducted in the provinces of Phu Tho and Tay Ninh.

JRC. 2010. Indirect Land Use Change from increased biofuels demand: Comparison of models and results for marginal biofuels production from different feedstocks. European Commission Joint Research Centre. Ispra.

Mant, R., Swan. S., Anh, H.V., Phương, V.T., Thành, L.V., Sơn, V.T., Bertzky, M., Ravilious, C., Thorley, J., Trumper, K. and Miles, L. 2013. Mapping the potential for REDD + to deliver biodiversity conservation in Vietnam: Preliminary analysis. Developed by UNEP-WCMC, Cambridge, UK; and SNV, Ho Chi Minh City, Vietnam.

Ministry of Agriculture and rural development (**MARD**). website. Data bases on land uses and crop production, 2006-2015. Available at: www.mard.gov.vn/Pages/statistic

MARD, 2017. Restructure of forestry sectors.

Ministry of Industry and Trade (MOIT). 2017. FAO Regional workshop Nov.16-17 "Sustainable Bioenergy Production and Use in Southeast Asia: Lessons Learnt and Future Opportunities, The orientation in the production and use of biofuels in Vietnam, Dr. Do Xuan Dong, Department of Science and Technology. Available at: www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/AG2/Viet_Nam_project/Final_Mettings/Dong_Do-Xuan.pdf

Viet Nam Finance. 2017. Viet Nam Export Import Report 2016 (translated from Vietnamese). Available at: http://vietnamfinance.vn/upload/news/hoanghung_btv/2017/3/29/BC%20XNK%202016.pdf [Accessed: 8 Jan 2018].

4.9 INDICATOR 9: ALLOCATION AND TENURE OF LAND FOR NEW BIOENERGY PRODUCTION

Pham Thi Thanh Thuy
The Asian Institute of Technology Center in Vietnam (AITCV)

DESCRIPTION:

Percentage of land – total and by land-use type – used for new bioenergy production where:
(9.1) a legal instrument or domestic authority establishes title and procedures for change of title; and
(9.2) the current domestic legal system and/or socially accepted practices provide due process and the established procedures are followed for determining legal title.

MEASUREMENT UNIT(S):

Percentages

4.9.1 Implementation of Indicator 9 in Viet Nam

A quantitative measurement of the indicator was not possible due to lack of data. However, an in-depth review of the relevant literature was carried out and a summary of it was. In particular, a comprehensive overview and analysis of the regulatory framework related to land tenure is provided below, together with a description of the main patterns related to land ownership and use for the areas under cassava cultivation.

In addition to secondary data, primary data were collected as well. In particular, a survey with cassava-growing households (63 in total) and cassava starch processing plants (due to the unavailability of ethanol plants) was carried out in two cassava-producing provinces: Phu Tho, in the Northern Midlands and Mountains, and Tay Ninh, in the South East region. The survey focused on the types, structure and tenure of land used by cassava-growing households and starch producing enterprises. It also investigated the public consultation on the land master plan, plan for land use and land dispute resolution mechanism as well as preferential policies for ethnic minorities and vulnerable groups. The survey was done with support from the Agricultural Extension Center (AEC) of the two provinces. Invitation letters were sent to cassava households in those communes where there are many starch producing plants and a large area of cassava cultivated areas. Cassava farmers were instructed on how to answer the questions in the survey and were supported by the field research experts. Interviews were also carried out with the managers of selected cassava processing plants. In addition to this, the research team arranged some interviews with land officials of communal land management divisions, but very little information was collected. This is because land officials were typically unavailable or were not open to share land information, especially sensitive information such as land disputes, land compensation and resettlement plans. Therefore, the only information obtained was related to land planning and land use plans of the communes.

4.9.2 Key findings

Land law in Viet Nam: a history

The land administration process is promulgated in the legal documents of Viet Nam, which can be divided into the following stages (detailed in **Table 63**):

- From 1945 to 1987: Land Law is designed
- From 1988 to 1993: Land Law 1987
- From 1993 to 2003: Land Law 1993
- From 2004 to 2013: Land Law 2003
- From 2014 to present: Land Law 2013

TABLE 63

DETAILS OF LAND REFORM IN VIET NAM, 1954-2013

DATE	REFORM	DETAILS
1954-1956	LAND REFORM	72 PERCENT OF THE FARMER HOUSEHOLDS IN NORTHERN VIET NAM WERE ALLOCATED LAND WITH A TOTAL AREA OF 810 000 HECTARES POLICIES ON PROMOTION OF AGRICULTURAL PRODUCTION
31 DECEMBER 1959	1959 CONSTITUTION	DEFINITION OF LAND OWNERSHIP INTO FOUR TYPES: STATE OWNERSHIP, COLLECTIVE OWNERSHIP, OWNERSHIP BY PRIVATE WORKERS AND OWNERSHIP BY NATIONAL CAPITALISTS (ARTICLE 1L)
1 JULY 1980	DECISION NO. 201/CP	FIRST LEGAL DOCUMENT DETAILING THE LAND ADMINISTRATION
18 DECEMBER 1980	ADOPTION OF 1980 CONSTITUTION	INTEGRATION OF TYPES OF LAND OWNERSHIP INTO OWNERSHIP BY ENTIRE POPULATION WITH UNIFORM MANAGEMENT BY THE STATE
29 DECEMBER 1987	LAND LAW 1987	DEFINES THE FUNCTIONS OF THE STATE WITH RELATION TO MANAGEMENT OF LAND, INCLUDING LAND PLANNING, REGISTRATION OF LAND AND SETTLEMENT OF LAND DISPUTES
14 JULY 1993	LAND LAW 1993	OVERCAME MANY OF THE SHORTCOMINGS OF THE LAND LAW OF 1987 (E.G. DIFFICULTY IN TAX CALCULATION, UNCLEAR LEGAL BASIS AND FINANCIAL POLICY) AND DEALT WITH IMPORTANT ISSUES IN MANAGEMENT AND USE OF LAND (NGUYỄN ĐỨC KHẢ, 2003)
2003 - 2013	LAND LAW 2003 AND REVISED LAND LAW 2013	FURTHER ENHANCED LAND USERS RIGHTS AND LAID OUT A COMPREHENSIVE LEGAL FRAMEWORK FOR DEVELOPING A MODERN LAND ADMINISTRATION AND MANAGEMENT SYSTEM IN THE COUNTRY

The New Land Law (2013)

The latest Land Law of Viet Nam was ratified by the country's National Assembly on 29 November 2013, and came into force on 1 July 2014 (the 2013 Land Law). Overall, the new Land Law introduces clearer terminologies[8] and concepts, which make the application of the New Land Law less confusing than that of the 2003 Land Law. This New Land Law also includes detailed regulations on land compensation and clearance, as well as a clearer procedure for issuance of certificates for land use right and ownership of assets on land. In addition, this New Land Law allows, for the first time, foreign invested enterprises (FIEs) to be treated equally to the domestic enterprises. It contains new provisions[9] related to the rights of foreign organizations and individuals, overseas Vietnamese and FIEs using land in Viet Nam.

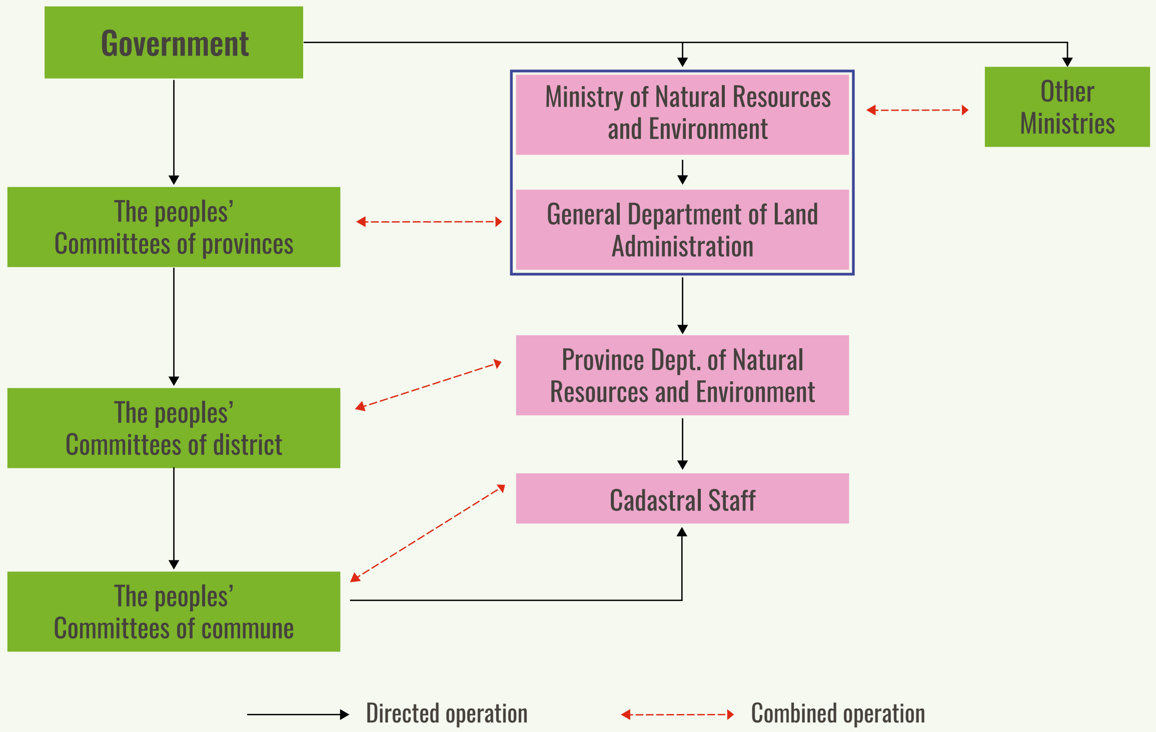
Land rights in Viet Nam are divided into three categories: land ownership, land management, and land use rights. According to Vietnam Constitution and the Land Law 2013, land is the property of the entire population, which is allocated or leased by the State to organizations, households or individuals for long-term or limited-term use. Depending on their status, land users are granted the rights of land to exchange, transfer, lease, sublease, inherit,

[8] The clearer terminologies are introduced in the New Land Law include the following:
- Definition of a Foreign invested enterprise (FIE)
- Clarification of requirements for foreign investor(s) in a domestic enterprise to be considered as a FIE
- Introduction of the term 'allocation of LUR' (meaning 'allocation of land') and 'lease of LUR' (meaning 'lease of land')

[9] These new provisions include the followings:
- Equal Footing for Domestic and Foreign Investors: The 2014 Land Law removes all of the differences between local and foreign investors in the regard to the land lease or land allocation. According to the 2014 Land Law, either local investors or foreign investors may lease land from the government and pay rent on an annual basis or as a lump-sum payment. Both may also acquire land via land allocation. However, land allocation is now only available for residential land.
- More Conditions for Land Acquisition: The 2014 Land Law sets out new harsh requirements for developers (both local and foreign), who want to lease or obtain land allocation from the government such as the lease (or allocation) of the land must have been provided for in the annual land use plan issued by the district-level People's Committee; the developers must meet a minimum level of statutory equity capital; and The developers must pay deposits to the government to ensure that they will pay the land rent (or land use fees) and develop the projects in a timely manner.
- New Land Price Determination Method: The 2014 Land Law requires the land price to be determined on a case-by-case basis by the provincial People's Committee. The government may hire land valuation firms to determine and advise on the land price.
- More Restrictions on Land Withdrawal: Under the 2014 Land Law, land withdrawal for a commercial or residential project must satisfy two conditions: (i) it may only be for significant projects; and (ii) it must have prior approval for land withdrawal from the provincial People's Council.

FIGURE 40

LAND MANAGEMENT HIERARCHY IN VIET NAM



Source: Nang, 2015

donate and mortgage land use rights, and contribute capital in form of land use rights. Because the state owns and controls the land, it alone assigns the purpose - agricultural, forestry, or residential - to a plot of land and decides who has the right to use the land and for how long[10].

The National Assembly, the People Councils and the Government and the People Committees at all levels are involved to exercise the rights of the land owner representative. In particular, the National Assembly promulgates laws and resolutions on land, decides on national master plans and plans on land use, and exercises the supreme right to supervise over land management and use nationwide. The People's Councils at all levels exercise the right to adopt local master plans and plans on land use before submitting them to competent agencies for approval, adopt land price tables and land recovery to implement socio-economic development projects for the national or public interest in their localities, and supervise the implementation of the land law in their localities. The Government and People's Committees at all levels exercise the rights of the land owner representative according to their competence prescribed in

[10] The rights of the state or the representative of the land owner include:
1. To decide on master plans, plans on land use;
2. To decide on land use purposes;
3. To prescribe land use quotas and land use terms; and
4. To decide on land recovery and land requisition.
5. To decide on land prices.
6. To decide on hand-over of land use rights to land users.
7. To decide on financial policies on land.
8. To prescribe the rights and obligations of land users

this Law. The Government performs the unified state management over land nationwide, with responsibility given to the MONRE. Related ministries and ministerial-level agencies, within the scope of their respective tasks and powers, assist the Government in performing the state management over land. People's Committees at all levels shall perform the state management over land in their localities according to their competence prescribed in this Law. The land management hierarchy is presented in the **Figure 40**.

Land registration procedure

Land registration is regarded as one of the State's administrative activities and is compulsory for land users. Registration of houses and ownership of assets on land is carried out at the request of the owner and at the Land Registration Offices (LRO) at different levels. At the central level, the Department of Land Registration (DLR) is the state function unit (under GDLA-General Department of Land Administration) and focuses on building Land Right policies and manages all embryos of Land Use Right (LUR) certificates.

TABLE 64

LAND USE RIGHT CERTIFICATES FOR MAIN TYPES OF LAND AS OF SEPTEMBER 2011

ECOLOGICAL REGIONS	AGRICULTURAL PRODUCTION LAND			FOREST LAND			RURAL RESIDENTIAL LANDA			URBAN RESIDENTIAL LAND			SPECIALIZED LAND		
	No OF CERTIFI-CATES	AREA	% OF AREA	No OF CERTIFI-CATES	AREA	% OF AREA	No OF CERTIFI-CATES	AREA	% OF AREA	No OF CERTIFI-CATES	AREA	% OF AREA	No OF CERTIF-ICATES	AREA	% OF AREA
WHOLE COUNTRY	16 173 096	8 316 529	85.1	2 629 232	10 371 482	86.3	11 671 553	435 697	79.3	3 685 259	83 109	63.5	149 845	466 552	60.5
NORTHERN MIDLANDS AND MOUNTAINS	2 186 396	1 079 077	66.4	1 068 558	4 312 110	79.3	1 997 909	98 591	90.7	525 546	11 709	67.7	29 241	80 928	49.7
RED RIVER DELTA	3 776 284	769 313	92.3	10 912	25 923	23	2 952 270	87 280	82.5	751 014	12 487	56.2	22 386	52 760	49.9
NORTH CENTRAL	2 138 193	684 864	80.3	267 552	1 829 507	75.9	1 834 186	73 165	75.9	320 831	10 302	85.9	16 399	38 670	69.7
SOUTH CENTRAL	1 649 099	743 624	74.7	323 433	1 207 999	82.1	1 118 752	40 438	74.7	458 953	10 910	65.5	16 485	127 454	73.7
CENTRAL HIGHLANDS	1 182 574	1 220 672	62.4	810 323	2 066 411	71.6	642 834	23 268	58.9	232 304	7 187	55.8	6 719	28 961	54.7
SOUTHEAST	1 283 987	1 273 728	87.8	153 898	720 056	87.3	880 108	27 654	61.2	863 678	15 790	53.9	24 066	84 335	67.5
MEKONG RIVER DELTA	3 956 563	2 545 251	95.9	53 992	303 476	82.3	2 245 494	85 571	85.7	532 934	16 100	70.01	34 549	53 445	55.2

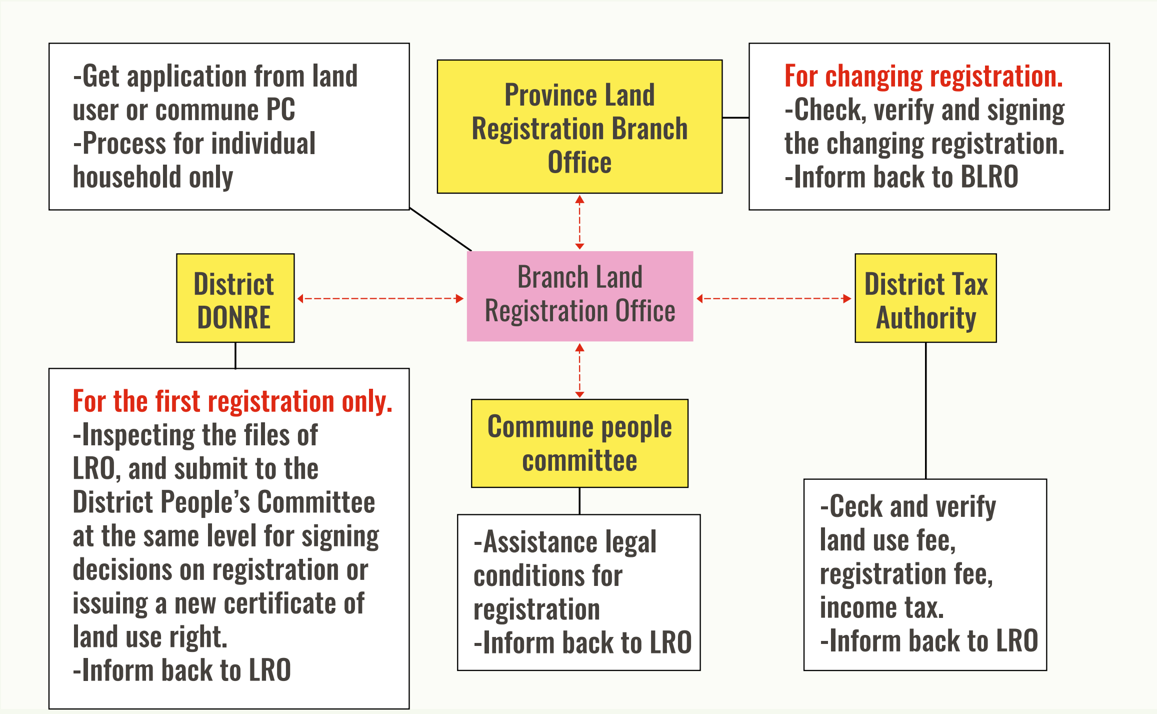
Source: General Department of Land Administration, no date

At the local level, each province has an LRO and its branch at districts in that province. Some main functions of the LROs are:

- To register and changing register of LUR certificate.
- Renew, re-issue the LUR certificate.
- Prepare, revise, update, store, and manage cadastral records, construction and management the land information system.
- Land inventory and making land use map; revision of cadastral maps; cadastral map extraction.
- Provide records, maps, land information, houses and other assets attached to land to organizations and individuals in accordance with this law

FIGURE 41

THE INSTITUTIONAL ARRANGEMENT AND ORGANIZATION FOR LAND REGISTRATION OR LAND CHANGE REGISTRATION



Source: Nang, 2015

The new adopted Land Law 2013 increased transparency in land use and management and facilitated the development of a property market, by setting out provisions on land use rights in the market for immovable property, land pricing and financial issues related to land. Normally, the land where the farmers cultivate on is stably used but not allocated or leased by the State. In this case, the State grants land use right to the farmers through the issuance of a certificate of land use right and ownership of houses and other land-attached assets for a certain land parcel. There are also rare cases where the farmers lease agricultural land from other farmers, cooperatives or from communes in the case of public land. Since the implementation of the New Land Law, the price of land has been rising in tandem with economic growth. The Vietnamese government is intent on investing five to ten percent of land revenue to build a modern Land Administration System (LAS), with support and assistance from developed countries and international organizations. This LAS can offer many benefits. A Land Tenure Certificate (LTC) is issued to current land users, protecting their rights, interests and obligations guaranteed by the state. In addition, the LAS offers the state a management tool for developing land-use strategies and planning that ensure sustainable development during the current fast-moving industrialization and modernization process. More importantly, matching LAS to market mechanisms makes land administration effectively self-propelling. A good LAS also provides a basis for settling land disputes and complaints, and uncovering and preventing violations of land by users and land officers. The core of the new LAS consists of digital cadastral maps that describe land parcels, as well as 'open bordered' land areas such as roads, drainage facilities and channels. Land statistics and inventories and the making of land use status quo maps are conducted periodically. In particular, land statistics are made once a year, except the year when a land inventory is conducted and a land use status quo map is drawn up (once every five years). Reports on annual land statistics and every five year land inventory can be downloaded from the website of the State General Statistics Office.

In order to facilitate an effective implementation of the new Land Law 2013, a number of other legal documents were issued, which include the following:

- Decree 43/2014/ND-CP, detailing a number of articles of the Land Law 2013;
- Circular No. 36/2014/TT-BTNMT dated 30 June, 2014, on land pricing method, compilation of and adjustment of land price lists, and determination of specific land prices and consultancy on land pricing;
- Circular No. 23/2014/TT-BTNMT dated 19 May 2014, providing certificates of land use right, house ownership and other properties associated with the land;
- Circular No. 24/2014/TT-BTNMT dated 19 May 2014, defining cadastral dossiers;
- Circular 02/2015/TT-BTNMT, detailing Decree No. 43/2014/ND-CP and Decree No. 44/2014/ND-CP,02/2015/TT-BTNMT; and
- Decree 01/2017/ND-CP decree amendments on the implementation Land Law.

One of these programmes was reviewed as part of the Indicator assessment – Programme 135 (National Targeted Programme for Sustainable Poverty Reduction and Socio-Economic Development Programme for the Most Vulnerable Communes in Ethnic Minority and Mountainous Areas). The rationale for establishing Programme 135 was to help people in ethnic minority and mountainous areas overcome poverty, narrow the income gap with other communes in other districts and provinces and eliminate risks for social instability. Programme 135 was designed to address the different causes of poverty particular to ethnic minorities such as: low capacity; small landholdings; lack of knowledge, skills and market information; health problems; large family size; unemployment; and vulnerability to risks (including social problems). Programme 135 mentions supporting the poor, especially poor ethnic minorities, to develop agricultural, forestry, aqua-cultural and salt production through training, technical/seedling transfer, production tools and equipment and pesticides.

In terms of land use, it is suggested that the poor, especially ethnic poor people, are supported to create production land through land reclamation and expansion of paddy fields. However, there has not been any detailed guidelines on how to implement these programmes.

LAND PRICE FRAMES

Article 113 in the New Land Law 2013 states that "the Government stipulates land price frames once every five years for each type of land, for each region. During the implementation of land price frames, if the popular price in the market increases by 20 percent or more over the maximum price or reduces by 20 percent or more over the minimum price stipulated in land price frames, the Government adjusts land price frames accordingly."

LAND PRICE TABLES

Based on the principles, methods of land valuation and land price frames, the province-level People's Committee develops and submits the land price tables to the People's Council of the same level for review before promulgation. Land price tables are developed once every five years and publicized on 1 January of the first year of the period.

During the implementation of land price tables, when the Government adjusts land price frames or there are changes in popular land price in the market, the province-level People's Committees adjusts land price tables accordingly.

Land price tables are used as basis for:

- Determination of land use fees either when the State recognizes land use rights of households or individuals for land area within land use norm or when the State approves a change of land use purpose;
- Determination of land use taxes;
- Determination of charges and fees in land management or use;
- Determination of penalties for administrative violations in the land sector;
- Determination of indemnification paid to the State for the damage caused in land use and management; and
- Determination of the value of land use rights paid to the people who return land to the State voluntarily.

SPECIFIC LAND PRICES

The province-level People's Committee determines specific land prices. The province-level land administration agency is responsible for assisting the province-level People's Committee in the determination of specific land prices. During the implementation, the province-level land administration agency is entitled to hire organizations having consultancy functions for advising on the determination of specific land prices.

Specific land prices are used as basis for the following cases:

- Determination of land use fees either when the State recognizes land use rights of households or individuals for land area within land use norm or when the State approves a change of land use purpose;
- Determination of land rental for agricultural land area in excess of land allocation norms;
- Determination of land use fee when the State allocates land with land use fees not through auction of land use rights, recognizes land use right or approves change of land use purpose for organizations which must pay a land use fee;
- Determination of land rental when the State leases land not through auction of land use right;
- Determination of the value of land use right upon equitization of State enterprises which are allocated land with land use fee, leased land with one-off rental payment;
- Determination of land rental in case the equitized State enterprises are leased land by the State with annual rental payment; and
- Determination of compensation amount upon land recovery by the State.

Household use of agricultural production land

AGRICULTURAL PRODUCTION LAND BY HOUSEHOLD

The 2011 Rural Agriculture and Fishery Census (GSO, 2011) classified households by size of agricultural production land into four groups: households having under 0.2 hectares of agricultural production land; households having from 0.2 to 0.5 ha; households having from 0.5 to 2 hectares; and households having 2 hectares and over. According to the 2011 Rural, Agricultural and Fishery Census (GSO, 2011), the whole country has 11.95 million households using agricultural production land, an increase of 295 thousand households (+2.5 percent) in comparison with the year 2006. In general, land scale of households has hardly changed in comparison with the year 2006 and the changes are normally minor. In 2011, 69 percent of households were still using agricultural production land under 0.5 ha (68.8 percent in 2006); 34.7 percent households had under 0.2 ha; and 25 percent of households used between 0.5 and 2 ha of land. However, by the year 2011, nearly 740 thousand households (accounting for 6.2 percent) had a scale of agricultural production land of two hectares or more, an increase of 55 thousand households from 2006 (+8.1 percent).

Table 65 shows that the average total agricultural production land area of a household in Phu Tho is smaller than the one of a household in Tay Ninh. 57.7 percent of households in Tay Ninh have more than 0.5 hectares while in Phu Tho it is only 10.91 percent of households.

ANNUAL CROP LAND BY HOUSEHOLD

In 2011, there were nearly 10.36 million households using land for annual crops, each household used on average of 0.62 ha. Households using land under 0.2 ha for annual crops accounted for nearly 40 percent and 88.3 percent of total households used under 1 ha of land for annual crops. Between 2006 and 2011, there was an increase in the proportion of households with larger land area for annual crops: those with 1 to 2 ha accounted for 7.7 percent in 2011 (an increase of 1.16 percent on 2006); and the households with over 2 ha accounted for 4.07 percent (an increase of 0.08 percent compared to the year 2006). Specific data for Phu Tho and Tay Ninh province on the structure of households divided by size of annual crop land used and size of paddy land used are shown in **Table 66** and **Table 67**.
According to the data on the results of the issuance of land use right certificates announced by the General Department of Land Administration, 84.3 percent of the agricultural production land of Phu Tho has been granted with the land use right certificates while this number for Tay Ninh is 96.8 percent.

TABLE 65

HOUSEHOLDS BY SIZE OF AGRICULTURAL PRODUCTION LAND (PERCENT)

PROVINCE	TOTAL (HOUSEHOLD)	HOUSEHOLDS BY SIZE OF AGRICULTURAL PRODUCTION LAND (PERCENT)			
		UNDER 0.2 ha	FROM 0.2 TO 0.5 ha	FROM 0.5 TO 2 ha	2 ha AND OVER
PHU THO	270 908	46.87	42.22	10.51	0.40
TAY NINH	123 864	21.92	20.38	41.88	15.82

Source: GSO, 2011

TABLE 66

HOUSEHOLDS BY SIZE OF ANNUAL CROP LAND IN PHU THO AND TAY NINH

PROVINCE	TOTAL (HOUSEHOLD)	HOUSEHOLDS BY SIZE OF ANNUAL CROP LAND (PERCENT)			
		UNDER 0.2 ha	FROM 0.2 TO 0.5 ha	FROM 0.5 TO 2 ha	2 ha AND OVER
PHU THO	258 936	62.03	34.37	3.34	0.26
TAY NINH	83 773	11.08	24.85	50.41	13.66

Source: GSO, 2011

TABLE 67

HOUSEHOLDS BY SIZE OF PADDY LAND IN PHU THO AND TAY NINH

PROVINCE	TOTAL (HOUSEHOLD)	HOUSEHOLDS BY SIZE OF PADDY LAND (PERCENT)			
		UNDER 0.2 ha	FROM 0.2 TO 0.5 ha	FROM 0.5 TO 2 ha	2 ha AND OVER
PHU THO	241 976	76.53	22.79	0.67	0.01
TAY NINH	52 655	4.11	28.99	57.41	9.49

Source: GSO, 2011

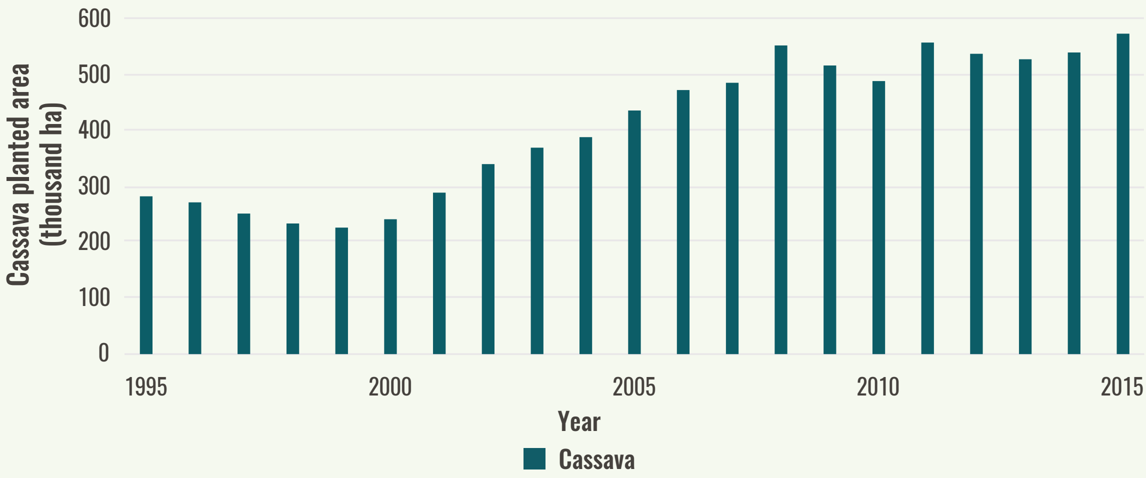
The literature does not provide any information or data on the issues related to the land used for cassava production such as tenure of cassava planted land, priority policies on land for ethnic groups, distribution of the information on the land planning and plan on land use to the communal people, or the grievance redress mechanism for land disputes.

CASSAVA CULTIVATION

Cassava planted area slightly decreased between 1995 and 2000, from 280 000 ha in 1995 to 220 000 ha in 2000; then it sharply increase from 2000 to 2008, with a peak of 554 000 ha, and remained stable around that value until 2015 (see **Figure 42**). The cassava planted area in Viet Nam, especially in the Central Highlands provinces in recent years sharply increased because of the increase in cassava price. Meanwhile, cassava is a plant species with low investment, which is easy to grow, adaptable to many different types of land and especially tolerant to drought. This meant that people planted cassava without following the local land use plan of the local authorities. Anecdotal evidence suggests that even in the remote mountainous areas of Dak Lak, Gia Lai and Kon Tum provinces, forests have been cleared for cassava planting. It is observed that the cassava planted area has decreased concurrently with decreasing cassava prices. However, no studies or literature on the correlation between

FIGURE 42

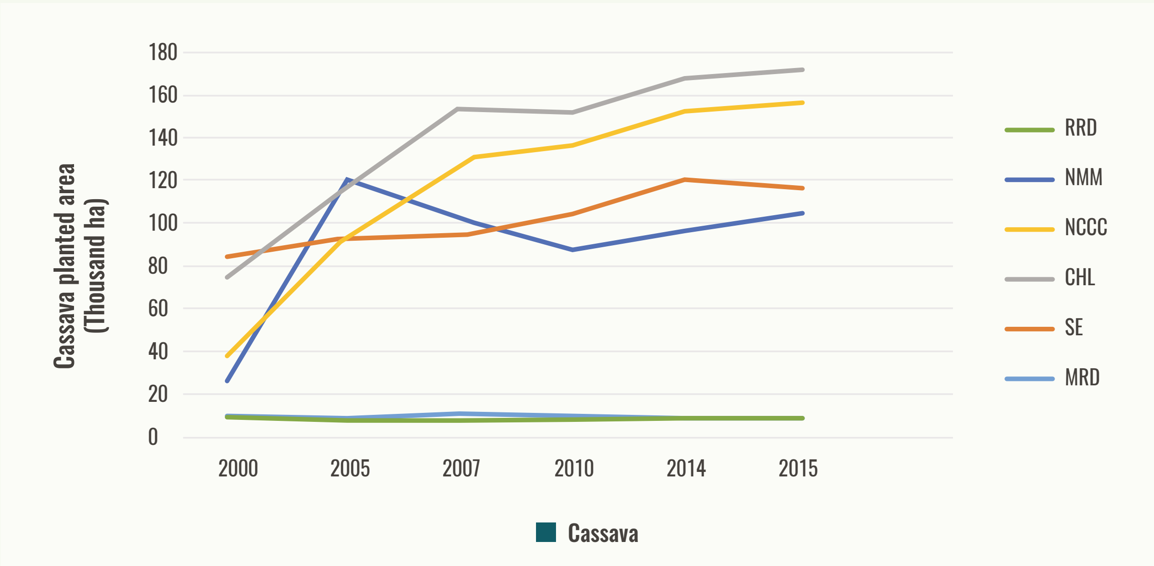
ANNUAL CASSAVA PLANTED AREA IN VIET NAM (THOUSAND HECTARES)



Source: GSO website

FIGURE 43

CASSAVA PLANTED AREA IN SEVEN ECO-AGRICULTURAL REGIONS (THOUSAND HECTARES)



Source: GSO website

the cassava price and the cassava planted area have been found.

Cassava is widely cultivated in most of the agro-ecological regions. As shown in **Figure 43**, in 2015, the regions of SE, NMM, NCCC and CHL all had over 100 thousand hectares of cassava planted area. These figures represent a sharp expansion from 2000 onwards. RRD and MRD regions have lower planted cassava area that remained relatively during the period 2000-2015. This is because these fertile regions are used for planting higher value crops.

FIELD SURVEYS IN PHU THO AND TAY NINH PROVINCES

According to the 2011 Rural, Agricultural and Fishery Census (GSO, 2011), shown in **Table 68**, the total area of agricultural production land of Phu Tho province is 282 160 hectares, of which 57 090 hectares is used for annual crop land (about 20 percent); 41 670 hectares for perennial crop land (15 percent), 178 340 hectares for forest land (63 percent) and 4 990 hectares for aquaculture land (1.8 percent).

For Tay Ninh province, this structure is a slightly different: 145 090 hectares is used for annual crop land (42 percent); 122 890 hectares (36 percent) for perennial crop land, 71 960 hectares for forest land (21 percent) and 1 630 hectares for aquaculture land (0.05 percent).

TABLE 68

AGRICULTURAL LAND BY PROVINCE, 2011

PROVINCE	TOTAL	ANNUAL CROP LAND		PERENNIAL CROP LAND	FOREST LAND	LAND FOR AQUACULTURE
		TOTAL	OF WHICH: PADDY LAND			
PHU THO	282.16	57.09	45.53	41.67	178.34	4.99
TAY NINH	342.54	145.09	83.50	122.89	71.96	1.63

Unit: 1000 ha

Source: The Rural Agriculture and Fishery Census (RAFC) (GSO, 2011)

In 2015, there were 8 300 ha under cassava cultivation in Phu Tho and 57 600 ha in Tay Ninh (GSO website). The results of the survey conducted in Phu Tho and Tay Ninh provinces presented in **Table 69** show the types of land used by cassava producing households, the average area of land per household and the tenure of land use.

TABLE 69

STRUCTURE OF HOUSEHOLD LANDS

TYPE OF LAND	PERCENTAGE OF HOUSEHOLDS WITH THE TYPE OF LAND (percent)	AVERAGE AREA OF LAND PER HOUSEHOLD (ha)	PERCENTAGE OF HOUSEHOLDS WITH LAND USE RIGHT CERTIFICATE (percent)
CASSAVA	93.7	1.31	87.3
RICE	52.4	0.43	85.3
OTHER CROPS	28.6	2.53	72.2
WATER SURFACE	6.3	0.05	100
RESIDENTIAL	100	0.94	96.7

Source: Survey in Phu Tho and Tay Ninh provinces, Viet Nam, April & May, 2017

It was found that 87.3 percent of interviewed cassava households with cassava crops in both Phu Tho and Tay Ninh provinces stably used land from one generation to another. According to the New Land Law, this land was recognized by the State and granted land use right certificates or "Red Books". More particularly, the land was registered and granted the land use right certificate at the Branch Land Registration Office under the district people committee. Only 12.7 percent of the households are waiting for the land use rights certificates to be issued. There are not any cases of using community/common land such as the land from the land fund of the commune or cooperatives in the commune. But there are very few cases where cassava households rent the land from those households who have land but do not cultivate on it.

No interviewed households had had any land disputes regarding the land used for cassava cultivation. Furthermore, there is no literature or evidence regarding land disputes in the main cassava producing areas. However, evidence was published in national newspapers of some land disputes mainly amongst family members in regards to land heritage and land compensation related to development projects nationwide, and more specifically in Tay Ninh provinces, although not exactly in the main cassava producing areas. The definition of land price used for land compensation and the definition of territories of a land plot were found to be the root causes of many land disputes of development projects in the country. The land dispute resolution follows the grievance redress mechanism for land disputes promulgated in the adopted Land Law 2013. If a land dispute is not satisfactorily dealt at the communal level, it can be submitted to the district or higher level, following the above mentioned land management hierarchy. The National Assembly has the supreme right to supervise land management and use.

As shown in **Table 70**, regarding public consultation on land, the survey reveals that 74.6 percent of interviewed people said that information on land policies is provided timely and adequately by the local authorities; 60.3 percent confirmed that information on land policies is transparent; but only 34.9 percent mentioned that information on land-related issues are provided in ethnic language.

TABLE 70

HOUSEHOLD ASSESSMENT OF LAND POLICIES

PERCENTAGE OF HOUSEHOLDS WHO MENTIONED THAT INFORMATION ON LAND POLICIES IS PROVIDED TIMELY AND ADEQUATELY BY THE LOCAL AUTHORITIES	PERCENTAGE OF HOUSEHOLDS WHO MENTIONED THAT INFORMATION IS ALSO PROVIDED IN ETHNIC MINORITIES' LANGUAGE	PERCENTAGE OF HOUSEHOLDS WHO MENTIONED THAT INFORMATION ON LAND POLICIES IS TRANSPARENT
74.6	34.9	60.3

Source: Survey in Phu Tho and Tay Ninh provinces, Viet Nam, April & May, 2017

Public consultations on the master plan, plan on land use as well as changes of land use plan were conducted by the local authorities quite effectively and in compliance with the public consultation process. The setting up and adjustment of land planning and land use plans at different levels is detailed in the Circular No. 29/2014/TT-BTNMT. The public consultation and disclosure of the land information must be done during this procedure. More than 65 percent of the households interviewed said that whenever there is any new information or changes in the land policies or plans, it is announced in the mass media and published in a public place, normally in the office of the communal People Committee. 82.5 percent of respondents stated that they were invited by the local authorities to consultation meetings and nearly 43 percent confirmed that information on land planning or changes on land use of the community was sent to their house. In general, the provision of information on land use plans and other land-related issues was evaluated as effective by 81 percent of the interviewees. However, there would be some hidden reasons that make the interviewees hesitant to speak out about the gaps between the land law and the current practice of the land law implementation. This report does not dig deeply into the root causes and effects of these gaps or investigate whether public consultation on any changes of land law, national master plan or plan on land use at the localities is really meaningful or not. This could be a research question for future studies.

TABLE 71

PUBLIC CONSULTATION ON CHANGES OF THE LAND PLANNING AND PLAN ON LAND USE

PERCENTAGE OF HOUSEHOLDS WHO MENTIONED THAT INFORMATION ON LAND PLANNING IS PROVIDED BY MASS MEDIA IN THE COMMUNE	PERCENTAGE OF HOUSEHOLDS WHO MENTIONED THAT HOUSEHOLDS WERE INVITED TO COMMUNE MEETING ON LAND PLANNING	PERCENTAGE OF HOUSEHOLDS WHO MENTIONED THAT INFORMATION ON LAND PLANNING WAS SENT TO THEIR HOUSEHOLDS	PERCENTAGE OF HOUSEHOLDS WHO MENTIONED THAT THE PROVISION OF INFORMATION ON LAND PLANNING WAS EFFECTIVE
65.1	82.5	42.9	81.0

Source: Survey in Phu Tho and Tay Ninh provinces, Viet Nam, April & May, 2017

Regarding the preferential policies or mechanisms on the land use for ethnic groups or ethnic poor groups, as shown in **Table 72**, most of interviewees said that they do not know any local preferential policies or mechanisms on the land use for ethnic groups or ethnic poor groups. Although, some of them mentioned Programme 135 described in detail above. In general, the public consultations on land and priority policies for ethnic minorities are in existence, but it is difficult to say if the public consultation is really meaningful and the implementation of the policies is effective or not.

TABLE 72

COMMUNICATION ON LAND POLICIES

PERCENTAGE OF HOUSEHOLDS WHO KNOW ABOUT THE PRIORITY POLICIES ON LAND FOR ETHNIC MINORITIES	PERCENTAGE OF HOUSEHOLDS WHO KNOW ABOUT POLICIES ON AGRICULTURAL LANDS FOR ETHNIC MINORITIES	PERCENTAGE OF HOUSEHOLDS WHO KNOW INFORMED ABOUT THE PRIORITY POLICIES ON OTHER LAND ISSUES FOR ETHNIC MINORITIES
15.9	20.6	14.3

Source: Survey in Phu Tho and Tay Ninh provinces, Viet Nam, April & May, 2017

CASSAVA PROCESSING PLANTS

Regarding land tenure, there are two types used for starch producing factories. The first type is privately owned lands which are normally registered at the local cadastres and given "Red Books". And the second type, which is not very common, is land which belongs to an industrial zone or park under the administration of the local authorities and is rented by starch processing enterprises; normally this land is rented for the period of fifty years. For the interviewed starch processing companies, there have not been any difficulties or constraints in the land lease or land rental process. All interviewed starch companies' owners or managers confirmed that their enterprises have not had any land disputes during the construction and operation of the factories so far. The land lease or land rental procedure is simple and clearly regulated in the Land Law.

Regarding consultation on land, all interviewees said that their representatives are informed and consulted whenever there is any change on the master plan, plan of land use and any other changes related to the government's polies and legal documents. According to the interviewees, the public consultation process is quite effective. Whenever there is a change in the local land use planning and plan, it is firstly published by the local authority at the communal People Committee's office. Then local people, including representatives of enterprises were invited to consultation meetings where they can raise their opinions, which were recorded as minutes of the consultation meetings and addressed after the consultation meetings. However, no clear answers were given to the question "What do you do if you are not satisfied with the feedback from the local authority to your opinions?" Interviewees suggested in their responses that there was no mechanism in these cases. The implication is that public consultation on the land planning and plan of land use exists but it is not clear if it is always effective and meaningful or not. There needs to be further research on this issue.

4.9.3 Main conclusions and recommendations

Approach used

The analysis was based on both primary and secondary data. Firstly, secondary data were collected from national statistics, reports such as of the Viet Nam Land Administration and previous studies such as the study on Land Transparency by the World Bank. This literature was reviewed and summarized in order to give an overview of the land used for cassava production and agriculture production in Viet Nam. Information and data about the planted cassava areas was available and accessible through the Viet Nam agricultural and forestry census (GSO, 2011), which is conducted every five years and the Statistical Yearbooks issued annually by the GSO. Information could also be attained from the General Department of Land Administration. However, information is particularly scarce in the case of areas recently converted to cassava cultivation. In addition, as confirmed by the testing in Viet Nam, in most cases it is not possible to identify the exact areas used for the production of bioenergy feedstock. This is due, among other things, to the fact that fresh cassava, before being transformed into ethanol, needs to be processed into cassava chips, which can be transported over long distances and traded.

To complement the literature, a survey with cassava producing households and cassava starch processing plants in two cassava-growing provinces was also conducted: Phu Tho, a province in the Northern Midlands and Mountains and Tay Ninh, a province in the South East region. The survey focused on the types, structure and tenure of land used by cassava producing households and starch producing enterprises. It also investigated the public consultation on the land master plan, plan for land use and land dispute resolution mechanism as well as preferential policies for ethnic minorities and vulnerable groups.

Results

With regards to the practicality, getting hold of the data and information required for the measurement of this indicator was quite challenging, given the sensitive nature of part of such data and information, and the complexity of the issues at stake. Because of this, a quantitative measurement of this indicator following the defined GBEP methodology was not possible. However, the results of the survey provided an indication of the situation in Phu Tho and Tay Ninh provinces. In these cassava growing regions, 93.7 percent of the interviewed households have land for cassava cultivation hectares and a further 87.3 percent of households confirmed that they already have the land use right certificates. Most of the land used for cassava cultivation is privately owned by households. A literature search also showed that, as of September 2011, there were a total of 16 173 096 land use right certificates for the main types of agricultural production land in the whole country, occupying 85.1 percent of the total agricultural production land area.

The assessment of the total land used for bioenergy production plants could not be conducted, given that cassava chip production took place in many places and was transported from a very long distance and traded through different cassava brokers to the ethanol plants. In addition, information and data about the total amount of cassava used for bioenergy production is not available, while interviews with bioethanol plants could not be arranged due to the complexity of the bioenergy development in Viet Nam currently. However, it is estimated that the total land used for two currently operating Cassava-based ethanol plants in Viet Nam is 9 219 hectares or correspondingly 1.63 percent of the total cassava harvested area.

Based on the primary data collected during the field survey, it is found that the average land area each cassava household owns is quite small and fragmented, an average of 1.3 hectares and located in different areas. This number is even smaller for cassava households in the uplands and mountainous areas which requires more labour intensity and does not enable the mechanization in cassava production.

Relating to the ownership of land, the land used for starch production is normally privately owned by the owners of the starch producing enterprises or/and publicly owned by the communal People Committees. In the latter case, enterprises rent the land, which is normally located in the area of the industrial parks or industrial zones, from the local People Committee and pay fees and taxes for land use. Exercising corporate social responsibility (CSR), starch enterprises normally contribute to the development of the commune by building roads, hospitals, and schools or do some charity activities such as building houses for the poor or offering scholarships for poor children.

Both cassava households and starch enterprises agreed that they were consulted by the local authorities and related departments on the master plan, plan of land use or any changes in these plans in a quite effective manner. Information about changes was published on the local media, in an open and easy to access place, normally in the office of the local People Committees. Sometimes the information was also delivered in the ethnic language. Generally, 81 percent of the interviewees stated that the provision of information on land planning was effective. This is somewhat inconsistent with the results of a recent World Bank study on land transparency in Viet Nam called the Vietnam Transparency Project (World Bank, 2014). The project, based on direct observation of the provision of information related to land, was an effort to systematically measure transparency, provide actionable advice on how to improve transparency, and analyse the causes and effects of transparency in Viet Nam.

Regarding the priority policies for ethnic groups, there are not many legal documents. The Land Law 2013 and also the National Target Programme on Poverty Reduction (Programme 135) mentions priorities for ethnic minorities on land used for residence and agriculture production, but there are not any specific or detailed guidelines on how to implement these policies. In fact, the communication of the policies is not effective and resulting very limited awareness and understanding of these policies amongst local people, including cassava cultivating households and starch producing enterprises. Only 14 to 20 percent of interviewed households know about different policies on land for ethnic minorities.

Practices and policies to improve sustainability

In the recent years, owning to the issuance and implementation of the Land Law 2003 and the new Land Law 2013, Viet Nam has achieved improvement in land administration and management. An LAS has also been step by step developed and used. Detailed circulars and guidelines on how to conduct annual statistics of land and land inventory, as well as the cadastral maps, help improve the effectiveness and quality of the land administration and management. In addition, the Government's and international donors' social safeguards, including resettlement, grievance redress mechanism and public consultation on land use, land acquisition and land compensation have been issued, implemented, monitored and evaluated.

However, as noted by the World Bank (2014), transparency of land-related information could be improved. They mention three main factors that need to be revised to improve transparency, namely, attitude, capacity and leadership.

The average cassava planted area that a household owns is small and fragmented, thereby requiring high labour intensity and not facilitating industrialization and modernization in agricultural production or the application of agricultural mechanization. Therefore, a continuation of the innovation policies on agriculture such as "dồn điền đổi thửa" (land consolidation and plot exchange) or "cánh đồng mẫu lớn" (large sample fields) is needed.

In terms of land allocation and tenure, Viet Nam generally has established and executed land tenure systems from local to national level that work jointly to record and enforce land tenure rights. Information about land use right certificates for the main types of agricultural production land is available. However, information or data on the land use right certificates for the cassava planted land which is converted to ethanol production is not available in any literature or studies. It is also very difficult or impossible for the research team to get this information from competent governmental land administration agencies, such as the land registration offices, without an official "introduction letter" from the higher level local authority. This means that the research needs be acknowledged and committed by the related competent authorities at different levels (from local to central levels) and must be constitutionalized in written documents.

Future monitoring

Modern bioenergy development is very critical for Viet Nam to ensure the energy security as well as to contribute to realization of Viet Nam's commitment to the reduction of greenhouse gas emissions. With the introduction of the nation-wide E5 mandate for RON92 gasoline as of January 2018, the ethanol demand will significantly increase in Viet Nam. Therefore, it will be crucial to monitor the sustainability of Cassava-based ethanol production, including in terms of possible effects on land tenure and access. For this study, a relatively small sample of households in two provinces was considered. For Future monitoring, a broader sample of households in a higher number of provinces should be surveyed. Cassava growing households and provinces with a high concentration of cassava cultivation should be targeted. In addition, for Future monitoring of indicator 9 in Viet Nam, there need to be a better coordination and collaboration between the related competent governmental agencies and ministries, such as the Ministry of Environmental and Natural Resources (Land administration), Ministry of Agriculture and Rural Development (raw materials planning for bioenergy production), Ministry of Industry and Trade (management of bioenergy projects) who can provided needed information to measure this indicator.

REFERENCES

General Department of Land Administration, no date. General Land Administration: Professional Technical Specification Documentation. Available at: www.gdla.gov.vn/index.php/download/Quy-dinh-ky-thuat-chuyen-nganh.html

Ginzburg, R.F., Thulstrup, A.W. & Nielsen, T.T., 2017. Study on Impacts of – and farmers' adaptation to – land allocation policies in the north central uplands of Vietnam. *Geografisk Tidsskrift-Danish Journal of Geography*, pp.1-20.

GSO, 2011. The Rural Agriculture and Fishery Census (RAFC)

GSO website. Statistical data (06.Agriculture, Forestry and Fishing), GSO website, available at: www.gso.gov.vn [Accessed 24 Jan. 2018]

Hieu, V.T., 2015. Biofuel development in Vietnam. Presentation at 3rd GBEP Bioenergy Week. Available at: www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/2015_events/3rd_Bioenergy_Week_25-29_May_Indonesia/26_5_3_HIEU.pdf

Nang, L.V., 2015. Presentation: Vietnam Land Administration and Land Registration. *Viet Nam Ministry of Natural Resource and Environment (MONRE)*. Available at: https://unstats.un.org/Unsd/geoinfo/RCC/docs/rccap20/%5BLandmanagementWS%5D5._Luu_Van_Nang_Land_A....pdf

Marsh S.P., MacAulay T.G. and Hung P.V. (eds), 2007. Agricultural development and land policy in Vietnam: policy briefs. ACIAR Monograph No. 126, 72p. Available at: http://aciar.gov.au/files/node/768/MN126_ENG.pdf

Tuan, N.D.A., Phong, N.A., Lan, N.N., Van, T.T.K., Tuong, T.T., Hung, P.D., Hoang, V.V. and Chuc, H.V., 2016. Status and potential for the development of Biofuels and rural renewable energy in Viet Nam. ADB, Philippines. ISBN 978-971-561-835-9. Available at: www.adb.org/sites/default/files/publication/30314/biofuels-viet-nam.pdf

VHLSS, 2004. Vietnam Household Living Standard Survey

VHLSS, 2010. Vietnam Household Living Standard Survey

VHLSS, 2014. Vietnam Household Living Standard Survey

World **Bank**, 2017. Land Transparency Study: Synthesis Report. Hong Duc Publishing House, Hanoi. Available at: http://documents.worldbank.org/curated/en/934431468121474463/pdf/931010WP0P13280udy00PUBLIC00ENGLISH.pdf

4.10 INDICATOR 10: PRICE AND SUPPLY OF A NATIONAL FOOD BASKET

Holger Matthey, Sergio René Araujo Enciso, Andrea Rossi
Food and Agriculture Organization of the United Nations

DESCRIPTION:

Effects of bioenergy use and domestic production on the price and supply of a food basket, which is a nationally-defined collection of representative foodstuffs, including main staple crops, measured at the national, regional, and/or household level, taking into consideration:
changes in demand for foodstuffs for food, feed, and fibre;
changes in the import and export of foodstuffs;
changes in agricultural production due to weather conditions;
changes in agricultural costs from petroleum and other energy prices; and
the impact of price volatility and price inflation of foodstuffs on the national, regional, and/or household welfare level, as nationally-determined.

MEASUREMENT UNIT(S):

Tonnes; USD; national currencies; and percentage.

4.10.1 Implementation of Indicator 10 in Viet Nam

During the inception meeting of the project and subsequent discussions with relevant Vietnamese institutions and experts, the need for capacity development in relation to GBEP indicator 10 and the associated methodologies was identified. Therefore, it was decided to organize a two-day training to introduce the Aglink-Cosimo model as a tool to measure GBEP Indicator 10 for the Cassava-based ethanol pathway[11].

The Aglink-Cosimo Model is a recursive-dynamic partial equilibrium model of world agricultural markets. It is managed by the Secretariats of the OECD and Food and Agriculture Organization of the United Nations (FAO). The Model is used to simulate developments of annual markets balances and prices for the main agricultural commodities produced, consumed and traded globally. It is a partial equilibrium model in that non-agricultural markets are not included and are treated as exogenous variables. The Aglink-Cosimo Model is used to generate the OECD-FAO Agricultural Outlook and policy scenario analysis. Both biofuel production and use are incorporated as part of the Aglink-Cosimo Model. Biodiesel and ethanol production are modelled using both an exogenous and endogenous component. The exogenous component is based on mandates and the endogenous part is a function of lagged production, the relation between output prices and feedstock costs and a trend component. The use of biofuels is separated into a use of biofuel feedstocks (which includes a technical time component to account for advances in technology) and the direct use of biodiesel and ethanol (with two main components: a market-driven part and a mandate-driven part).

The training on the Aglink-Cosimo Model in Viet Nam brought together around 20 experts from the national Centers of excellence involved in the project and from national agencies conducting forward-looking economic analyses for the agricultural sector. Participants were familiarized with the structure and general functionality of the Aglink-Cosimo Model and its application in assessing the impact of the biofuel sector on domestic agricultural

[11] Partial Equilibrium models and the Aglink-Cosimo Model were specifically mentioned in the report on the GBEP Sustainability Indicators for Bioenergy (FAO, 2011) as possible instruments to measure Tier III ("Quantitative assessment") of Step 2 within indicator 10, i.e. 'Assessing the links between bioenergy use and domestic production and changes in the supply and/or prices of relevant components of food basket(s)'. According to the methodology of indicator 10, the measurement of this indicator could have stopped at Tier I (i.e. "Preliminary indication") of Step 2, as no significant volumes of ethanol consumption were reported in Viet Nam over the past few years. However, given the interest expressed by relevant national organizations and experts in the Aglink-Cosimo Model and its application to ethanol, it was decided to go ahead with the quantitative assessment using this model.

commodity markets. They designed and discussed simulation scenarios closely reflecting their interests and concerns in the development of the bioenergy and agricultural sectors. The model was calibrated in order to reflect local circumstances and official data and information (part of which were provided directly by the trainees) were used.

In particular, two scenarios were run and analysed for the Cassava-based ethanol pathway in Viet Nam, i.e.:

- A backward-looking scenario, in order to assess the impacts of ethanol consumption between 2013 and 2016[12]; and
- A forward-looking scenario (2018-2026), in order to assess the future impact of the introduction, in 2018, of the E5 mandate.

The main results emerging from these two scenarios (compared to a reference with no ethanol demand) are presented and discussed below.

4.10.2 Key findings

Backward-looking scenario (2013-2016)

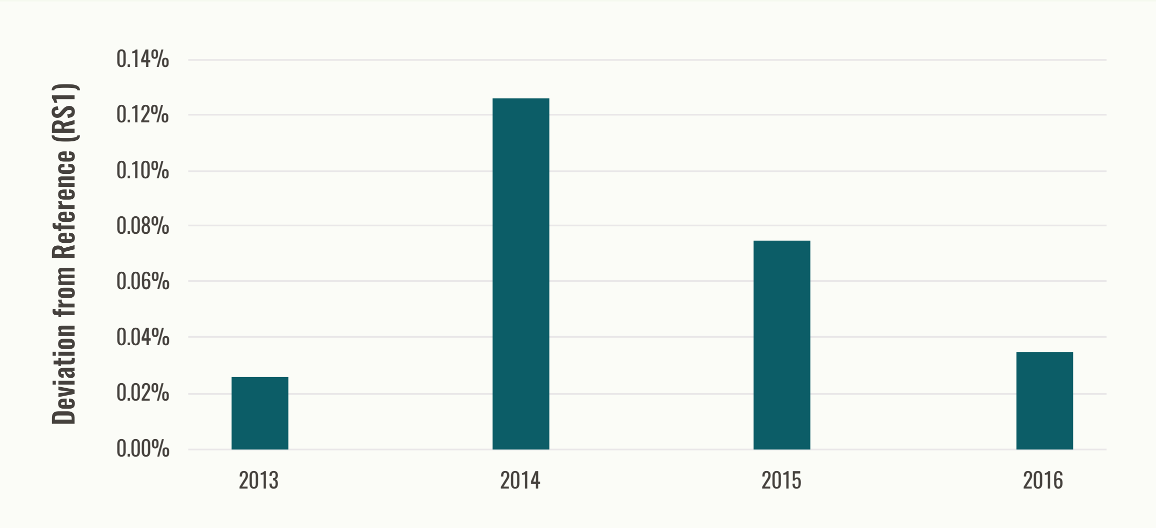
This scenario aimed to assess the impact of ethanol consumption in Viet Nam on domestic cassava production, price and use, during the 201@3-2016 period. The results of this scenario are presented below, expressed in terms of deviation (due to the impact of ethanol demand in the cassava markets) from a hypothetical historical reference with no ethanol demand (RS1).

The cassava industry in Viet Nam is heavily export-oriented. In particular, during the aforementioned period, exports accounted between 80 percent and 91 percent of the total cassava demand. Therefore, the domestic price of cassava depends on the global market.

During the 2013-2016 period, the demand for ethanol (for the fuel market) accounted for a minimal share of total cassava demand, comprised between 1.2 and 2.9 percent. During this timeframe, the ethanol demand had a negligible impact on cassava production (**Figure 44**) and a minor impact (i.e. an increase

FIGURE 44

IMPACT OF ETHANOL DEMAND ON CASSAVA PRODUCTION, 2013-2016



[12] For this scenario, only the 2013-2016 period could be considered, due to the lack of accurate data related to ethanol consumption during the 2007-2012 period.

FIGURE 45

IMPACT OF ETHANOL DEMAND ON CASSAVA PRODUCER PRICE, 2013-2016

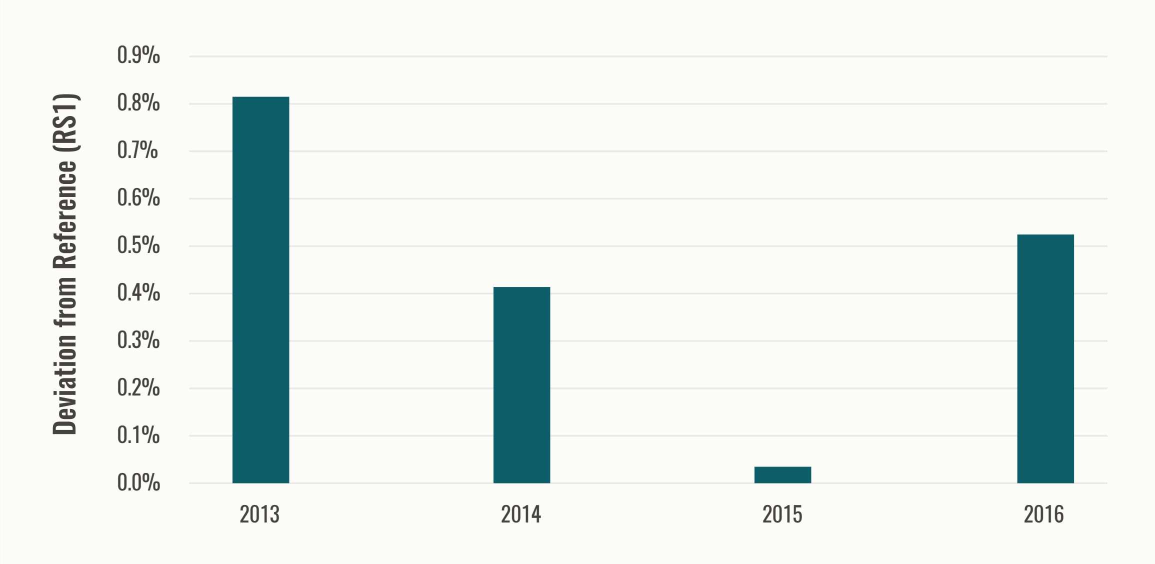
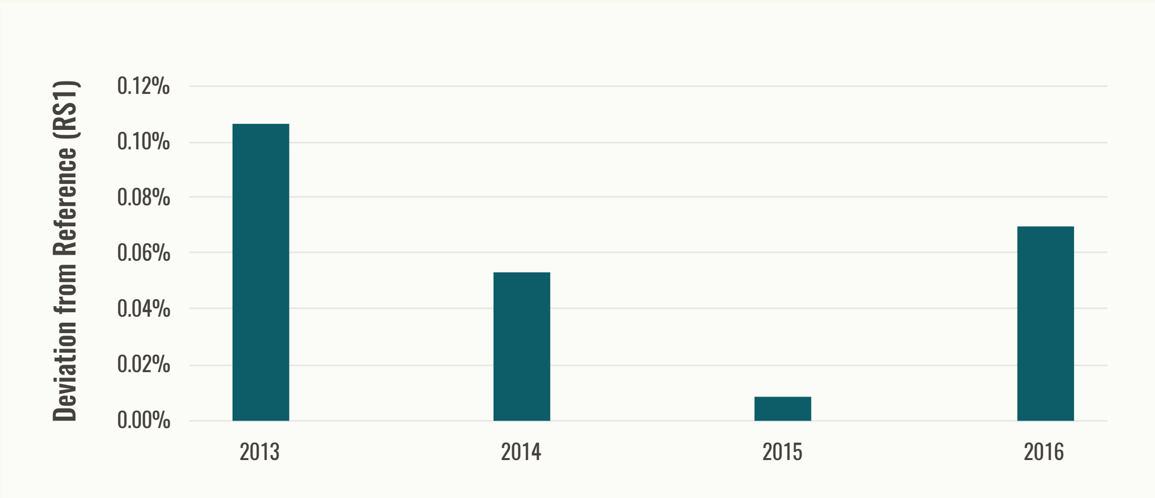


FIGURE 46

IMPACT OF ETHANOL DEMAND ON CASSAVA FOOD USE, 2013-2016



of less than 1 percent) on the producer price of cassava, compared to the reference RS1 (**Figure 45**).

Exports and the other sources of cassava demand (i.e. food, feed and industrial use) were hardly affected by ethanol. The cassava demand for food, for instance, decreased by less than 0.11 percent, compared to the reference RS1 (**Figure 46**).

In summary, in the period 2013-2016, ethanol consumption was very low in Viet Nam, as was the use of cassava as ethanol feedstock compared with the total demand for this crop. As a result, the demand for ethanol did not have any negative impacts on food security, neither by significantly increasing cassava (producer) prices, nor by reducing its demand for food. This is because there is a large surplus of cassava in Viet Nam, with the vast majority of the domestic production of this crop being exported.

Forward-looking scenario (2018-2026)

This scenario aimed to assess, during the 2018-2026 period, the impact on the cassava market in Viet Nam of an ethanol blending ratio gradually increasing from 3.5 percent in 2018 to 5 percent by 2023. This ratio was then assumed to remain constant (at 5 percent) until the end of the timeframe considered, i.e. 2026. In terms of ethanol feedstock, in this scenario it was assumed that other crops beside cassava will be used. More precisely, around 40 percent of the ethanol produced in Viet Nam was assumed to come from cassava, with sugarcane molasses accounting for another 40 percent, followed by sugarcane with around 10 percent and other crops with around 5 percent. The results of this scenario are presented below, expressed in terms of deviation from a projection with no ethanol demand (RS2).

Despite the increase in ethanol demand and in the use of cassava as ethanol feedstock in order to reach the aforementioned blending ratios, only a relatively minor increase in the producer price of cassava is expected in the 2018-2026 period, compared to the projection (RS2) (**Figure 47**).

According to the results of this scenario, this price increase would not significantly stimulate domestic production of cassava, as the market would remain dominated by exports. While the additional ethanol demand is expected to be supplied domestically, the production would be partially based on imported feedstock. In particular, cassava exports would decrease and imports would increase, compared to the projection (RS2). However, net trade would remain positive (**Figure 48**).

FIGURE 47

IMPACT OF ETHANOL DEMAND ON CASSAVA PRODUCER PRICE, 2018-2026

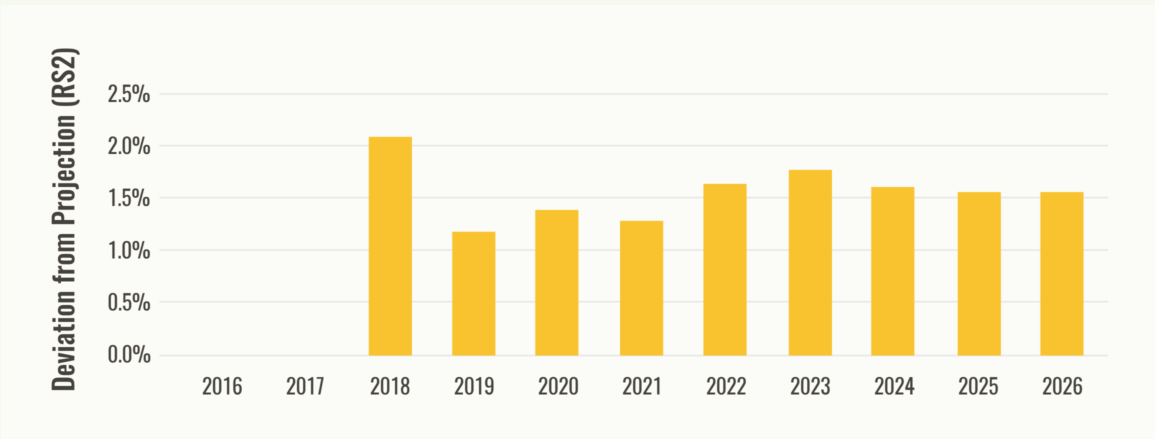
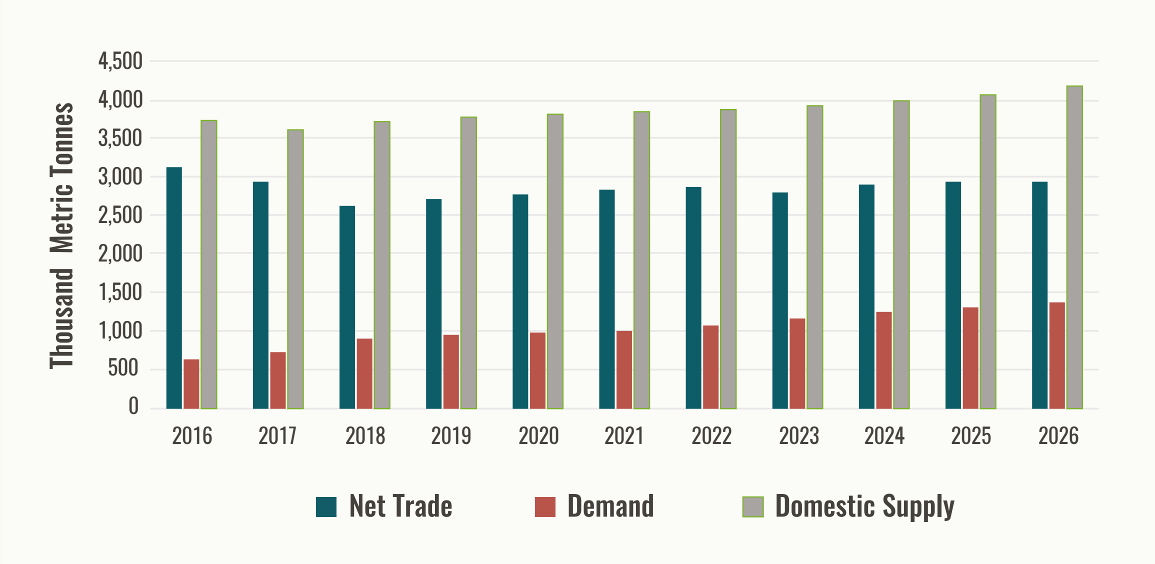


FIGURE 48

IMPACT OF ETHANOL DEMAND ON DOMESTIC SUPPLY, NET TRADE AND DEMAND OF CASSAVA, 2018-2026



As a result of the above, other domestic uses of cassava (i.e. food, feed and industrial use) would not be affected by the increase in the demand for ethanol during the 2018-2026 period.

4.10.3 Main conclusions and recommendations

Approach used

In Viet Nam, Indicator 10 was measured using a partial equilibrium model called Aglink-Cosimo. Two scenarios were run: one backward-looking, aimed to assess the impacts of ethanol consumption between 2013 and 2016; and one forward looking (2018-2026), aimed to assess the future impact of the introduction, in 2018, of a country-wide E5 mandate.

Results

Under both of the scenarios considered, the Aglink-Cosimo Model did not show any significant impact of the ethanol demand on the price and supply of cassava, compared to a reference with no ethanol demand. Furthermore, the other uses of this crop (i.e. food, feed and industrial) were not affected. This is because there is a very large surplus of cassava in Viet Nam, with exports absorbing the vast majority of domestic production.

Practices and policies to improve sustainability

As discussed above, in neither one of the two scenarios analysed was ethanol demand found to have a significant impact on the cassava market. Nonetheless, in order to meet the growing demand for ethanol over the coming years, an increasing share of cassava will be used as feedstock for this biofuel.

In order to minimize the risk of competition with other uses and of trade-offs with exports, a sustainable intensification of cassava cultivation should be promoted. This way, the expansion in the cassava demand for the ethanol market could be met through an additional supply of this crop resulting from a yield increase.

Future monitoring

The Aglink-Cosimo Model and the two scenarios described above are based on a set of assumptions, as any other model and related scenarios. Viet Nam has recently introduced a country-wide E5 mandate for RON92 gasoline. A sharp increase in the demand for ethanol and in the share of cassava used as ethanol feedstock are expected over the coming years.

The forward-looking scenario analysed in this study did not show any significant impact of the future ethanol demand on the cassava market. However, given the assumptions and limitations that every model is subject to, it is recommended to continue monitoring the effects of the growing ethanol demand on domestic cassava supply, prices and use, so as to validate the results of the aforementioned scenario and adjust the related assumptions (e.g. in terms of shares of different ethanol feedstocks) as necessary.

REFERENCES

FAO. 2011. The Global Bioenergy Partnership Sustainability Indicators for Bioenergy. First Edition. ISBN 978-92-5-107249-3. Available at: www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/Indicators/The_GBEP_Sustainability_Indicators_for_Bioenergy_FINAL.pdf

4.11 INDICATOR 11: CHANGE IN INCOME

Ho Thi Lan Huong
Asian Institute of Technology Center in Viet Nam (AITCV)

DESCRIPTION:

(11.1) wages paid for employment in the bioenergy sector in relation to comparable sectors
(11.2) net income from the sale, barter and/or own-consumption of bioenergy products, including feedstock, by self-employed households/individuals, saving cost from production (energy and fertilizer)

MEASUREMENT UNIT(S):

(11.1) local currency units per household/individual per year, and percentages (for share or change in total income and comparison)
(11.2) local currency units per household/individual per year, and percentage (for share or change in total income)

4.11.1 Implementation of Indicator 11 in Viet Nam

For both the Cassava-based ethanol and biogas value chains, secondary data on income per employee and household in the bioenergy value chain were found and used. These data were validated and complemented through a survey that was carried out in two provinces of Viet Nam: Phu Tho, which is a province in the North with a significant amount of ADs in operation; and Tay Ninh, which is a province in the South with a major volume of cassava production (AITCV, 2017). No data could be found or collected for certain stages of the value chains analysed, including cassava dealers, biogas equipment and appliance suppliers. Regarding the processing stage of the Cassava-based ethanol value chain, since no information on wage and income was available for ethanol plants, data were collected from cassava starch plants with the same processing capacity.

4.11.2 Key findings

According to the Vietnam Household Living Standard Surveys (VHLSS, 2014), the average income per capita across the country was about 2 637 thousand dong (USD 125.29) per month. However, there was a gap of nearly two times between the average urban and rural income per capita – 3 964 thousand dong (USD 188.76) for urban areas and 2 038 thousand dong (USD 97.05) for rural areas. The VHLSS also shows that average income per capita in the period 2012-2014 increased 9.0 percent per year. However, the income gap between regions remained. The highest income per capita was still seen in the Southeast region (where Ho Chi Minh City is located), 2.6 times higher than the lowest income per capita seen in the Northern Midlands and Mountain areas.

Within this study, a survey was conducted to collect data and information in relation to wages and income in key stages of the Cassava-based ethanol and biogas value chains in the Phu Tho and Tay Ninh provinces (AITCV, 2017).

Concerning the Cassava-based ethanol value chain, 63 cassava producing households were interviewed. These household had between 2 and 9 members, with an average size of 5.49 members. All of the interviewees were over 30 years old. Their income comes from multiple sources, of which agricultural production is the major one. Most cassava households have two main labourers and two to three dependents, and are not classified as poor or near poor.

In addition to cassava producing households, cassava collectors in the village and commune, and cassava middlemen and traders in the district and province were also invited for interviews in the Tay Ninh Province. Cassava collectors in the village and commune buy roots from cassava farmers. A cassava collector/dealer normally has contractor(s) and hires a number of local labourers in the village or surrounding areas for collecting roots, driving tractors and transporting cassava to starch processing plants or storehouses. The cassava middlemen buy dry chips from the cassava collectors in the village or commune and sell them to processing units or exporters. Finally, interviews were conducted with the owners and chief engineers of five cassava starch processing plants located in three districts of the Tay Ninh Province, where there is a high concentration of such plants (86 in total).

For the biogas value chain, interviews were carried out with 57 biogas-using households. The size of surveyed households was on average 6.3 people, and ranged from 2 to 12 members. Monthly income of the surveyed households was quantified by asking respondents to take into account income of the whole family from all different sources. The result showed that household income comes mainly from two types of agricultural activities: livestock and plantations.

Wages along the cassava value chain

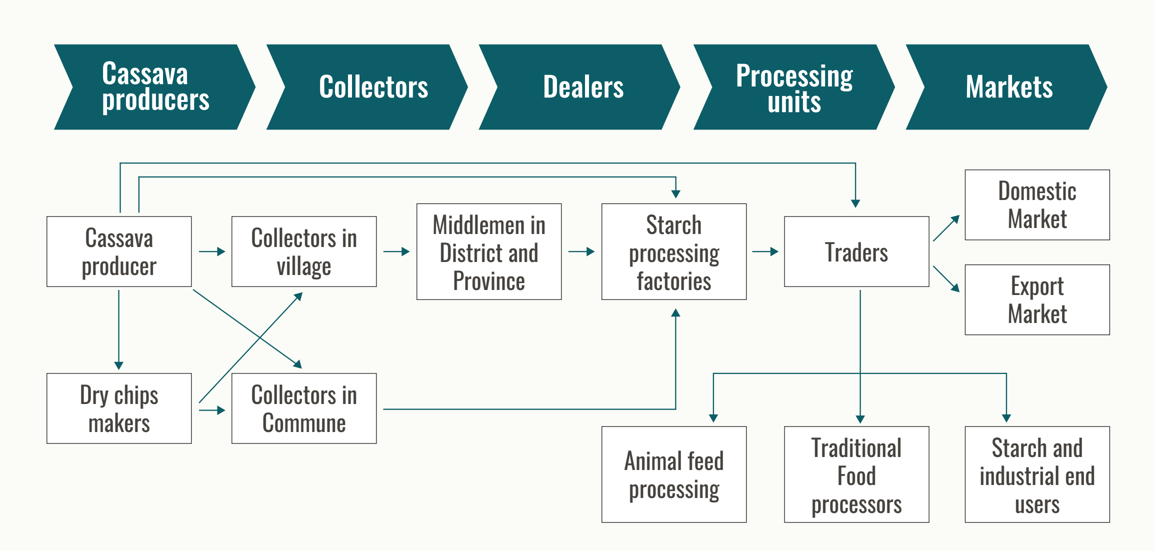
Three types of actors involved in the cassava value chain were considered: (1) cassava cultivators/producers; (2) cassava collectors or whole sale agents in the village, commune, district and province; and (3) starch processing plant employees. In Viet Nam, fresh cassava is used for starch processing whilst dry cassava slices or chips are addressed to ethanol and animal feed production, if not exported.

As shown in **Figure 49**, three main different paths for cassava distribution were identified in the country, two of which (i.e. Paths 1, 2) are related to cassava starch production, while the third one is relevant for the ethanol pathway:

- Path 1: cassava producers → collectors → starch processing factories → domestic or export market. In this case, processing factories use only fresh cassava. The results from the survey conducted with cassava starch factory owners and chief engineers show that around 30 percent of the fresh cassava processed by these factories is purchased from cassava dealers/collectors. In fact, cassava producers whose fields are far from factories or who do not have means for transportation, sell fresh cassava to dealers.
- Path 2: cassava producers → starch processing factories → domestic or export market. Under this path, processing factories also use fresh cassava. Approximately 70 percent of the fresh cassava processed by cassava starch plants is purchased directly from cassava producers, i.e. households located nearby factories with about 1-2 ha of cassava per household.

FIGURE 49

CASSAVA VALUE CHAIN



- Path 3: cassava producers → dry chip makers → small dealers → big dealers → ethanol factories/export market/animal foodstuff.

Cassava producers represent the first actor of any cassava distribution path. The results of the field survey showed that cassava area per household is very small in Phu Tho (about 0.01-1 ha/household) and larger in Tay Ninh (about 1-2 ha/household). The cassava yield varies between 18 and 24 tonnes per ha (2014-2016). If a selling price of 1 400-1 700 VND/kg of fresh cassava is considered, cassava farmers are able to generate from 25.2 to 40.8 million VND/ha (1 145.45-1 854.54 USD/ha). Average production cost varies from 13.86 to 15.9 million VND/ha (630-722.73 USD/ha). Therefore profit from cassava growing is about 9.3-26.94 million VND/ha (422.72-1 224.54 USD/ha). The price of dry chips is much higher than that of fresh cassava. The average chip selling price is about 3 000 VND/kg (0.136 USD/kg). In addition, dried chips could be easily stored and farmers can take advantage of family workers to generate extra income. As a result. Overall, cassava was to found to play an important role in the income structure of the rural households that were interviewed. In the Phu Tho and Tay Ninh provinces, the income from cassava varies from 38.5 to 60 percent of the total income of cassava-producing households (AITCV, 2017).

As part of the cassava production stage, as well as household income, there is also wage income of farm labourers and tractor drivers. The average wage for a farm labourer hired to harvest roots is around 7.7 USD/tonne. Each farm worker can collect two tonnes of roots per day. It means a farm worker harvesting cassava earns an average of 15.4 USD/day. A tractor driver is paid 4.4 USD per tonne of collected cassava root, meaning that average wage paid for this work varies from 79.2 to 105.6 USD/ha. A tractor driver can move 10-15 tonnes/day for about 2.5 months per year. Therefore, on average, the tractor driver can earn from 44 to 66 USD/day during the harvesting period.

The self-employed collectors at village and commune level buy cassava roots from farmers and sell them to cassava dealers in the district or province, or directly to the starch processing factories. Expenditure sustained by collectors for cassava collection and transportation per tonne of fresh roots varies from VND 205 000 to VND 215 000 (USD 9.32-9.77). A collector deals with, on average, 800-1 000 tonnes of fresh cassava per year and earns VND 175 000 (USD 7.95) per tonne. In addition, she/he also collects about 200-400 tonnes of dry chips per year. The profit margin for one tonne of dry chips varies from USD 6.20 to USD 6.50.

Cassava middlemen or wholesalers buy dry chips from local collectors in the district. The transaction quantity varies from 5 to 15 tonnes/day in low season to 15 to 20 tonnes/day in the

TABLE 73

SUMMARY OF AVERAGE INCOME/WAGES FOR ACTORS IN THE CASSAVA VALUE CHAIN

ACTOR	INCOME/WAGES	UNIT
CASSAVA CULTIVATOR	422.72-1 224.54	USD/ha
FARM LABOURER	15.4	USD/DAY
TRACTOR DRIVER	44-66	USD/DAY
COLLECTOR AT VILLAGE/COMMUNE LEVEL	7.95 6.20-6.20	USD/TONNE FOR FRESH CASSAVA USD/TONNE FOR CASSAVA CHIPS
	6 360-7 975 1 240-2 600	USD/YEAR FOR FRESH CASSAVA USD/YEAR FOR CASSAVA CHIPS
CASSAVA MIDDLEMAN	1.30-1.50 3.90-4.50	USD/TONNE FOR FRESH CASSAVA USD/TONNE FOR CASSAVA CHIPS
	7 800-9 000	USD/YEAR FOR CASSAVA CHIPS
STARCH PROCESSING FACTORY	12.9-14.1	USD/TONNE OF DRY CHIPS PROCESSED TO FLOUR

Source: AITCV, 2017

peak season (from July to September), with an average of 2 000 tonnes/year purchased. The margin for dry chips varies between 3.90 and 4.50 USD/tonne, and from 1.30 to 1.50 USD/tonne of fresh cassava.

Local collectors and district wholesalers sell dry chips to starch producing factories and processing units. The selling price of cassava flour is around 0.18-0.19 USD/kg. On average, the processing unit makes profits of 12.9 to 14.1 USD/tonne of dry chips processed to flour.

The average income of actors in the cassava value chain is summarised in **Table 73**.

Wages along the biogas value chain

The study identified four different professional figures involved in the biogas value chain: i) households raising livestock, the waste of which is used as feedstock for the AD; ii) masons; iii) technicians in provinces and districts; and iv) biogas equipment agents/suppliers.

Results of the survey conducted within this study show that the income sources of biogas households are various, but derived mainly from crop cultivation and livestock raising as indicated in **Table 74** and **Figure 50**. For a biogas household, the average annual per capita income is USD 539.46, of which USD 93.34 (17.3 percent) comes from livestock activity (AITCV, 2017). This means that the average annual household income is USD 3 398.6 per year, of which USD 588 are generated by the livestock activities. Given this data, most biogas households are not considered poor according to Vietnamese standards.

TABLE 74

MAIN INCOME SOURCES OF BIOGAS HOUSEHOLDS

PRODUCTION ACTIVITIES	DISTRIBUTION OF HOUSEHOLDS BY THE MAIN INCOME SOURCE (percent)	DISTRIBUTION OF HOUSEHOLDS BY THE SECONDARY INCOME SOURCE (percent)
CROP	69.6	22.8
LIVESTOCK	23.2	70.2
WAGE	5.4	1.8
NON-FARM BUSINESS	1.8	0

Source: AITCV, 2017

Data collected through the survey show that the use of biogas does not directly increase the income for the biogas user household but allows it to save on the purchase of LPG and electricity for cooking, heating and lighting, and inorganic soil fertilizer, thus reducing the related expenditures sustained by each household (AITCV, 2017). Logically, the savings from using biogas depend on the size of the AD and on the level of utilization of biogas and digestate (AD by-product). The size of biogas tanks can be categorized into three main groups and the annual per capita income of interviewed biogas households under these three groups is shown in **Table 75**.

Looking at **Table 75**, it is seen that total per capita income and per capita income from agricultural production activities increase according to the size of the AD, as the larger the AD size, the greater the volume of livestock production and related income. On the other hand, the use of biogas and digestate helps save costs; **Table 76** shows the average annual household savings from the use of an AD of 11.6 m^3. As shown in **Figure 51**, most of these savings (91 percent) come from reduced purchase of other fuels for cooking.

FIGURE 50

MAIN INCOME SOURCES OF BIOGAS HOUSEHOLDS

Source: AITCV, 2017

TABLE 75

SIZE OF BIODIGESTERS AND PER CAPITA INCOME OF BIOGAS USERS

TANK SIZE	NUMBER OF OBSERVATIONS	PER CAPITA INCOME (thousand VND/year)	PER CAPITA INCOME (USD/year)	PER CAPITA INCOME FROM AGRICULTURAL PRODUCTION ACTIVITIES (thousand VND/year/person)	PER CAPITA INCOME FROM AGRICULTURAL PRODUCTION ACTIVITIES (USD/year/ person)
< 10 M^3	14	6 439	292.69	898.5	40.84
10-15 M^3	36	12 632	574.17	1 984.2	90.19
> 15 M^3	3	15 939	724.49	2 488.9	113.13
TOTAL	56				

Source: AITCV, 2017

TABLE 76

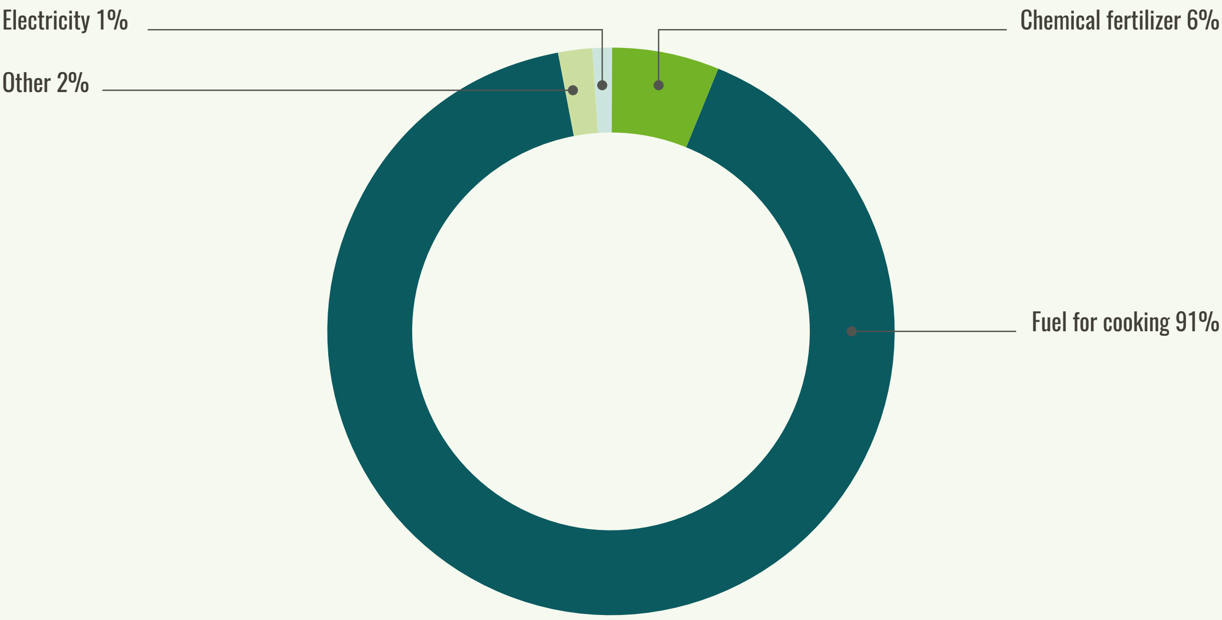
AVERAGE SAVINGS REALIZED ANNUALLY FOR A HOUSEHOLD WITH AN AD OF 11.6 M^3

KINDS OF SAVING	VALUE (USD)	RATIO (%)
FUEL FOR COOKING	167.18	91.27
ELECTRICITY	2.18	1.19
CHEMICAL FERTILIZER	11.13	6.08
OTHER	2.67	1.46
TOTAL COST SAVINGS	183.16	100

Source: AITCV, 2017

FIGURE 51

AVERAGE SAVINGS REALIZED ANNUALLY FOR A HOUSEHOLD WITH AN AD OF 11.6 m^3, BY SOURCE



Apart from households with ADs, there are also other workers along the biogas value chain, namely biogas masons and technicians, and workers in companies that supply appliances and technical services for biogas. Most masons work as self-employed individuals or in a team rather than as employed workers of an enterprise or a company. There is at least one team per district. For example, there are 15 teams in the Phu Tho Province and four teams in the Tay Ninh Province (AITCV, 2017). In Phu Tho, the average wage paid for a mason is around 5 000 000 VND/month (227.27 USD/month). This is equal to the average wage of a general (non-biogas) mason in the Province and lower than the average wage of technical civil workers, even though the construction of an AD requires specific skills and experience. In fact, in order to become a professional AD mason, a mason must be trained and certified. A mason team normally includes two to three skilled workers and some unskilled ones; the wages paid to skilled and unskilled masons differ by 4.73-6.99 USD/day (average daily wage for unskilled mason is USD 6.98 and for a skilled mason is USD 11.71-13.97). In Tay Ninh, the wage for masons is paid on a man-hour basis and is equivalent to VND 37 500 (USD 1.87) per hour or VND 300 000 (USD 15) for eight working hours. In general, information concerning the number of hours worked daily, hourly wages and the incidence of overtime hours and days was not thoroughly and consistently reported by the participants during the survey.

As reported by the technicians interviewed in the survey, the average wage for a technician varies between 10 and 15 million VND per month (equivalent to 466.9-700.4 USD/month).

Information on the wages of workers in companies/enterprises that supply appliances and technical services for biogas were not available at the time of this study.

4.11.3 Main conclusions and recommendations

Approach used

For Cassava-based ethanol, wages paid for employment along the cassava value chain were evaluated, using both literature and primary data collected through a dedicated survey conducted in Tay Ninh and in Phu Tho provinces (AITCV, 2017).

For the biogas value chain, income of all groups along the value chain were obtained, except for the income of the workers in companies/enterprises that supply appliances and technical services, which was not available in the literature and with whom interviews could not be conducted.

Results

a. Cassava-based ethanol

The results of the survey suggest that cassava generates very good income for all stakeholders, especially for the collectors, middlemen and starch processing enterprises (AITCV, 2017). Furthermore, cassava harvesting creates unskilled jobs for local people, including farm labourers and tractor drivers. The incomes of the various actors in the cassava value chain are summarised in **Table 73**. Results from the survey suggest that the average profit for cassava cultivation is 422.72-1 224.54 USD/ha (AITCV, 2017).

b. Biogas pathway

For sub-indicator 11.1, income was calculated for actors in the biogas value chain. Although most biogas technicians are part-time staff, wages are paid to them at a rate equal to USD 466.9-700.4 per capita per month. For masons, average wages are USD 6.98 per day for unskilled workers and USD 11.71-13.97 per day for skilled workers (AITCV, 2017).

For sub-indicator 11.2, income of biogas households was measured by cost saving, such as savings on fuel for cooking, electricity for lighting, heating and fertilizer, with an average total saving of USD 183.16 per household per year. This confirmed that the use of biogas and of digestate helps to reduce expenditures sustained by households for buying fuel for cooking, heating and lighting, and for buying inorganic fertilizers, although the greatest savings (92 percent) were realised from the reduced need to purchase alternative fuels for cooking. Furthermore, the use of biogas reduces the time spent by household components for collecting firewood, cooking and for other daily activities, which can then be used for agricultural production and to generate additional income for the biogas user households (see Indicator 13).

Future monitoring

Monitoring of indicator 11 is extremely important, as the income effects associated with bioenergy feedstock production and processing are a key component of the overall socio-economic impacts of the bioenergy sector. Therefore, it is important to gather additional and more in-depth data and information, also through tailor made surveys and interviews addressed to different target groups, such as producers and workers. These surveys should better define the wages and prices paid to producers, especially along the Cassava-based ethanol value chain. In particular, it would be important to obtain information related to wages in ethanol plants, and biogas equipment and appliance suppliers, for which income data could not be found.

REFERENCES

AITCV. 2017. Survey conducted within this study in Phu Tho and Tay Ninh provinces, Vietnam, April & May 2017.

Dong, D.X. 2017. The orientation in the production and use of biofuels in Vietnam, Department of Science and Technology, MOIT, FAO, Sustainable Bioenergy Production and Use in Southeast Asia: Lessons Learnt and Future Opportunities, 16-17 November 2017, Hanoi. Available at: www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/AG2/Viet_Nam_project/Final_Mettings/Dong_Do-Xuan.pdf. [Accessed: 13 Feb 2018].

EPRO Consulting JSC. 2014. Biogas User Survey 2013. Available at: http://biogas.org.vn/english/getattachment/An-pham/2014/BIOGAS-USER-SURVEY-2013/Biogas-User-Suvey-Report-2013_eng.pdf.aspx

EPRO Consulting JSC. 2016. Biogas User Survey 2014

Luu, D.H., Potvin, C., Kooijman-van Dijk, A. and Guerts, P. 2011. Vietnam Biogas Assessment - Research Project. ETC Energy, The Netherlands.

Viet, H.C. et al., no date. Cassava value chain analysis. Available at: www.academia.edu/11748243/Cassava_Value_Chain_Analysis

Vietnam Household Living Standard Surveys (VHLSS). 2014

4.12 INDICATOR 12: JOBS IN THE BIOENERGY SECTOR

Ho Thi Lan Huong
The Asian Institute of Technology Center in Vietnam (AITCV)

DESCRIPTION:

Net job creation as a result of bioenergy production and use, total (12.1) and disaggregated (if possible) as follows:
(12.1) total net jobs created in bioenergy production and use;
(12.2) skilled/unskilled;
(12.3) indefinite/temporary;
(12.4) Total number of jobs in the bioenergy sector; and
(12.5) In relation to comparable sectors.

MEASUREMENT UNIT(S):

(12.1) number and number per MJ or MW
(12.2) number, number per MJ or MW, and percentage
(12.3) number, number per MJ or MW, and percentage
(12.4) number and as a percentage of (working-age) population
(12.5) percentages

4.12.1 Implementation of Indicator 12 in Viet Nam

Yearly statistical data on employment for Viet Nam is categorized into three main economic mega-sectors: service, construction and industry; agriculture, forestry and fishing; and special occupation (e.g. manager, senior expert, expert, junior staff, etc.). At present, no official data on employment in the bioenergy sector are available and it is difficult to estimate with accuracy the actual size of the workforce involved in the sector.

The direct employment associated with the supply chains of Cassava-based ethanol and household level biogas was estimated, based on data and information from official statistics and reports. In the case of Cassava-based ethanol, interviews with selected industry representatives were carried out and the feasibility study of an ethanol plant was used as a source of information as well. For the Cassava-based ethanol pathway, the following stages of the supply chain were considered: cassava cultivation (including harvest) and conversion to ethanol. For the biogas supply chain (household level), the analysis focused on the following activities: management of the biogas support programmes; and construction, installation and maintenance of the biodigesters.

No data were available for the other stages of the aforementioned supply chains (e.g. transportation of cassava and ethanol), whose employment effects are expected to be minimal. Due to lack of data, the share of temporary and indefinite jobs could be estimated only for the conversion stage of the Cassava-based ethanol pathway. Another important limitation of the analysis presented below relates to labour conditions, as no information could be found on the share of jobs adhering to nationally recognized standards consistent with the ILO Declaration on Fundamental Principles and Rights at Work. Finally, the lack of data made it impossible to estimate the indirect jobs associated with the selected pathways.

4.12.2 Key findings

According to the Vietnam Employment Survey Report 2016, as of 2015, there were around 56 million workers in Viet Nam, of which about 24.65 million in agriculture, forestry and fishing, accounting for 44 percent of the total, down from 47.4 percent in 2012. There are other sectors as well (e.g. service, construction and industry) that include workers whose occupation is linked to activities related to the biogas pathway and to the post-harvest stages of the Cassava-based ethanol supply chain. However, agriculture (i.e. cassava cultivation and harvest) accounts for the vast majority of workers employed in the bioenergy sector.

Cassava-based ethanol

For Cassava-based ethanol, only jobs associated with cassava cultivation/harvest and conversion to ethanol were estimated. According to MARD (2016), cassava accounts for around 11.7 percent of total jobs in agriculture, forestry and fishing, i.e. around 2.88 million jobs in 2015.

As explained in indicator 8, in 2015 1.53 percent of the cassava cultivated in Viet Nam was used to produce ethanol. Therefore, 1.53 percent of the jobs associated with cassava cultivation and harvest can be attributed to feedstock cultivation for ethanol, i.e. 44 000 jobs. If an E5 blending mandate had been in place, then 19.17 percent of the cassava cultivated in the country would have been needed for ethanol production, and the associated number of jobs would have increased to 550 000. Self-employment and unpaid family labour accounts for the large majority of these jobs, but seasonal and casual labour are likely to play a role as well. The shares of these different types of employment, and of indefinite vs. temporary jobs could not be determined.

Regarding the conversion to ethanol, based on the feasibility study of the Dung Quat ethanol plant, a plant with a capacity of 100 million litres per year needs around 200 employees when running at full capacity. As of 2016, in Viet Nam there were only two ethanol plants in operation, with a total capacity of around 200 million litres per year. These plants were operating at less than 15 percent of their capacity. Nonetheless, as indicated by a number of experts and industry representatives, even in order to run an ethanol plant under its capacity requires at least 50 percent of the total employees. Therefore the total number of employees needed to run the two ethanol plants currently in operation can be estimated at 200. In order to meet a hypothetical E5 mandate, around four plants with a capacity of 100 million litres per year and operating at almost full capacity would have been needed. Assuming that each of these plants would employ 200 workers (in line with the aforementioned feasibility study), the number of jobs would have increased to 800.

According to the feasibility study of the Dung Quat plant, 77 percent of employees at the plant are skilled, while the rest are unskilled. Skilled employees include leaders, manager, technicians, accountants and trained workers while unskilled ones include janitors, guards, cleaners and some seasonal employees. Based on these shares, out of the 200 employees at the two ethanol plants currently in operation, 154 can be considered skilled and 46 unskilled. According to the information provided by selected industry representatives, approximately 30 percent of unskilled workers (i.e. 15) are temporary. In case of a hypothetical E5 mandate, assuming the same shares as above, the number of skilled employees would have been 616, while the remaining 184 would have been unskilled. Among the latter, 55 could be considered as temporary. The aforementioned estimates are summarized in **Table 77** and **Table 78**.

TABLE 77

DIRECT JOBS ASSOCIATED WITH THE CASSAVA-BASED ETHANOL VALUE CHAIN, 2015

DIRECT JOBS	NUMBER OF JOBS	JOBS/MJ	SHARE (percent)
TOTAL JOBS (SUB-INDICATOR 12.1)	44 200	7.1×10^{-5}	100
SKILLED JOBS (SUB-INDICATOR 12.2)	154	2.9×10^{-5}	0.35
UNSKILLED JOBS (SUB-INDICATOR 12.2)	44 046	2.47×10^{-7}	99.65
INDEFINITE JOBS* (SUB-INDICATOR 12.3)	185	2.97×10^{-7}	70
TEMPORARY JOBS** (SUB-INDICATOR 12.3)	15	2.4×10^{-8}	30

* For this sub-indicator, only the jobs in the conversion stage of the Cassava-based ethanol supply chain was considered. The share in the right column was expressed in relation to the total number of jobs for this specific stage of the chain.

** Ditto.

TABLE 78

DIRECT JOBS ASSOCIATED WITH CASSAVA-BASED ETHANOL VALUE CHAIN, WITH HYPOTHETICAL E5 MANDATE, 2015

DIRECT JOBS	NUMBER OF JOBS	JOBS/MJ	SHARE (percent)
TOTAL JOBS (SUB-INDICATOR 12.1)	550 000	7.04×10^{-5}	100
SKILLED JOBS (SUB-INDICATOR 12.2)	616	7.89×10^{-8}	0.11
UNSKILLED JOBS (SUB-INDICATOR 12.2)	549 384	7.04×10^{-5}	99.89
INDEFINITE JOBS* (SUB-INDICATOR 12.3)	745	9.54×10^{-8}	93.12
TEMPORARY JOBS** (SUB-INDICATOR 12.3)	55	7.04×10^{-9}	6.88

* For this sub-indicator, only the jobs in the conversion stage of the Cassava-based ethanol supply chain was considered. The share in the right column was expressed in relation to the total number of jobs for this specific stage of the chain.
** Ditto.

Biogas

For the biogas supply chain (household level), the following activities were analysed under this indicator and the related direct jobs estimated: management of the biogas support programmes; and construction, installation and maintenance of the ADs.

As explained in Chapter two, over the past few decades, various programmes have been implemented in Viet Nam to support the adoption of anaerobic digesters at household level, under the leadership of MARD and in cooperation with the Netherlands Development Organization (SNV), the Asian Development Bank and the World Bank. Around 450 000 household level biodigesters have been installed (with an average size of 10 m^3), of which 90 percent (i.e. 405 000) are in operation. The total capacity of these digesters is estimated at 9 579 060 GJ.

According to MARD (2016), the total number of employees of central offices of the biogas programmes is 100. All of them are part-time and they spend only 50 percent of working time on biogas programme-related activities. In addition, the total number of staff are: 220 part-time staff in provincial offices is 220; 9 709 part-time technicians at district and commune levels; 10800 masons and biogas equipment suppliers. Overall, the total number of direct jobs associated with the household level biogas pathway is 20 829. These figures are presented in **Table 79**.

TABLE 79

JOB CATEGORIES ALONG THE HOUSEHOLD LEVEL BIOGAS VALUE CHAIN, 2016

JOB CATEGORIES	JOBS	SHARE (percent)
PART-TIME WORKERS IN CENTRAL OFFICES OF THE BIOGAS PROGRAMMES UNDER MARD	100	0.48
PART-TIME WORKERS IN PROVINCIAL PROJECT OFFICES	220	1.06
PART-TIME WORKERS IN DISTRICT/COMMUNAL PROJECT OFFICES	9 709	46.61
MASONS, BIOGAS EQUIPMENT AND APPLIANCE SUPPLIERS	10 800	51.85
TOTAL	20 829	100

Source: MARD, 2016

All part-time workers employed in the central, provincial and district/communal offices of the biogas programmes under MARD are skilled. Regarding ‘masons, biogas equipment and appliance suppliers’, 50 percent are skilled workers and the rest are unskilled workers who are hired on a daily-basis (with no formal employment contracts). Overall, the total number of skilled jobs associated with the household level biogas pathway is 15 429, while the remaining 5 400 are unskilled. Regarding the share of indefinite and temporary workers, no estimates could be made due to a lack of data. This is shown in **Table 80**.

TABLE 80

DIRECT JOBS ASSOCIATED WITH THE HOUSEHOLD LEVEL BIOGAS VALUE CHAIN, 2016

DIRECT JOBS	NUMBER OF JOBS	JOB/MJ	RATIO (percent)
TOTAL JOBS (SUB-INDICATOR 12.1)	20 829	2.17×10^{-6}	100
SKILLED JOBS (SUB-INDICATOR 12.2)	15 429	1.61×10^{-6}	74
UNSKILLED JOBS (SUB-INDICATOR 12.2)	5 400	5.64×10^{-7}	26

Source: MARD, 2016

4.12.3 Main conclusions and recommendations

Approach used

This study used both secondary data, which were collected from the MARD's reports Biogas Projects' reports and also reports of other VAAS and VJIIT, as well as primary data, which were gathered during field research that used a sample of 57 biogas households and 63 cassava-growing households in Tay Ninh and Phu Tho provinces. However, a complete data set needed to measure Indicator 12 (Indicators 12.1, 12.2, 12.3, 12.4 and 12.5) was not available. Therefore some assumptions have been made, such as the percentage of temporary jobs created in both ethanol and biogas pathways, and the percentage of employment (50 percent) needed to run an ethanol plant under its capacity. In addition, beside four biogas programmes under MARD, there are a number of other biogas projects which were not considered in the measurement of this indicators. It is currently impossible to measure Indicator 12.4 because of the lack of data on the age of labourers working in the bioenergy sector.

TABLE 81

RESULTS OF INDICATOR MEASUREMENT

SUB-INDICATOR	VALUE	UNIT
12.1	68 299 8.2×10^{-5}	NUMBER OF JOBS JOBS/MJ
12.2	32 803 SKILLED 35 496 UNSKILLED 3.1×10^{-5} SKILLED 5.1×10^{-5} UNSKILLED	NUMBER OF JOBS JOBS/MJ
12.3	24 307 INDEFINITE 11 189 TEMPORARY 3.6×10^{-5} INDEFINITE 1.5×10^{-5} TEMPORARY	NUMBER OF JOBS JOBS/MJ
12.4	NOT AVAILABLE	
12.5	0.27	PERCENTAGE OF TOTAL EMPLOYMENT IN AGRICULTURAL SECTOR

Results

With the data collected and assumptions made, indicators related to jobs created in bioenergy are shown in **Table 81**.

Practices and policies to improve sustainability

As shown by this indicator, Cassava-based ethanol production tends to be quite labour-intensive in Viet Nam, due to the high labour requirements of the stages related to feedstock production. This is due to the low mechanization level of cassava cultivation and harvest, which contributes to the low productivity of this crop in Viet Nam. In order to improve the efficiency and sustainability of this value chain, improved varieties, practices and technologies should be promoted.

Regarding the quality of the jobs associated with the two selected bioenergy pathways, the indicator did not provide insights into the share of temporary vs. indefinite jobs due to lack of data. In relation to the quality of employment, for Cassava-based ethanol, an issue highlighted by the analysis was the high prevalence of unskilled jobs, which is mainly the result of the weight of the feedstock production stage (which is dominated by jobs generally classified as 'unskilled') within the total workforce along the supply chain. The situation is very different for the household-level biogas pathway, which appears to have generated a very significant share of skilled jobs.

Future monitoring

The estimates that were made under this indicator and the related analysis focused on specific stages of the supply chains of the selected bioenergy pathways, i.e. cassava cultivation (including harvest) and conversion to ethanol for the Cassava-based ethanol pathway; and management of the biogas support programmes, and construction, installation and maintenance of the biodigesters for the other pathway. Even though these stages account for the vast majority of jobs along the supply chains analysed, for Future monitoring it would be useful to consider other stages as well, such as transportation (of both cassava and ethanol).

In order to shed light on the quality of employment along the supply chains considered, information related to the share of temporary and indefinite jobs (which could be estimated only for ethanol plants at this stage) should be collected. Another important limitation of the analysis that was carried out relates to labour conditions, as no information could be found on the share of jobs adhering to nationally recognized standards consistent with the ILO Declaration on Fundamental Principles and Rights at Work. Furthermore, estimates should be made of the indirect jobs associated with the selected bioenergy pathways. With the strong increase in the demand for ethanol associated with the recent adoption of the country-wide E5 mandate, it would be important to fill these gaps and complement the analysis presented here.

In order to obtain the necessary information currently missing for a thorough assessment of this indicator in the future, and get access to data considered sensitive (as it is often the case when it comes to labour conditions), a close cooperation should be established with relevant government authorities and producers' organizations. In case of data gaps, primary data should then be collected, mainly through surveys.

REFERENCES

GSO. 2016. Vietnam Employment Survey Report 2016.

MARD. 2016. Real situation and solutions for environmental treatment of livestock production. Report Document 2016.

SNV. 2018. Viet Nam Biogas Programme. Available at: www.snv.org/project/vietnam-biogas-programme

4.13 INDICATOR 13: CHANGE IN UNPAID TIME SPENT BY WOMEN AND CHILDREN COLLECTING BIOMASS

Pham Thi Thanh Thuy
The Asian Institute of Technology Center in Vietnam (AITCV)

DESCRIPTION:

Change in average unpaid time spent by women and children collecting biomass as a result of switching from traditional use of biomass to modern bioenergy services

MEASUREMENT UNIT(S):

Hours per week per household, percentage

4.13.1 Implementation of Indicator 13 in Viet Nam

In most developing countries, firewood collection is a time- and energy-intensive activity. Particularly, in remote rural areas and in certain regions of the world, women and sometimes children are responsible for the collection of biomass for cooking and heating (FAO, 2011). Some studies have noted the pivotal role of women in collecting biomass for cooking in rural and mountainous areas in Viet Nam, and addressed the issue of the time saved collecting biomass due to the switch to biogas, showing relatively different results (Liên danh RCD – ASEC, 2016). In order to complement these studies, a sample of 57 biogas-using households were selected in two provinces with an important number of biogas projects: Phu Tho in the Northern Midlands and Mountains, and Tay Ninh in the South East. The selection of biogas-using households for this project was conducted with the support of the Centers of Agricultural Extension. The invitation was distributed to biogas-using households in those communes with the highest number of biogas projects. Interviews were conducted with the members of the selected households, of which 56 percent were men and 44 percent were women. The interviews with the selected households included questions related not only to the time saved per day from collecting biomass or firewood, but also the time saved per day from cooking and cleaning cooking appliances following the switch to biogas stoves.

4.13.2 Key findings

The existing studies addressing (among other things) the issue of the time saved by women and children collecting biomass and cleaning cooking appliances as a result of the switch to biogas show pretty heterogeneous results, which might reflect, at least in part, regional and local differences.

According to Cuong *et al.* (2011), on average, a household may save up to 3-4 hours a week, or 25-34 minutes per day fetching or buying fuels.

According to the Biogas User Survey 2010-2011 (Dung, 2011), women benefit from the introduction biogas because it saves time and is quick and clean. Women stated to have saved, on average, 2.3 hours daily. With this spare time, 10.9 percent of women, mostly in the Northern provinces, declared to be involved in income generation activities. 32.3 percent also said that they could enjoy more time with their friends and neighbours in social activities, and 29.4 percent stated that they could now help their children study.

The Biogas User Survey 2014 (EPRO, 2016) found that, on average, a biogas user household saves 83.4 minutes (1.39 hours) per day from cooking, cleaning and other daily activities by using a biogas stove. Owing to the use of biogas stoves, a woman in a biogas household saves on average 36.6 minutes (0.61 hours) per day. However, the Baseline survey of the Low Carbon Agriculture Support Project (LCASP) (Liên danh RCD – ASEC, 2016) concluded that there was no clear indication of the time saved for women in housework before and after installing biogas stoves.

The survey conducted as part of this research in Phu Tho and Tay Ninh provinces in April and May, 2017 shows that, on average, before switching to biogas, household members spent 1.83 hours per day collecting biomass, 2.15 hours cooking and 0.61 hours cleaning cooking appliances. After the transition to biogas, the average time spent per day by the same household members performing these activities had been reduced significantly, to 0.14 hours (for biomass collection), 1.18 hours (for cooking), and 0.33 hours (for cleaning cooking appliances), with almost 1.7 hours less collecting firewood and a total time saving of 2.94 hours (see **Table 82**). The survey indicates that the time saved is mainly used for production activities (91.1 percent) and entertainment (41.3 percent); and very little time saved is used for studying (4.4 percent households).

TABLE 82

TIME USED FOR COLLECTING BIOMASS AND OTHER DAILY ACTIVITIES BEFORE AND AFTER BIOGAS INSTALLATION

	NUMBER OF OBSERVATIONS	BEFORE USING BIOGAS	AFTER USING BIOGAS	TIME SAVED
TIME USED FOR FIREWOOD COLLECTION (HOURS/DAY)	33	1.83	0.14	1.69
TIME USED FOR COOKING (HOURS/DAY)	41	2.15	1.18	0.97
TIME USED FOR CLEANING COOKERS AND COOKING APPLIANCE (HOURS/DAY)	32	0.61	0.33	0.28

Source: Survey in Phu Tho (April, 2017) and Tay Ninh (May, 2017)

This survey did not cover the time used to operate and maintain the biogas system and in fact such information and data are not found elsewhere. As reported in Dung (2011), biogas pipes, pressure meters and biogas valves tend to be the most problematic and were normally fixed or repaired by the households themselves with the help of the biogas shops. According to the Liên danh RCD – ASEC (2016), 80 percent of biodigester operators are men and 100 percent of problems with the biogas systems are fixed by men.

Regarding the users of the biogas stoves, among the 57 households interviewed in the Phu Tho and Tay Ninh provinces, 96.5 percent were adults and 3.5 percent were children; 71.9 percent of men claimed to be the main users of such stoves, versus 31.6 percent of women.

The high share of male users of the biogas stoves reflect some important changes that took place in the Vietnamese society in recent years. A patriarchal family, with the man as the head of the household, was the traditional structure of the Vietnamese family in the past. This was very common in the rural and mountainous areas. In a traditional family, women were normally cooking and doing housework. Nowadays, due to industrialization and urbanization, the family structure as well as the labour distribution between men and women can be seen to be changing. There is a tendency for women to move to the cities to find jobs. In addition, there are different sources of cooking fuel that a household can use besides biogas, such as electricity, gas and coal (in addition to solid biomass). Women might prefer using other sources of cooking fuel than biogas, for instance because they may find it easier/safer. This could partly explain why the percentage of male primary users of the biogas stoves is higher than that of female users.

4.13.3 Main conclusions and recommendations

Approach used

Data for the measurement of this indicator come from a survey of 57 biogas-using households in two provinces of Viet Nam. The study measures time saved by a biogas user household as a whole from fetching firewood as the survey was not able to address gender differences such as the share of male-headed/female-headed households interviewed or who is mainly responsible for collecting firewood and for cooking in the case of solid biomass and biogas stoves. The study used a 'before and after' design to measure the time used for fetching firewood before and after biogas installation, therefore the continuous change over time in hours was not measured.

Results

Based on the analysis of the primary data collected from the two field surveys in Phu Tho and Tay Ninh provinces, it was found that on an average a biogas household saves 1.68 hours per day in collection of firewood. During the field survey it was also found that the time saved by women and children living in an urban area would be different from the ones living in the rural and remote/mountainous areas.

Previous studies show varied results. Cuong *et al.* (2011) conclude that, on average, a household may save up to around half an hour per day fetching or buying fuels, while the EPRO (2016) found that, on average, a biogas user household saves about one and a half hours per day from cooking, cleaning and other daily activities owing to the biogas use, and a woman in a biogas household saves on average 36.6 minutes per day. Dung (2011) has a different result; they found that women save on an average 2.3 hours daily from collecting firewood, cooking and cleaning cooking appliances.

Practices and policies to improve sustainability

As described above, with the switch from traditional biomass use to biogas, households can save a significant amount of time, especially in firewood collection. The saved time can be used for income-generating activities, education or leisure, with positive socio-economic effects. Continuing to promote the uptake of household level biogas systems could thus yield important social and development returns.

Future monitoring of Indicator 13 in Viet Nam

Within this project, a possible baseline value for indicator 13 was produced but it was not possible to estimate changes in time spent collecting biomass due to lack of comparable information in different moments of time. Future monitoring will allow for comparison with the baseline established by the initial study.

Apart from biogas, the main substitute fuel for cooking in Viet Nam was found to be electricity and, more often, gas. The decrease in wood fuel consumption that has been reported in Viet Nam during the past decade appears to be linked to the increase in access not only to biogas but also these other fuels. Therefore, although the time savings measured by this indicator are a result of the transition away from traditional biomass use, which the adoption of biogas systems positively contributes to, time saved by households using biogas cannot be attributed only to biogas use. In the future, in order to assess the social impacts of bioenergy separately from those of other energy sources, the sample of households should also include non-biogas user households.

In terms of future data collection, in order to increase the validity of measurement of this indicator, there should be a larger sample of households covering different regions of the country. The current sample size was quite small and was selected in only two provinces, representing only two regions, while Viet Nam has six regions where biogas projects are built in many different provinces. Each region has different socio-economic development planning so a stratified sample should be obtained that takes into account geographical and income factors during sample selection.

Future surveys should also take into consideration gender factors in order to be able to distinguish the different gender roles in relation to collection of firewood, biogas operation and cooking. To better describe the Vietnamese context, a gender neutral title could be adopted for this indicator (e.g. "time spent collecting biomass per household"), which would still allow for disaggregation of time spent by different members of the household within the measurement.

In addition, due to memory limitations, interviewees may struggle to remember exactly how much time he or she spent 20 or 30 years ago collecting firewood and it is not clear how many days the firewood he or she collected can be used for. That is why it is suggested that a combination of a time-use survey with direct observation would be a better approach, providing more reliable data.

REFERENCES

Cuong, N.D. et al, 2011. Exploring Biogas Market Opportunities in Viet Nam. Available at: https://documents.tips/education/giz2013-en-exploring-biogas-market-opportunities-vietnam.html

Dung, N.Q. 2011. Biogas user survey 2010-2011. Independent Consultant Group, June 2011.

EPRO Consulting JSC, 2014. Biogas User Survey 2013. Available at: http://biogas.org.vn/english/getattachment/An-pham/2014/BIOGAS-USER-SURVEY-2013/Biogas-User-Suvey-Report-2013_eng.pdf.aspx

EPRO Consulting JSC. 2016. Biogas User Survey 2014

Liên danh RCD – ASEC. 2016. LCASP Baseline survey Report (Agriculture Support Project Low Carbon)

SNV. no date. Vietnam Biogas Programme. Available at: www.snv.org/project/vietnam-biogas-programme

4.14 INDICATOR 14: BIOENERGY USED TO EXPAND ACCESS TO MODERN ENERGY SERVICES

Do Tien Minh
Vietnam Japan International Institute for Science of Technology (VJIIST) at the Hanoi University of Science and Technology (HUST)

DESCRIPTION:

(14.1) Total amount and percentage of increased access to modern energy services gained through bioenergy measured in terms of (14.1a) energy and (14.1b) numbers of households.
(14.2) Total number and percentage of households using bioenergy disaggregated into modern bioenergy and traditional biomass.

MEASUREMENT UNIT(S):

(14.1a) Modern energy services can take the form of liquid fuels, gaseous fuels, solid fuels, heating, cooling and electricity. A change in access to each of these forms of modern energy can be measured in MJ per year and this is preferable in order to allow comparison of different forms of energy service, but each may also be measured in appropriate units of volume or mass per year, which may sometimes be more convenient, leading to the following possible units for this indicator component:

- Liquid fuels: litres/year or MJ/year and percentage;
- Gaseous fuels: cubic meters/year or MJ/year and percentage;
- Solid fuels: tonnes/year or MJ/year and percentage;
- Heating and cooling: MJ/year and percentage; and
- Electricity: MWh/year or MJ/year (for electricity used), MW/year (if only electricity generation capacity to which new access is deemed to have been gained can be measured), hours/year (for the time either for which electricity is used or for which there is access to a functioning electricity supply) and percentage.

(14.1b) number and percentage
(14.2) number and percentage

4.14.1 Implementation of Indicator 14 in Viet Nam

Sub-indicator 14.1

In order to calculate component 14.1, data on the amount of modern energy consumed by household sector, the amount of biogas generated by a household anaerobic digester (AD), the number of households owning an AD and the number of households with access to modern energy services[13] are needed. Data needed for calculating the amount of modern energy consumed by the household sector are: total final energy consumption by the household sector (IEA, 2017); share of households using kerosene for cooking and lighting; share of households using improved cookstoves to burn biomass for cooking (MECON Project, 2014); share of households using electricity generated from biomass and biofuels (ADB, 2015; EVN, 2015); and share of households using biofuels for transportation and irrigation (data unavailable).

To measure this indicator in relation to the biogas produced by household biodigesters in Viet Nam, the following data were used: number of household ADs in operation (MARD,

[13] GBEP defines 'modern energy services' as 'availability for the end user of: electricity for lighting, communication, healthcare, education and other uses; modern fuels or technologies for cooking, heating and cooling; mechanical power for productive use (e.g. irrigation, agricultural processing), provided through electricity or modern fuels, or directly through renewable sources such as hydropower; and transport, provided through electricity or modern fuels. The GBEP definition of modern energy services is based on two criteria: energy efficiency and safety to human health. Where modern energy services rely on the combustion of fuels, the fuels (whether solid, liquid or gaseous) must be burned in efficient and safe combustion chambers, improved cookstoves or fuel cells. Efficiency is meant here as the energy output as a percentage of the heating value of the fuel. Safety refers to the absence of indoor air pollutants and low amount of air pollutants released in the open air by the energy system' (FAO, 2011, pp.208-209).

2016); average heat generated per household AD (FAO, 2012); and the number of households with access to modern energy services (with the electrification rate reported in EVN (2015) used as a proxy) gained through bioenergy.

Sub-indicator 14.2

The estimated value of number of households using modern bioenergy was obtained by dividing the quantity of energy from bioenergy sources provided to households through grids in the form of electricity, cooling or heating by the average the energy consumption per household. To disaggregate this figure into modern and traditional use of biomass, the share of households using traditional biomass and total number of Vietnamese households was compared. The strategy and the data sources used to define/collect the above mentioned data are as follows:

- Quantity of energy from bioenergy sources provided to households through grids in the form of electricity, cooling or heating;
- Average amount of energy consumed by a Vietnamese household (EPRO, 2014);
- Share of households using traditional biomass (MECON Project, 2014); and
- Total number of households of Viet Nam (GSO, 2014).

4.14.2 Key findings

Sub-indicator 14.1:

Total amount and percentage of increased access to modern energy services gained through bioenergy measured in terms of (14.1a) energy and (14.1b) numbers of households.

Sub-indicator 14.1a: Total amount of increased access to modern energy services gained through bioenergy, measured in terms of energy.

Total modern energy consumed by the household sector

According to IEA (2017), over the period 2010-2015, total modern energy consumed by the household sector in Viet Nam increased from 4 816 to 6 297 KTOE, or 5.5 percent per year. The highest contribution to this growth was provided by electricity, with 9.8 percent per year, followed by oil products, with 1.1 percent per year. In contrast to growth of electricity and oil products consumption, there was a decrease in coal use by 1.6 percent per year in the same period. In 2015, total final modern energy consumption by the household sector was 6 297 KTOE, of which coal (that is mineral coal to make honeycomb coal briquette), oil products and electricity accounted for 17.7 percent, 13.5 percent and 68.8 percent respectively. This figure, however, should be adjusted based on GBEP's definition of modern energy services. Under this definition, coal used as honeycomb coal briquette could be considered a type of modern energy because it is burned in an oven with a chimney, while kerosene is not as it is used in a traditional open fire. In addition, energy generated from biomass through combustion or fire with chimney, for example biomass-based electricity, biofuels for transportation and irrigation, and biomass burning in the improved cookstoves, should be considered modern energy. The amount of energy from kerosene and biomass-based electricity should be negligible due to the following two reasons. Firstly, according to the MECON project (2014), only 0.7 percent and 1.7 percent of surveyed households used kerosene for cooking and lighting, respectively. Secondly, in the total energy generation mix in 2014, biomass-based electricity accounted only for 0.49 percent, and only 35.6 percent of this amount was consumed by the household sector (ADB, 2015). For transportation, ethanol use or E5 gasoline does not give new access to modern energy services since it replaces gasoline that was used before and does not give access to modern energy to more people compared to the benchmark. Therefore, the amount of bioenergy that should be added to total modern energy consumed by the household sector includes biomass used for improved cookstoves and biogas from household ADs.

The amount of energy produced from burning biomass in improved cookstoves was calculated as follows. The survey in the MECON project shows that in 2014, only 7.4 percent of total households interviewed used improved cookstoves. According to EPRO (2014), a household that uses solely biomass for cooking and heating, will consume, on average, 10.87 Kg of firewood (LHV14 = 15 MJ/Kg) and 4.26 Kg of agricultural residues (e.g. rice straw and rice husk, LHV2 = 12MJ/Kg) per day. This is equal to 129 834 000 GJ/year or 3 103.1 KTOE:

According to the Institute of Heat Engineering and Refrigeration of the Hanoi University of Science and Technology (GACC, 2013), the average efficiency of the improved cook stoves is assumed to be around 17.6 percent, therefore the amount of energy provided by biomass from improved cookstoves is 546.2 KTOE (3 103.1 x 0.176).

In order to evaluate the contribution of household biogas to increasing access to modern energy, the amount of biogas generated by household digesters was estimated based on the number of household ADs that are in use and the average amount of energy generated by each of them. For the number of ADs, according to the statistical data released by of the Department of Livestock Production, MARD (2016), 450 000 small digesters, with average capacity of 10 m^3, were built over the period 2010-2015, mostly for treating waste from pig husbandry, and 90 percent of these plants are in use. Thus the number of operational ADs could be equal to 405 000. EPRO (2014) also confirms that each household who has already installed an AD has only one. For the average amount of energy generated by each AD, FAO (2014), shows that every m^3 of AD can produce 0.3 m^3 of biogas per day with an energy content of 0.0216 GJ/m^3. Therefore, a 10 m^3 biodigester could produce 24 GJ per year (10 x 0.3 x 365 x 0.0216). Therefore, at the national level, the 405 000 ADs can generate 9 720 000 GJ per year (405 000 bio-digesters x 24 GJ/year), equal to 232.3 KTOE. However, this value represents the gross energy output generated by ADs, whereas the net usable energy[15] of households from using biogas depends on the efficiency of the final use of biogas, for example heating, cooking, lighting or electricity generation. According to EPRO (2014), more than 98 percent of biogas is used for cooking and heating at household level. Therefore, the net energy for households from biogas is equal to the amount of biogas produced by the ADs multiplied by the efficiency of the biogas cooker. Efficiency of an uncontrolled biogas cookstove is 32.7 percent (as shown in indicators 1, 4 and 18). So the net energy value is 75.9 KTOE (232.3 KTOE x 32.7/100).

So, taking into account both the IEA (2017) and the GBEP (FAO, 2011) definition of modern energy services, the total amount of modern energy consumed by the household sector in Viet Nam is (6 297 + 546.2+ 75.9) = 6 919.1 KTOE.

Total amount and percentage of increased access to modern energy services gained through modern bioenergy

- Total amount of modern bioenergy consumed by the household sector = amount of energy from burning biomass in improved cookstoves + amount of energy generated by household ADs = 546.2 + 75.9 = 622.1 KTOE
- Share of modern bioenergy in total modern energy consumption by household sector = (622.1/6 919.1) x 100 = 8.99 percent. In particular biomass energy from improved cookstoves, and ADs (biogas) account for 7.89 and 1.1 percent of total modern energy consumption, respectively.

Sub-indicator 14.1b: Total amount and percentage of increased access to modern energy services gained through bioenergy, measured in terms of numbers and percentage of households with access to modern energy services.

Number of households with access to modern energy through improved cookstoves

According to MECON Project (2014), the share of households who have access to modern energy through the use of improved cookstoves is equal to 7.4 percent of the total number of Vietnamese households (22 444 322); this gives a total of 1 660 880 households (22 444 322 x 7.4) with access to modern energy through improved cookstoves.

14 According to the Engineering Tool Box (2017).

15 Net usable energy = gross energy output – energy losses (from e.g. leakage or efficiency)

Number of households with access to modern energy services through biogas

As indicated by MARD (2016), the number of households with and AD is 450 000 but only 90 percent of these are actually operational, therefore the number of households with access to modern energy services through biogas is 405 000.

Total number of households with access to modern energy services

In 2015, 98.76 percent of Vietnamese households were grid-connected (EVN, 2015). This rate was used as a proxy for the share of households with access to modern energy services. The number of Vietnamese households with access to modern energy services is therefore: 22 444 322 x 98.76/100 = 22 166 012.

Amount and percentage of households with access to modern energy services from bioenergy

- Number of households with access to modern energy from modern bioenergy = number of households with access to modern energy from improved cookstoves + number of households with access to modern energy from biogas = 1 660 880 + 405 000 = 2 065 880.
- The percentage of households with access to modern energy through bioenergy is 9.32 percent, of which shares of households with access to modern energy from improved cookstoves and biogas are 7.49 percent and 1.83 percent, respectively.

$$\frac{\textit{No. of households with access to modern energy from modern bioenergy}}{\textit{No. of households with access to modern energy services}} \times 100$$
$$= \frac{2{,}065{,}880}{22{,}166{,}012} \times 100 = 9.32 \textit{ percent}$$

Sub-indicator 14.2:

Total number and percentage of households using bioenergy disaggregated into modern bioenergy and traditional biomass.

Number of households using modern bioenergy

The number of households using modern bioenergy is equal to the quantity of energy from bioenergy sources provided to households through biofuels (ethanol), electricity, cooling or heating divided by the average energy consumption per household.

As indicated above, modern bioenergy services provided to households in the form of electricity are negligible, therefore, only biogas, ethanol and biomass for improved cookstoves are considered.

- For the biomass used in improved cookstoves, the amount of energy provided is 546.2 KTOE.
- For biogas, there are two sources. The first is from cassava starch production plants. However, this biogas source is used for heating of the plant only, while the biogas surplus is flared into the air without any household use. So this first source can be ignored. The second source is household ADs, which are mostly used for cooking and heating (98.56 percent, EPRO 2014). As calculated above, the amount of energy from household ADs in 2014 was 75.9 KTOE.
- For the ethanol to produce E5 gasoline, the energy released from burning ethanol in the combustion engine can be estimated based on the amount of E5 consumed by motorbikes and cars that are being used by households. According to the Viet Nam Register, in 2016 Viet Nam has 45 million motorbikes. It was assumed that each motorbike travels 5 km per day and that the average consumption of economic fuel is 3 litres of gasoline per 100 km (HUST, 2017). Therefore, the total amount of gasoline consumed by all Vietnamese motorbikes per year can be calculated as 2 463 750 m^3:

$$\textit{No. motorbikes} \times \textit{travel per day} \times \textit{days per year} \times \textit{consumption}$$
$$= 45{,}000{,}000 \times 5 \times 365 \times 3 \times 10^{-2} \times 10^{-3} = 2{,}463{,}750\ m^3$$

In 2016, the total amount of gasoline consumed by cars and motorbikes nationwide was 7.4 million m^3, of which E5 gasoline accounted for 8 percent or 592 000 m^3. Assuming that E5 gasoline is used equally in both cars and motorbikes, the total amount of E5 consumed by motorbikes in 2016 was 197 100 m^3:

$$\frac{\textit{Total gasoline consumed by motorbikes}}{\textit{Total gasoline consumed by cars \& motorbikes}} \times \textit{Total E5 consumed}$$
$$= \frac{2{,}463{,}750}{7{,}400{,}000} \times 592{,}000 = 197{,}100\ m^3$$

The amount of E5 gasoline consumed by cars in 2016 was 395 000 m^3 (592 000 – 197 000). According to the Viet Nam Register, the number of household cars accounted for 35 percent of the total car population in Viet Nam and the rest belong to Government offices and businesses.

Assuming that all cars consume the same amount of E5 gasoline, the total volume of gasoline used by household cars in 2016 was 138 250 m^3. Therefore, the total amount of E5 gasoline consumed by the household sector in 2016 was 335 350 m^3 (197 100 for motorbikes + 138 250 for cars). Each m^3 of E5 gasoline contains five percent ethanol so the amount of ethanol to produce 335 350 m^3 of E5 gasoline is 16 767.5 m^3 (335 350 x 0.05). Heat released from burning 1 m^3 of ethanol is 21 100 MJ, therefore the gross heat output from burning 16 767.5 m^3 of ethanol is 353 794 250 MJ (16 767.5 x 21 100), equal to 8.46 KTOE (353 794 250/41 840 000). On average, efficiency of a gasoline combustion engine is 40 percent, therefore, the net useful heat from burning 16 767.5 m^3 ethanol in a gasoline combustion engine is 3.38 KTOE (8.46 x 0.4).

Therefore, the total amount of modern bioenergy consumed by the household sector is 625.48 KTOE (546.2 from improved cookstoves + 75.9 from biogas + 3.38 from E5 gasoline).

Average energy consumption per household can be calculated by dividing the total energy consumption of the household sector (6 919.1 KTOE) by the total number of households (22 444 322), which is equal to 3.083×10^{-4} KTOE per household per year.

The number of households using modern bioenergy is therefore 2 028 803 households ($625.48/3.083 \times 10^{-4}$).

Number of household using traditional biomass

The MECON project (2014) shows that 34.1 percent of Vietnamese households use traditional biomass. According to GSO, at present, Viet Nam has 22 444 322 households. Therefore, the number of households using traditional biomass is 7 653 514 (22 444 322 x 34.1).

Number and percentages of households using bioenergy disaggregated into modern bioenergy and traditional biomass

In Viet Nam, households using improved cookstoves and biogas stoves tend to use other types of fuels and technologies as well for cooking, heating and lighting, including traditional biomass. For this reason, it was not possible to compute this sub-indicator.

4.14.3 Main conclusions and recommendations

Approach used

In this research, indicator 14 was analysed at the national level using mostly data from national and international statistics and reports. In order to overcome data gaps, some assumptions were made. For example, it was assumed that there was no change over time in the shares of Vietnamese households using traditional biomass and improved cookstoves for cooking since the 2014 MECON project report. Similarly, the ratio of the household ADs that are not in operation was assumed to still be 10 percent. Finally, to reflect the context of this research, some data were adjusted, for instance, traditional biomass used in improved cookstoves is considered as modern energy while kerosene is not, as it is not used in an efficient way.

With the above data sources and mentioned assumptions, the computation of indicator 14 was carried out in the following way:

- For sub-component 14.1, the amount of modern energy and bioenergy were calculated based on biomass used for improved cookstoves and biogas generated by household ADs. The number of households with access to modern energy and bioenergy services were estimated based on the total number of Vietnamese households, the share of households with access to electricity, the share of households using improved cookstoves and the number of households with ADs. Finally, the total amount and percentage of increased access to modern energy services gained through bioenergy measured in terms of (14.1a) energy and (14.1b) number of households were calculated based on the results of the first two steps.
- For sub-component 14.2, the number of households using bioenergy was calculated based on the average energy consumption per household and total amount of bioenergy used by households including biomass for improved cookstoves, biogas from household ADs and ethanol from E5 gasoline. The number of households using traditional biomass was estimated based on the total number

and share of Vietnamese households using traditional biomass. Finally, total number and percentage of households using bioenergy disaggregated into modern bioenergy and traditional biomass were computed based on the results of the two previous steps.

Results

The results of the measurement of indicator 14 show that biogas plays a fairly important role in modern energy consumption in the household sector. As a matter of fact, biogas accounted for 1.1 percent of total modern energy consumed by households. Although only 1.83 percent of Vietnamese households currently use biogas, the potential for further biogas development in Viet Nam is high if the following factors are taken into consideration. Firstly, the number of Vietnamese households with pig husbandry is six million, and 81 percent of these households currently without biogas stated that they wanted to build an AD and among those 55 percent would also build an AD without the help of a subsidy (EPRO, 2014). Secondly, apart from household ADs, the country also has 23 000 small pig farms and 1 500 industrial-scale pig farms where a large volume of biogas could be produced (LCASP, 2017). Finally, a significant amount of biogas is being wasted in the cassava starch production plants and this amount of energy should be used for power generation and distributed to local households.

Policies and practices to improve sustainability

For biogas to enhance access to modern energy services, support is required from government policies, such as the National Energy Policy and Renewable Energy Policy, among others. This would facilitate the biogas market development and application of advanced technologies so that biogas can be used in an efficient and safe way.

Future monitoring

For Future monitoring, it is important to overcome some gaps relating to data sources and coordination among institutions, as well as keeping the available data sources updated. For instance, the share of households using improved cookstoves and traditional biomass may change over time as a result of increasing income. In addition, due to the change in the structure of agricultural production, the number of pig farms will likely increase while the number of pig-raising households (which could install an AD) will likely decrease. This may lead to a change in the use of bioenergy. High income households will use cleaner and more convenient energy sources such as LPG and electricity instead of agricultural residues and biogas. It is necessary to conduct some deeper studies to understand the impact of living standards on energy use and impact of prices on substitute energy types so that appropriate policies could be made to facilitate efficient use of bioenergy. In order to carry out these studies successfully, strong coordination and cooperation is required amongst local and international institutions.

REFERENCES

ADB. 2015. Vietnam energy sector assessment, strategy, and road map. Available at: www.adb.org/sites/default/files/institutional-document/178616/vie-energy-road-map.pdf [Accessed on 15 Apr 2016]

Engineering Tool Box. 2017. Wood and Biomass Heat. Available at: www.engineeringtoolbox.com/wood-biomass-combustion-heat-d_440.html [Accessed on 15 February 2018]

EPRO. 2014. Biogas User Survey 2013. Available at: www.biogas.org.vn/english/getattachment/An-pham/2014/BIOGAS-USER-SURVEY-2013/Biogas-User-Suvey-Report-2013_eng.pdf.aspx [Accessed on 15 Apr 2017]

EVN. 2015. Electricity of Viet Nam. Annual report. Available at: www.evn.com.vn/UserFile/User/tcdl/BCTN%202015_Fi_Final.pdf [Accessed on 15 Apr 2017]

FAO. 2014. The Low Carbon Agricultural Support Project (LCASP) in Vietnam: Carbon balance appraisal with the Ex-Ante Carbon balance Tool4. Available at: www.fao.org/fileadmin/templates/ex_act/pdf/case_studies/draft_aout2012-clear.pdf [Accessed on 9 Sept 2017]

FAO. 2011. The Global Bioenergy Partnership Sustainability Indicators for Bioenergy. First Edition. ISBN 978-92-5-107249-3. Available at: www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/Indicators/The_GBEP_Sustainability_Indicators_for_Bioenergy_FINAL.pdf

GACC. 2013. The clean cooking catalog. Product and performance data for the cookstove sector. Available at: http://catalog.cleancookstoves.org/test-results/622 [Accessed on 9 Sept 2017]

GSO website. 2014. Mid-term population census and housing statistics. Available at: www.gso.gov.vn/default.aspx?tabid=403&idmid=&ItemID=14259 [Accessed on 15 Apr 2017]

HUST. 2017. Combustion Engine Laboratory at the Hanoi University of Science and Technology, Fuel economy of combustion engine.

IEA. 2017. Vietnam: Energy balance for 2015. Available at: www.iea.org/statistics/statistics-search/report/?year=2014&country=Vietnam-&product=Balances [Accessed on 15 Apr 2017]

LCASP. 2017. Annual Report 2017. Available at: http://lcasp.org.vn/uploads/kien-thuc/2017_04/131326556632985253_lcasp-lic-annual-rep.pdf [Accessed on 15 Apr 2017]

MARD. 2016. Real situation and solutions for environmental treatment of livestock production.

MECON Project. 2014. Household energy efficiency: a socio-economic perspective, Vietnam. Available at: www.meconproject.com [Accessed 15 Apr 2017]

Viet Nam Register. 2016. Available at: www.vr.org.vn

4.15 INDICATOR 15: CHANGE IN MORTALITY AND BURDEN OF DISEASES ATTRIBUTABLE TO INDOOR SMOKE

Nguyen Viet Cuong
The Asian Institute of Technology Center in Vietnam (AITCV)

DESCRIPTION:

(15.1) Change in mortality and burden of disease attributable to indoor smoke from solid fuel use (firewood and coal)
(15.2) Changes in these as a result of the increased deployment of modern bioenergy services, including improved biomass-based cookstoves.

MEASUREMENT UNIT(S):

Percentages

4.15.1 Implementation of Indicator 15 in Viet Nam

Nationally representative data on health, especially respiratory diseases, are very limited in Viet Nam. Collection of health data is costly. There are several household surveys, but they mainly contain data on healthcare utilization and spending. Health data related to indoor smoke are even rarer. Moreover, detecting the causal effect of smoke on health is almost impossible. It requires a randomized control trial with a long time duration. In this project, a small field survey was implemented to collect data on health status and respiratory diseases of households using biogas. However, only a few individuals reported their health problems. In addition to the survey, we conduct a review of available studies in Viet Nam to have assessment on the effect of smoke on health as well as the role of biogas on health improvement.

4.14.2 Key findings

As already mentioned in Chapter three, in Viet Nam there are around 450 000 household level anaerobic digesters, of which 90 percent (i.e. 405 000) are operational (LCASP, 2016). Furthermore, over 1.66 million households (i.e. around 7.4 percent of the total) use improved cookstoves (MECON Project, 2014). However, over one third of Vietnamese households still rely on traditional biomass for cooking (MECON Project, 2014), and almost five percent of them use coal (GSO, 2011). In most cases, this biomass is burned in inefficient stoves, leading to a high level of indoor pollution. According to the World Health Organization, in 2004 70 percent of the Vietnamese population was exposed to indoor pollution from solid fuel use (WHO, 2018), while the Global Alliance for Clean Cookstoves (GACC, 2018) reports that 51 percent of the population (i.e. over 45.3 million people and 9.8 million households) are affected by household air pollution.

Exposure to indoor air pollution and the associated health risks are particularly high for households living in a house without a separate kitchen, as typical kitchens in Viet Nam do not have a chimney. According to the Vietnam Household Living Standard Survey (VHLSS) 2016 (GSO, 2016), 32 percent of households live in a permanent house, 60 percent of households live in a semi-permanent house, and 8 percent live in a temporary house. A permanent house often has a separate kitchen, whilst there are no data on the proportion of semi-permanent and temporary houses with a separate kitchen.

In case of households not having a separate kitchen, a large living room can reduce the density of smoke. In Viet Nam, households are considered to have 'deprivation in living areas' if per capita living area is less 8 m^2 (Le *et al.*, 2015). According to the 2016 VHLSS (GSO, 2016), the percentage of households living in a semi-permanent or temporary house with a per capita living area less than 8 m^2 was 8.2 percent in 2016. These households are more likely to be exposed to the health risks associated with indoor smoke, if they use biomass for cooking.

Nationally representative data on health, especially respiratory diseases are very limited in Viet Nam. Health data related to indoor smoke are even rarer. However, a few estimates of the possible deaths and DALYs attributable to indoor air pollution have been made for Viet Nam. According to GAAC (2018), in 2016 the number of deaths attributable to household air pollution in the country were almost 33 600, of which over 660 were child under five. For the year 2004, despite the higher number of households exposed to indoor air pollution from solid fuel use (i.e. 70 percent), a lower number of estimated deaths were reported by WHO, i.e. nearly 24 000. WHO (2018) provides information related to the DALYs due to indoor air pollution as well, which were estimated at 2.8 per 1 000 people in 2004. Local mass media sometimes report several cases of death due to indoor coal use, mainly for heating (e.g. Đức Tiến, 2017). Despite the differences in the data and estimates provided by WHO and GACC (which can be partly explained by the different years they refer to, i.e. 2004 and 2016), the figures mentioned above show the magnitude of the health issues associated in Viet Nam with indoor air pollution, which the burning of traditional biomass in inefficient stoves with no chimney or hood significantly contributes to, showing the benefits of a transition to biogas and improved cookstoves in general.

EPRO (2011) analysed air pollution in eight households in Ngoc Lu commune, Binh Loc district, Ha Nam province, and found that using biogas can significantly reduce air pollution compared with using coal and wood for cooking. The level of CO 60 minutes after cooking in households using wood and straw was found to be five times higher than households using biogas for cooking. The level of H_2S and NH_3 in households using wood and straw for cooking is also around five times higher than households using biogas for cooking. Thus compared to using traditional biomass, using biogas for cooking helps households reduce air pollution significantly.

No studies have been carried out on the health benefits associated with the transition that over 400 000 Vietnamese households have undertaken from traditional biomass to biogas. However, there are several studies on the perception and assessment of households about the benefits of biogas, including from a health perspective. In a survey of 303 households, 96 percent mentioned that the use of biogas reduces smoke in the kitchen and improves indoor air quality (Nguyen, 2011). Dang *et al.* (2011) studied households' self-assessment of the effects of using biogas; most households reported that the main advantage of biogas technology was the improvement in hygiene and health conditions. In addition to a reduction in indoor air pollution, another benefit of biogas mentioned by the interviewed households was the reduction in the exposure to pathogens contained in pig manure[16]. These findings are similar to those of another survey of 340 households using biogas (EPRO, 2014). Most households targeted by the survey suggested that 60-80 percent of environmental pollution from animal husbandry was solved by installing the biodigester. The biogas use was also mentioned to bring positive impacts on the health of household members. More precisely, improvements in the health of women, children and men were perceived by 45 percent, 37 percent and 43 percent, respectively, of the surveyed households.

As already mentioned (e.g. under indicator 13), in order to complement existing studies, a sample of 57 biogas-using households were selected in two provinces with an important number of biogas projects: Phu Tho in the Northern Midlands and Mountains, and Tay Ninh in the South East. As emerged during the interviews that were conducted with these households, with the transition to biogas (e.g. from traditional biomass and stoves) an important reduction in the time spent cooking was reported, i.e. from an average of 2.15 hours to 1.18 hours per day. This, combined with the lower emissions associated with biogas stoves, leads to a significant reduction in indoor air pollution associated with cooking activities.

[16] Evidence of this benefit is lacking in literature. According to some studies (e.g. Le-Thi *et al.*, 2017), anaerobic digestion can actually exacerbate this problem, especially if digesters are poorly designed and maintained and if the resulting effluent (i.e. the so-called digestate) is not properly managed.

4.1.5.3 Main conclusions and recommendations

Approach used

Nationally representative surveys on health, especially respiratory diseases, are very limited in Viet Nam, since collection of health data is very costly. Health data related to indoor smoke are even rarer. In this project, a small field survey was carried out to collect data on health status and respiratory diseases of households using biogas. However, only a few individuals reported their health problems.

In addition to the survey, we conduct a review of available studies in Viet Nam to have an assessment of the effects of smoke on health as well as the role of biogas on health improvement. We used statistics on health related to indoor air pollution from different sources, such as GACC and WHO.

Results

Firewood consumption has been decreasing in Viet Nam. However, 34.1 percent of Vietnamese households still use traditional biomass, mainly wood and straw, and 4.7 percent of rural households using coal for cooking (MECON Project, 2014). The use of wood, straw and coal for cooking can cause indoor smoke and health problems. According to GACC (2018), 51 percent of the population were affected by household air pollution in 2012. WHO (2018) estimates that in 2007, 70 percent of population were affected by indoor air pollution caused by solid fuel use.

GACC (2018) estimates that the number of deaths in 2012 due to household air pollution was 45 thousand. WHO (2018) estimates that nearly 24 thousand people died in 2007 because of indoor air pollution. Although the two data sources provide different estimates, both emphasize the serious problem of household air pollution. Thus, reducing air pollution from wood and coal by changing to biogas can reduce the risk to health.

In Viet Nam, only rural households use biogas. The proportion of rural households using biogas increased from 1.3 percent in 2011 to 2.7 percent in 2016. Although there are no data on the causal effect of biogas on health, there are several studies showing the important role of biogas in reducing indoor air pollution and health problems compared to the use of wood and coal in Viet Nam (e.g. Nguyen, 2011; Dang *et al.*, 2011; EPRO, 2011; EPRO, 2014).

Practices and policies to improve sustainability

Pig manure is the most commonly used feedstock for biogas production at household and farm level in Viet Nam. According to the GSO website, in 2015 there were almost 28 million pigs in the country, with an average of 22 heads for each pig-raising household. Therefore, the theoretical biogas potential is significant. As discussed in this indicator, biogas can play an important role in the reduction of indoor air pollution due to cooking and of the associated health risks. Furthermore, if properly managed, the anaerobic digestion process can potentially reduce the exposure of pig farmers to the pathogens contained in pig manure, even though evidence of this potential benefit is scarce.

It is very important to disseminate information about the adverse health effects of indoor air pollution from the use of solid fuels and especially traditional biomass in inefficient stoves without chimney or hood, especially for women and children. To promote the use of biogas, awareness should be raised, both among decision-makers and the general population, about the benefits of this technology and the important role it can play in mitigating the adverse health effects mentioned above.

Furthermore, it would be important to better train biogas masons and pig farmers on the construction and maintenance of anaerobic digesters and on the management of the digestate, in order to ensure that such digesters function correctly and efficiently, and so that their potential benefits can be fully exploited, including in terms of reduced indoor air pollution and reduced exposure to the pathogens contained in pig manure.

Future monitoring

Information on the health benefits associated with the use of biogas (in comparison with other fuels and technologies such as traditional biomass and stoves) would be very important. However, gathering evidence on the causal effects of biogas consumption on health is challenging, as it would require long-term, costly studies based on a large sample of households (e.g. a large-scale randomized controlled trial for rural households). Furthermore, the effects of biogas use should isolated from those of multiple other factors affecting the health of household members. However, there is plenty of evidence regarding the negative health impacts of exposure to indoor air pollution due to the use of solid fuels and especially traditional biomass and stoves, and thus the positive effects of a transition to biogas are unquestionable.

Another data source that might be useful in monitoring health problems and diseases related to fuel use is hospitals. Using this data, we could compare the incidence of diseases such as respiratory infections in areas with a high proportion of households using biogas and other areas (with similar environmental and socio-economic conditions) with a low proportion. In this study, however, we were not able to obtain such data from hospitals.

REFERENCES

Đức Tiến. 2017. "Vợ chồng tử vong nghi do ngạt khói than tổ ong" (Smoke from firewood suspected as cause of death of husband and wife). Available at: http://thanhnien.vn/thoi-su/vo-chong-tu-vong-nghi-do-ngat-khoi-than-to-ong-794374.html [Accessed: 23 Feb 2017]

EPRO. 2011. Báo cáo Nghiên cứu Đánh giá hiệu quả Giảm ô nhiễm không khí Tại nơi đun nấu nhờ sử dụng Khí sinh học, Công ty Cổ phần Tư vấn EPRO.

EPRO Consulting JSC. 2014. Biogas User Survey 2013. Available at: http://biogas.org.vn/english/getattachment/An-pham/2014/BIOGAS-USER-SURVEY-2013/Biogas-User-Suvey-Report-2013_eng.pdf.aspx

Global Alliance for Clean Cookstoves (GACC). 2018. Country profile: Viet Nam, Available at: http://cleancookstoves.org/country-profiles/70-viet-nam.html [Accessed: 20 Jan 2018]

GSO. 2011. The Rural Agriculture and Fishery Census (RAFC)

GSO. 2016. Viet Nam Household Living Standards Survey 2016.

GSO website. Statistical data (06.Agriculture, Forestry and Fishing), GSO website. Available at: www.gso.gov.vn [Accessed: 24 Jan 2018]

LCASP. 2017. Annual Report 2017. Available at: http://lcasp.org.vn/uploads/kien-thuc/2017_04/131326556632985253_lcasp-lic-annual-rep.pdf [Accessed: 15 Apr 2017]

Le, H., Cuong, N. and Phung, T. 2015. Multidimensional poverty: evidence from Vietnam. *Economics Bulletin, AccessEcon*, vol. 35(4), pages 2820-2831.

Le-Thi, T., Pham-Duc, P., Zurbrügg, C., Luu-Quoc, T., Nguyen-Mai, H., Vu-Van, T. and Nguyen-Viet, H. 2017. Diarrhea risks by exposure to livestock waste in Vietnam using quantitative microbial risk assessment. *International journal of public health*, 62(1), pp.83-91.

Luu, D.H., Potvin, C., Kooijman-van Dijk, A. and Geurts, P. 2011. Vietnam Biogas Assessment Research Project, ETC Energy, The Netherlands.

MECON Project. 2014. Household energy efficiency: a socio-economic perspective, Vietnam. Available at: www.meconproject.com [Accessed: 15 Apr 2017]

Nguyen, D. 2011. Biogas User Survey 2010-2011, Biogas Development Program For Livestock Sector In Vietnam 007 - 2012, Ministry of Agricultural and Rural Development and Netherlands Development Organization (SNV).

SNV. 2018. Vietnam Biogas Programme, SNV Vietnam, Available at: www.snv.org/project/vietnam-biogas-programme [Accessed: 10 Jan 2018]

USAID. 2015. Lessons Learned in Development of NAMAs for Biogas in Vietnam: The AILEG Project. Available at: http://pdf.usaid.gov/pdf_docs/PA00KRW2.pdf

World Health Organization (WHO). 2018. Country profile: Viet Nam, Available at: www.who.int/quantifying_ehimpacts/national/countryprofile/vietnam.pdf [Accessed: 20 Jan 2018]

4.16 INDICATOR 16: INCIDENCE OF OCCUPATIONAL INJURY, ILLNESS AND FATALITIES

Nguyen Viet Cuong, AITCV

DESCRIPTION

Incidences of occupational injury, illness and fatalities in the production of bioenergy relation to comparable sectors

MEASUREMENT UNIT(S)

Number/ha (for comparison with other agriculture activities) or number/MJ or MW (for comparison with alternative energy sources)

4.16.1 Implementation of Indicator 16 in Viet Nam

In Viet Nam, indicator 16 was not deemed relevant for the biogas pathway given that it is primarily used at household or farm-scale level for self-consumption and has very low labour intensity. As a result, the analysis focused on the Cassava-based ethanol value chain. There is very limited information available on the incidence of occupational injury, illness and fatalities along this value chain in Viet Nam, as well as for agriculture as a whole and other economic sectors. However, based on available data and statistics (e.g. from the Viet Nam Household Living Standard Survey (VHLSS) and the Viet Nam Enterprise Census), a few estimates were made. Furthermore, a field survey was carried out, with the aim to collect data on occupational injury, illness and fatalities among cassava-growing households as well as ethanol firms.

4.16.2 Key findings

An important share of the area under cassava cultivation in Viet Nam is on sloping land, particularly in mountainous areas in the North and the Centre (Dao *et al.*, 2006). This makes the cultivation of cassava more difficult, increasing the risk of accidents. In particular, during the rainy season, floods and landslides can take place on this land, causing injuries and fatalities. Farmers who produce cassava are also exposed to health risks associated with the application of chemicals and especially pesticides. Even though specific figures are not available for cassava, according to MOLISA (2007), in the agricultural sector, about 30 percent of people exposed to pesticides show signs of poisoning. In 2004 alone, this caused 154 deaths. Furthermore, the distance between farms and markets or sellers may be high, and accidents can take place during the transportation phase (Dao *et al.*, 2006).

To estimate the incidence of sickness and injury in agricultural households, the 2008 VHLSS was used. Unlike the more recent VHLSSs (from 2010 to 2014), the 2008 VHLSS contains data on sickness of individuals during the past 4 weeks and the past 12 months. **Table 83** reports that 16 percent of individuals working in the agricultural sector were sick or injured during the 4 weeks prior to the survey, and 35.2 percent of them were sick or injured in the 12 month period prior to the survey. Among the sick or injured people, the average number of sick days during those 12 months was 11.3.

The 2008 VHLSS includes disaggregated data for households with and without annual crop land. Furthermore, for the latter, a further disaggregation is made between households with and without cassava land. These data are only available for households with land and no data could be obtained on individual farm labourers. As shown in **Table 83**, cassava-growing households appear to be slightly less likely to be ill or injured than households growing other annual crops.

Regarding the processing stages, Ceco (2015) notes some of the occupational health and safety risks workers are exposed. Firstly, the high density of dust during the preparation of the raw material (i.e. dry cassava) can cause respiratory diseases for workers. Secondly, since the output is ethanol, the risk of fire and explosion is high. Furthermore, exposure to

TABLE 83

SICKNESS OF WORKERS IN AGRICULTURE

HOUSEHOLD TYPE	PERCENTAGE SICK OR INJURED DURING THE PAST 4 WEEKS (percent)	PERCENTAGE SICK OR INJURED DURING THE PAST 12 MONTHS (percent)	NUMBER OF SICK DAYS DURING THE PAST 12 MONTHS (AMONG SICK OR INJURED PEOPLE)
HOUSEHOLDS WITHOUT ANNUAL CROP LAND	17.9	37.4	9.7
HOUSEHOLDS WITHOUT CASSAVA LAND BUT WITH OTHER ANNUAL CROP LAND	15.8	36.4	11.6
HOUSEHOLDS WITH CASSAVA LAND	15.0	29.8	11.8
TOTAL	16.0	35.2	11.3

Source: Own estimates based on the Vietnam Household Living Standard Survey (2008)

leaked gases such as CH_4, CO_2, SO_2 and NO_2, some of which are flammable and/or toxic, can be very dangerous and harmful to health. Thirdly, factories often use coal-fired boilers; exposure to indoor air pollution generated by these boilers can be harmful to the health of workers, causing respiratory diseases and lung cancer. Finally, ethanol factories have high industrial noise, which can affect hearing function and even cause deafness in workers.

The 2011 Vietnam Enterprise Census provides data related to labour accidents in all firms, disaggregated by sector, including twenty plants producing ethanol both for the fuel market and for other markets (e.g. the beverage industry). **Table 84** presents the main characteristics of the over 339 000 firms covered by the Census and those specific to the 20 ethanol plants, which tend to be larger than the average firm, as measured by the number of workers and by revenues.

TABLE 84

CHARACTERISTICS OF ALL FIRMS VS. FIRMS PRODUCING ETHANOL

FIRM TYPE	NUMBER OF FIRMS	AVERAGE NUMBER OF WORKERS	AVERAGE NUMBER OF FEMALE WORKERS	AVERAGE WAGE PER WORKER (million VND/ year)	REVENUE (million VND/ year)
ALL FIRMS	339 268	31.4	13.9	45.6	32 471.6
FIRMS PRODUCING ETHANOL	20	206.9	86.9	44.8	244 271.8
TOTAL	339 288	31.4	13.9	45.6	32 483.1

Source: Own estimates based on the Vietnam Enterprise Census (2011)

The incidence of labour accidents and the related impacts for all firms in Viet Nam is shown in **Table 85**. As shown in the Table, no labour accidents were reported by ethanol firms in 2010. It is important to note, however, that the number of ethanol firms is limited and that those producing ethanol for the fuel market have been operating at very low capacity over the past few years. Furthermore, the Census does not capture the long-term health problems that workers might incur.

TABLE 85

LABOUR ACCIDENTS IN ALL FIRMS VS. FIRMS PRODUCING ETHANOL, 2011

FIRM TYPE	NUMBER OF ACCIDENTS DURING THE PAST YEAR	NUMBER OF INJURED WORKERS DURING THE PAST YEAR	NUMBER OF ACCIDENTS THAT CAUSED FATALITY DURING THE PAST YEAR	NUMBER OF FATALITIES AMONG WORKERS DURING THE PAST YEAR
ALL FIRMS	11 535	11 874	193	210
FIRMS PRODUCING ETHANOL	0	0	0	0

Source: Own estimates based on the Vietnam Enterprise Census (2011)

4.16.3 Main conclusions and recommendations

Approach used

Indicator 16 was measured only for the Cassava-based ethanol value chain as it was not deemed relevant in the case of biogas. Both the cassava cultivation and processing phases were analysed.

Measurement was carried out on the basis of data and statistics from the VHLSS and the Viet Nam Enterprise Census, supplemented by information obtained from the field survey carried out with cassava-growing households and ethanol firms as part of this research.

Results

Data on sickness and injury related to cassava production are very limited as official data on work-related injuries, illnesses and fatalities reported in cassava growing are not available. Compared with households who produce other crops, households growing cassava reported a slightly lower rate of sickness and injury in Vietnam Household Living Standard Survey 2014.

Workers in firm producing ethanol are vulnerable to different risks including dust during preparation of raw materials, air pollution and smoke during the distillation process, and noise pollution, and risk of fire, explosion and leakage of gas. Data from the Vietnam Enterprise Census 2011 show no accidents and injuries in firms producing ethanol. However, given the low overall rate of injuries and deaths in all firms (e.g. 0.00062 deaths due to accidents per firm per year), we would expect these figures for the 20 ethanol firms present in the country. There are no data on long-term diseases on workers in ethanol-producing firms.

Practices and policies to improve sustainability

One of the main causes of labour accidents in the agricultural sector is the lack of awareness of farmers about the main health and safety risks associated with their work. Farmers lack proper information and training, in particular, in relation to the use of agricultural machinery and the application of chemicals, particularly pesticides. In order to mitigate risks, farmers' awareness and capacities should be strengthened by properly disseminating information on health and safety issues in the agricultural sector. In particular, trainings should be carried out for farmers on the proper use of machinery, and the application of fertilizers and pesticides with the right dosage and timing. The use of protective equipment should be promoted and monitored.

At present, the problem of occupational safety in the agricultural sector has not been paid due attention by local authorities. There is no system of legal documents regulating and guiding the implementation of labour safety standards for farmers, or the responsibilities and powers of the authorities at all levels. The inspection and examination of occupational health and safety for agriculture and farmers is not carried out. As a medium- to long-term measure, the State should implement synchronous measures to research and construct a legal system around agricultural health and safety, whilst providing professional staff to guide farmers to implement measures to ensure occupational safety and health in agricultural production, thus avoiding labour accidents in production.

Most of the issues discussed above also apply to the processing stages of the Cassava-based ethanol value chain. As described in the previous sections, workers in ethanol plants are exposed to occupational health and safety risks associated with the various steps of the processing stage. The risk of explosion and gas leakage is high. Hence, electric, gas and boiling systems should be regularly checked. Furthermore, it is important to provide workers with adequate protective equipment. As in the case of cassava cultivation, for firms producing ethanol, labour safety needs to be guaranteed and inspected by local authorities.

Future monitoring

Information and data on occupational health and safety issues and in particular labour accidents may be highly sensitive and thus difficult to obtain from economic operators. However, with the expected expansion in ethanol production as a result of the introduction of the country-wide E5 mandate, it is key to assess the occupational health and safety risks along the various stages of the Cassava-based ethanol value chain. Furthermore, as mentioned above, regular inspections should be carried out by relevant authorities in order to ensure compliance with – and enforcement of – adequate occupational health and safety standards.

In addition to monitoring labour accidents, the long-term health of workers and the incidence of diseases should be assessed as well. Regarding the agricultural sector and cassava cultivation in particular, relevant questions could be added to the VHLSS, which are conducted every two years

REFERENCES

Anh, D.T., Thinh, L.D., Binh, V.T. and Huan, D.D. 2006. Pathways out of Poverty through Secondary Crops and Private Sector Processing as well as Institutional Arrangements in Viet Nam, CAPSA Working Paper No. 95, Economic and Social Commission for Asia and the Pacific.

Ceco. 2015. The investment plan of the bio-ethanol factor, The bioenergy company in central Vietnam.

MOLISA. 2007. "Tai nạn lao động ở Việt Nam - Thực trạng và giải pháp". Available at: http://molisa.gov.vn/vi/Pages/chitiettin.aspx?IDNews=16456

World Health Organization. 2014. "Non communicable Diseases (NCD) Country Profiles"

4.17 INDICATOR 17: PRODUCTIVITY

Cassava-based ethanol pathway: **Dao The Anh and Bui Quang Duan**
Biogas pathway: **Nguyen Thi Dieu Linh**

Centre for Agrarian Systems Research And Development (CASRAD) at Viet Nam Academy of Agricultural Sciences (VAAS)

DESCRIPTION:

(17.1) Productivity of bioenergy feedstock by feedstock or by farm/plantation
(17.2) Processing efficiencies by technology and feedstock
(17.3) Amount of bioenergy end product by mass, volume or energy content per hectare per year
(17.4) Production cost per unit of bioenergy

MEASUREMENT UNIT(S):

(17.1) Tonnes ha per year
(17.2) MJ/tonne
(17.3) Tonnes/ha per year, m^3/ha per year or MJ/ha per year
(17.4) USD/MJ

4.17.1 Implementation of Indicator 17 in Viet Nam

Cassava-based ethanol

To calculate indicator 17 for productivity of Cassava-based ethanol in Viet Nam, various sources of secondary data were used, including GSO website, the Vietnam Export - Import Report 2016 (Viet Nam Finance, 2017), and several other publications and peer reviewed papers. Research and synthesis of documents and data related to ethanol production were carried out to provide an overview of the feedstock sources, ethanol production technologies and cost of ethanol production in Viet Nam.

Biogas

For the measurement of Indicator 17 for the biogas value chain, secondary data were obtained from official national statistics (GSO website). To complement this, primary data were obtained from a survey conducted on 47 households in the Thanh Thuy and Tam Nong districts in the Phu Tho Province, two pig farms in the same province, and two cassava starch processing factories in the Tay Ninh Province.

4.17.2 Key findings

Cassava-based ethanol

a. Productivity (fresh cassava)

According to the GSO data shown in **Table 86**, in 2015 the total harvested area of cassava was around 567 thousand hectares and the total production of fresh cassava was 10 700 thousand tonnes. The weighted average yield was 18.0 tonnes/ha (see indicator 18). Cassava productivity in Viet Nam is relatively low in comparison to other countries – only 50 percent of India's cassava productivity, 15 percent lower than Indonesia and 9 percent lower than Thailand (Viet Nam Finance, 2017). Therefore, Viet Nam could still increase its cassava production in the future, without increasing the harvested area, by using improved cassava varieties, advanced cultivation techniques and good agricultural practices.

TABLE 86

CASSAVA YIELD IN DIFFERENT PROVINCES OF VIET NAM, 2015

	AREA (1000xha)	CAPACITY (1000xtonne)	FRESH CASSAVA YIELD (tonne/ha)	DRIED CASSAVA CHIP YIELD (tonne/ha)
VIET NAM	**567**	**10 700**	**18.0***	**7.2***
YIENBAI	15.8	305.0	19.3	7.5
SON LA	31.2	359.5	11.5	4.5
NGHE AN	17.4	410.0	23.6	9.2
QUANGNGAI	19.7	376.4	19.1	7.5
BINHDINH	13.6	335.5	24.7	9.6
PHU YEN	23.0	397.2	17.3	6.7
BINHTHUAN	30.9	510.8	16.5	6.4
KON TUM	39.5	590.2	14.9	5.8
GIA LAI	63.7	1 180.9	18.5	7.2
DAKLAK	34.0	666.5	19.6	7.6
BINHPHUOC	17.7	410.9	23.2	9.1
TAY NINH	57.6	1 868.3	32.4	12.6
DONG NAI	15.8	399.2	25.3	9.9

** weighted average*

Source: GSO website

Cassava is a crop that has many uses in industrial processing, e.g. production of monosodium glutamate (MSG), alcohol, instant noodles, glucose, syrup, candy, cookies, barley sugar, adhesives (Glue paste for fabric, wood), food additives, pharmaceutical additives, biofuel and ethanol.

As of 2016, the total production of dry cassava chips in Viet Nam was about 4 million tonnes, obtained from 10.7 million tonnes of fresh cassava harvested in the country. In 2015, in terms of dry cassava chips, imports and exports of cassava and cassava products amounted respectively to 1 million tonnes (from Cambodia) and 3.7 million tonnes (Viet Nam Finance, 2017). Thus, about 1.3 million tonnes of dry cassava chips were consumed domestically, mainly for processing animal feeds, and 66 375.7 tonnes were used for ethanol production.

China remained the main export market in 2016, accounting for an 87 percent market share, although there was a decrease of 12 percent in volume and 25.7 percent in value compared with the same period in 2015. In 2016, the Viet Nam import value of cassava and cassava products fell sharply compared to the previous year, for example: Philippines (down 36 percent), Taiwan (down 25.4 percent) and China (down 25.7 percent) (Viet Nam Finance, 2017).

b. Processing efficiencies by technology and feedstock (cassava to ethanol)

As of now, there are eight fuel ethanol plants in Viet Nam, seven of which have been completed and one which was halted due to lack of capital. Five of these plants import and use Chinese technology and the other three use technologies developed in India and the Unites States, but still import equipment from China (Dantri, 2016).

Currently, only two ethanol plants are operating, at very limited capacity (MOIT, 2017). Of these two plants, one is located in the centre of the country and the other one is located in the South (Dong Nai province). The capacity and operation status of all the ethanol plants established in Viet Nam are shown in **Table 87**.

TABLE 87

CAPACITY AND OPERATIONAL STATUS OF FUEL ETHANOL PLANTS IN VIET NAM, 2017

	NAME OF FACTORY	CAPACITY		LOCATION (PROVINCE)	TECHNOLOGY	OPERATIONAL STATUS
		ETHANOL (million litres/year)	CASSAVA CHIPS (tonnes/year)			
1.	PHUTHO BIO-ENERGY CO.	100	250 000	PHU THO	US	NOT OPERATIONAL
2.	DAI TAN ETHANOL PLANT, DONG XANH CO.	120	300 000	QUANG NAM	CHINA	OPERATIONAL
3.	DUNG QUAT ETHANOL PLANT	100	250 000	QUANG NGAI	US	NOT OPERATIONAL
4.	ORIENT BIO-FUEL CO.	100	250 000	BINH PHUOC	INDIA	NOT OPERATIONAL
5.	TUNG LAM ETHANOL FACTORY	76	190 000	DONG NAI	CHINA	OPERATIONAL

Source: Elaborated from Loan T. Le **et al.**, *2013 and MOIT 2017*

The starch content of fresh cassava in Viet Nam is about 25–35 percent, therefore 1 kg of dry cassava chips can theoretically be produced from 2.3–2.5 kg of fresh cassava (Ho Sy Chinh, 2013).

According to data collected through surveys conducted within this study, cassava and ethanol processing technologies currently installed in Vietnamese plants can produce 2.5 kg of dry cassava chips from 6 kg of fresh cassava. From 2.5 kg of dry cassava chips, 2.2 kg of wet cassava starch can be produced, and 2.2 kg of wet cassava starch can produce 1 litre of 99.5 percent ethanol (Institute of Agricultural Science for Southern Viet Nam, 2014). Therefore, 2.5 tonnes of dry chips are needed to produce 1 000 litres of ethanol (equivalent to 6 tonnes of fresh cassava with about 30 percent starch content).

According to the conversion values, 1 litre of ethanol = 21.1 MJ. Given that 2.5 tonnes of dry cassava chips can produce 1 000 litres of ethanol, the processing efficiency of ethanol is 8 440 MJ/tonne of dry cassava chips (equal to 3.52 MJ/tonne of fresh cassava).

c. Amount of bioenergy end product (ethanol)

According to GSO website, in 2015 the average yield was 18 tonnes/ha of fresh cassava, equal to 7.2 tonnes/ha of dry cassava chips (2.5 kg of fresh cassava = 1 kg of dry cassava chips). 2.5 tonnes of dry cassava chips can produce 1000 litres of ethanol, which can generate 21 100 MJ. According to these conversion values, 7.2 tonnes/ha of dry cassava chips can produce 2 880 litres of ethanol, equivalent to 60 768 MJ. Thus, the yield of bioenergy end product is 60 768 MJ/ha per year.

d. Ethanol production cost

Data on ethanol production cost could not be obtained from ethanol plants, due to the commercial sensitivity of this information.

However, according to other studies of ethanol (99 percent) production from cassava, the cost of raw materials (dry cassava chips) accounts for 64 percent of ethanol production cost, the rest being attributed to other costs such as coal, labour, electricity and water, among others (Thanh_tan weblog, 2014).

As the price of dry cassava chips in 2017 (average FOB price) was 175 USD/tonne, an ethanol production cost of about 684 USD/1 000 litres of ethanol (equivalent to 0.68 USD/litre and 0.032 USD/MJ) was estimated.

Biogas

a. Productivity of biogas feedstocks

Animal manure from livestock farms is the feedstock most commonly used for biogas production in Vietnamese households. According to the GSO, in 2015 there were 7 890 thousand heads of cattle (buffalo, cattle), 27 800 thousand heads of pig and 342 000 thousand heads of poultry in the country (**Table 88**).

TABLE 88

LIVESTOCK POPULATION IN VIET NAM, 2011 TO 2015

TYPE OF ANIMAL	2011	2012	2013	2014	2015
BUFFALO	2 712.0	2 627.8	2 559.5	2 521.4	2 524.0
CATTLE	5 436.6	5 194.2	5 156.7	5 234.3	5 367
PIG	27 056	26 494	26 264.4	26 761	27 751
POULTRY	322 600	308 500	317 700	327 700	341 900

Unit: Thousand heads
Source: GSO website

TABLE 89

POTENTIAL DAILY PRODUCTION OF MANURE AND BIOGAS

ANIMAL TYPE	POTENTIAL DAILY PRODUCTION OF FRESH MANURE (kg/head)	POTENTIAL DAILY PRODUCTION OF BIOGAS (litre/kg)
COW	15-20	15-32
BUFFALO	18-25	15-32
PIG	1.2- 4.0	40-60
POULTRY	0.02-0.05	50-60

Source: SNV, 2011

Taking into account the total number of animals raised in Viet Nam (**Table 88**) and the potential daily production of manure and biogas from such animals (**Table 89**), the amount of manure produced by the livestock sector in Viet Nam from 2011 to 2015 was estimated (**Table 90**). According to these estimates, a total amount of 84.8 million tonnes of fresh manure is produced per year from livestock: thus, a large amount of suitable feedstock is theoretically available for bioenergy production through Anaerobic Digestion.

Biogas from pig manure at household and farm level

Pig manure is the most common feedstock used for biogas production at household and farm level in Viet Nam. The body weight of a pig is, on average, approximately 50 kg. The volume of pig waste per day is 5.2 percent of body weight (LCASP, 2017). For each pig, this is equal to 2.6 kg of fresh manure per day or 949 kg of fresh manure per year.

According to EPRO (2016), the average number of pigs per pig-raising household is 22. As a consequence, the amount of fresh manure produced daily by pigs raised by households is approximately 55 kg. Based on these figures, the average amount of fresh manure produced annually by the pigs raised by each household is approximately 20.9 tonnes.

At farm level, the country has 23 000 small pig farms and 1 500 industrial-scale pig farms where a large volume of biogas could be produced (LCASP, 2017 and RuDeC, 2017). The average scale of a Vietnamese pig farm is 709 heads. Therefore, the average amount of fresh manure produced annually by each farm is 673 tonnes.

TABLE 90

TOTAL AMOUNT OF FRESH MANURE FROM LIVESTOCK ACTIVITIES IN VIET NAM, 2011 - 2015

TYPE OF ANIMAL	2011	2012	2013	2014	2015
BUFFALO	21 282 420	20 621 660	20 085 676	19 786 686	19 807 090
COW	34 726 282	33 177 952	32 938 421	33 434 091	34 282 990
PIG	25 676 144	25 142 806	24 924 915	25 396 568	26 335 414
POULTRY	4 120 819	3 940 589	4 058 579	4 186 316	4 367 849
TOTAL	85 805 665	82 883 008	82 007 592	82 803 662	84 793 343

Unit: tonnes/year

Biogas from cassava starch production wastewater at industrial level

In Viet Nam, there are 102 cassava starch processing plants: seven plants have a capacity of more than 50 000 tonnes of cassava starch/year; 40 plants have a capacity of 20 000 - 50 000 tonnes of cassava starch/year; and 55 plants have a capacity of less than 20 000 tonnes of cassava starch/year (Van Dinh Son Tho, 2017).

This indicator was measured on the basis of data collected through surveys conducted within this project in cassava starch processing factories in the Tay Ninh province. In these plants, wastewater from cassava starch production is the main feedstock used for biogas production. The plants have the capacity to process on average 13 500–75 000 tonnes of cassava starch/year and produce an amount of wastewater varying from 243 000 m^3/year to 1 500 000 m^3/year. Thus, a cassava starch plant with an average capacity of 36 750 tonnes per year discharges into the environment almost 720 750 m^3 of wastewater per year (**Table 91**).

Based on these figures, the average volume of wastewater produced and released into the environment from processing 1 tonne of cassava starch is approximately 19.6 m^3.

b. Processing efficiencies by biogas technology and feedstock

Biogas production technologies in Viet Nam

According to the MARD (2016), the following biogas technologies are used in Viet Nam: KT1 - Chinese technology; KT2 and KT3, i.e. floating biogas digester (India); biogas bags made of nylon polyethylene (PE); and biogas cover with tarpaulin HDPE, i.e. composite digester. The total number of ADs installed in Viet Nam, by type of technology and scale/volume, is shown in **Table 92** and more details on biogas technology can be found in Chapter 3.

According to MARD (2016), the existing anaerobic digesters in Viet Nam could be classified depending on their scale/volume as follows: Small Biogas Plants (SBP), Medium

TABLE 91

CAPACITY AND WASTEWATER OUTPUT IN CASSAVA STARCH PROCESSING PLANTS IN THE TAY NINH PROVINCE

NO.	NAME OF FACTORY	CAPACITY (tonnes of cassava starch/ year)	TOTAL WASTEWATER VOLUME (m^3/year)
1	HUNG DUY TRADING INDUSTRY TRANSPORT IM-EXPORT CO., LTD	75 000	1 500 000
2	PHU DAI DONG PRIVATE COMPANY	18 000	330 000
3	THANH BINH CO. LTD	13 500	243 000
4	QUOC DUNG PRIVATE COMPANY	40 500	810 000
	AVERAGE	**36 750**	**720 750**

Source: CASRAD, 2017

TABLE 92

BIOGAS PLANTS IN VIET NAM BY TYPE OF TECHNOLOGY

TYPE OF TECHNOLOGY USED	FARM SCALE (MBP AND LBP)	HOUSEHOLD SCALE (SBP)
TOTAL NUMBER OF BIOGAS PLANTS	15 370	450 000
KT1, KT2	4 032	201 469
COMPOSITE	2 390	89 147
OTHER TYPES	8 948	159 384

Source: MARD, 2016

Biogas Plants (MBP) and Large Biogas Plants (LBP). The SBP digesters have an average volume of 10 m^3, the MBP digesters have an average volume of 500 m^3 and the LBP digesters have an average volume of 2000 m^3.

All ADs installed at household level are classified as SBP, while both MBP and LBP can be found at farm level. The number of SBP digesters (10 m^3) is 450 000 (of which 405 000 in operation), the number of MBP digesters (500 m^3) is 14 370, and the number of LBP digesters (2000 m^3) is 1 000.

Household and farm level

As calculated within Indicator 18, each kg of wet pig manure can generate 1.2 MJ of biogas. With the assumption that 5 percent of biogas is leaked during biogas conversion and that electricity consumption for the processing of 1 kg of wet manure is 0.04 MJ/kg, net energy generation amounts to 1.165 MJ/kg of pig manure on a wet base.

Industrial level (biogas from cassava starch wastewater)

As reported within Indicator 18, currently the biogas yield varies from 2.17 to 4.55 m^3 per m^3 of wastewater. On average, 1 m^3 of wastewater produces 3.06 m^3 of biogas (based on COD of wastewater). Burning 1 m^3 of biogas (LHV) will release 21.6 MJ of heat (FAO, 2012). Therefore, 1 m^3 of wastewater could produce 3.06 x 21.6 = 66.096 MJ of thermal energy. Biogas in cassava starch factories is mainly used to heat the furnace for drying starch. Indicator 18 also explains that the share of produced biogas used in the drying process varies in a range of 50-81 percent, with an average of 58.16 percent. For this reason, it could be said that the actual amount of energy recovered in the process is equal to: 66.1 * 58.16 = 38.44 MJ per m^3 of wastewater (**Table 93**).

TABLE 93

PRODUCTION AND USE OF BIOGAS FROM CASSAVA STARCH WASTEWATER

CONTENT	VALUE	UNIT
BIOGAS YIELD (BASED ON COD OF WASTEWATER SYSTEM)	3.06	m^3 BIOGAS/m^3 OF WASTEWATER
THERMAL ENERGY RELEASED FROM COMBUSTION OF 1 m^3 OF BIOGAS	21.6	MJ/m^3 BIOGAS
SHARE OF PRODUCED BIOGAS USED FOR CASSAVA STARCH DRYING	58.16	PERCENT
AMOUNT OF THERMAL ENERGY FROM BIOGAS USED FOR CASSAVA STARCH DRYING	38.44	MJ /m^3 OF WASTEWATER

c. Potential thermal energy generation biogas

At household and farm level (biogas from livestock manure)

According to FAO (2012), 1 m^3 of wastewater from animal husbandry can generate 0.3 m^3 biogas per day and burning 1 m^3 of biogas (LHV) can release 21.6 MJ of heat (FAO, 2012).

Using these figures, the biogas output at SBP scale (10 m^3) is 24 GJ/plant/year (0.3 x 10 x 0.0216 x 365). Total biogas output of the country for all SBPs is (24 x 405 000) = 9 720 000 GJ/year of thermal energy.

Considering the same FAO figures, the biogas output at MBP level (500 m^3) is 1 134 GJ/plant/y (0.3 x 500 x 0.0216 x (365–15)); this includes an estimated 15 days a year for maintenance of the biogas plants (e.g. for repairing and fixing pipeline, repairing digester tank, replacing stove and removing sediment). Assuming that the share of operating digesters is equal to 90 percent, the total biogas output of the country at MBP scale is 14 666 022 GJ/year.

Using the same methodology, it can be estimated that, at LBP scale (2000 m^3), the total thermal energy generated by biogas in the country could reach 4 082 400 GJ/year. The total potential biogas production at all scales is reported in **Table 94**.

TABLE 94

TOTAL BIOGAS PRODUCTION AT HOUSEHOLD AND FARM LEVELS

TYPE	QUANTITY	NUMBER OF PLANTS (90% in use)	BIOGAS PRODUCED IN GJ/ plant/y	TOTAL BIOGAS PRODUCTION (GJ/y)
SBP (10 m^3)	450 000	405 000	24	9 720 000
MBP (500 m^3)	14 370	12 933	1 134	14 666 022
LBP (2000 m^3)	1 000	900	4 536	4 082 400

Source: MARD, 2016

Industrial level (biogas from cassava starch wastewater)

On average, a cassava starch plant generates 720 750 m^3/year of wastewater. 1 m^3 of this wastewater can yield 66.1 MJ of biogas. Therefore, each plant can produce on average 47 641 575 MJ of biogas per year. Assuming that each of the 102 cassava starch factories in the country has an AD installed, the total amount of thermal energy potentially generated by the biogas produced from cassava starch wastewater is 4 859 440 650 MJ/year. On average, 58.16 of the produced biogas (i.e. 2 826 250 682 MJ/year) is used by the factories to dry cassava starch (**Table 95**).

d. Biogas production cost

For the measurement of indicator 17.4, the cost of biogas production was measured based on the results of the survey conducted on 47 households in the Thanh Thuy and Tam Nong districts in the Phu Tho Province, two pig farms in the same Province and two cassava starch processing factories in the Tay Ninh Province.

TABLE 95

BIOGAS PRODUCTION AT INDUSTRIAL LEVEL

CONTENT	VALUE	UNIT
TOTAL WASTEWATER VOLUME	720 750	m^3/PLANT/YEAR
BIOGAS PRODUCTION PER CASSAVA STARCH PLANT	47 641 575	MJ/PLANT/YEAR
TOTAL NUMBER OF CASSAVA STARCH PLANTS	102	PLANT
TOTAL BIOGAS PRODUCTION	4 859 440 650	MJ/YEAR
SHARE OF PRODUCED BIOGAS USED FOR CASSAVA STARCH DRYING	58.16	PERCENT
AMOUNT OF PRODUCED BIOGAS USED FOR STARCH DRYING	2 826 250 682	MJ/YEAR

Household and Farm Levels

TABLE 96

PRODUCTION COST OF BIOGAS AT HOUSEHOLD AND FARM LEVELS IN THE PHU THO PROVINCE

No.	CONTENT	HOUSEHOLD LEVEL (SAMPLE = 47 HOUSEHOLD)		FARM LEVEL (SAMPLE = 2 PIG FARMS)	HOUSEHOLD LEVEL		FARM LEVEL (SAMPLE = 2 PIG FARMS)
		COMPOSITE DIGESTER	KT1 DIGESTER		COMPOSITE DIGESTER	KT1 DIGESTER	
		UNIT: USD/MJ			PERCENT BIOGAS PRODUCTION COST		
1	FEEDSTOCK COST	0	0	0	0	0	0
2	DEPRECIATION COST	0.004934	0.002915	0.003501	26.1	23.6	22.1
3	OPERATION COST						
	- ELECTRICITY COST	0.001271	0.000845	0.001476	6.7	6.9	9.3
	- LABOUR COST	0.010840	0.007932	0.009984	57.3	64.4	63.1
4	MAINTENANCE COST	0.000453	0.000062	0.000766	2.4	0.5	4.8
5	TRANSPORTATION COST	0.001430	0.000571	0.000107	7.5	4.6	0.7
	TOTAL PRODUCTION COST	**0.018928**	**0.012325**	**0.015835**	100	100	100
	AVERAGE		**0.015627**				

Source: CASRAD, 2017

Feedstock cost: the feedstock used for the biogas digester in the surveyed households is comprised of human faeces, along with pig, chicken, cattle and poultry manure. In the surveyed households, before installation of the biogas plant, manure was seldom used as soil organic fertilizer or discharged, and it was never sold. Therefore, the economic value of manure is negligible. As a consequence, the cost of raw materials used for ADs can be considered null.

Depreciation cost: Cost of building a biogas plant divided by the estimated lifetime of the biogas plant, e.g. 20 years in the case of a KT1 or composite digester (Viet Nam Biogas Association, 2014).

Operation cost: Mostly labour cost and electricity cost for pumping water into the digester.

Maintenance cost: Including replacing stoves, siphoning residue, removing scum, repairing the digester cover, repairing the pipe. Considering that these problems do not occur often and that the biogas plants of the surveyed households were built between 2014 and 2016, very low maintenance costs have so far been reported.

Transportation cost: Labour cost for transporting biogas by-product (digestate) to the field.

Cost of biogas production / year / household. Households using a composite biogas plant have the highest biogas production cost (0.018928 USD/MJ), which is 50 percent higher than a KT1 biogas plant (0.012325 USD/MJ). At farm level, the average biogas production cost was 0.015835 USD/MJ, slightly higher than the production cost for the composite biogas plant at household level (0.015627 USD/MJ). In general, the labour cost for operating the plant represents the highest share (around 60 percent) of the total biogas production cost, at both levels considered, followed by the plant depreciation cost (22-26 percent).

Industrial level

TABLE 97

PRODUCTION COST OF BIOGAS FROM CASSAVA STARCH PROCESSING FACTORIES IN THE TAY NINH PROVINCE

NO	CONTENT	HUNG DUY TRADING INDUSTRY TRANSPORT IM-EXPORT CO., LTD	THANH BINH CO., LTD	HUNG DUY TRADING INDUSTRY TRANSPORT IM-EXPORT CO., LTD	THANH BINH CO., LTD
		UNIT: USD/MJ		PERCENT BIOGAS PRODUCTION COST	
1	FEEDSTOCK COST	0	0	0	0
2	DEPRECIATION COST	0.001791	0.001042	62.7	31.0
3	OPERATION COST				
	- ELECTRICITY COST	0.000604	0.001392	23.9	41.5
	- LABOUR COST	0.000368	0.000853	12.9	25.4
4	MAINTENANCE COST	0.000015	0.000073	0.5	2.1
	TOTAL PRODUCTION COST	**0.002858**	**0.003359**	**100.0**	**100.0**
	AVERAGE		**0.003108**		

Source: CASRAD, 2017

Feedstock cost: wastewater from cassava starch processing plant cannot be sold or re-used. Hence, the feedstock cost is zero.

Depreciation cost: investment costs (for building wastewater treatment systems and associated facilities) divided by the average life expectancy of biogas plants (15 years).

Operation cost: Mostly labour cost and electricity cost for pumping water into the digester.

Maintenance costs: including the replacement of lubricating oil, the repair of machinery for the operation of the wastewater treatment system (pumps, etc.), and electricity cost for operating the plant (e.g. to pump wastewater into anaerobic digesters).

The biogas production cost at the Hung Duy plant is 0.002858 USD/MJ, slightly lower (-0.0005 USD/MJ) compared to the Thanh Binh plant. At the industrial level, the depreciation cost and the cost of electricity used to operate the biogas plant account for the highest share of the total production cost (86.6 percent for Hung Duy Trading Industry Transport Im-Export Co., Ltd and 72.5 percent for Thanh Binh Co., Ltd).

As shown in **Table 98**, the lowest production cost of biogas is at industrial level (0.003108), with cassava starch wastewater as feedstock. Wood is the only fuel whose price is lower than this biogas production cost, while the prices of other fuels such as sawdust, rice husk, DO and LPG are higher.

Regarding biogas from animal manure, the production cost at both household and farm levels is higher compared to other fuels such as wood, sawdust, rice husk and DO, but lower than LPG.

4.17.1 Main conclusions and recommendations

Cassava-based ethanol

Approach used

To calculate indicator 17 for productivity of Cassava-based ethanol in Viet Nam, various sources of secondary data were used, including the GSO website, the Vietnam Export - Import Report 2016 (Viet Nam Finance, 2017), and several other publications and peer reviewed papers. Research and synthesis of documents and data related to ethanol production were carried out

TABLE 98

PRODUCTION COST OF BIOGAS AND PRICES OF OTHER FUELS

No.	FUEL	UNIT	CONVERSION COEFFICIENT OF ENERGY UNIT (MJ)	FUEL PRICE IN 2016 (VND/kg)	FUEL PRICE IN 2016 (USD/kg)	PRODUCTION COST PER ENERGY UNIT (USD/MJ)
1	LPG	KG	45.638	21 833	0.966	0.021168
2	DIESEL OIL (DO)	KG	42.707	12 380	0.547	0.012827
3	WOOD	KG	15	600	0.027	0.001770
4	RICE HUSK	KG	11.72	1 650	0.073	0.006229
5	SAWDUST	KG	17.58	2 300	0.102	0.005789
6	BIOGAS AT HOUSEHOLD LEVEL					**0.015627**
7	BIOGAS AT FARM LEVEL					**0.015835**
8	BIOGAS FROM STARCH PRODUCTION PLANTS WASTEWATER					**0.003108**

Source: MOIT, 2016 and Phat Hung Company website

to provide an overview of the feedstock sources, ethanol production technologies and cost of ethanol production in Viet Nam.

Results

The weighted average yield was 18.0 tonnes/ha (see indicator 18). Cassava productivity in Viet Nam (i.e. 18 tonnes/ha) is relatively low in comparison to other countries – only 50 percent of India's cassava productivity, 15 percent lower than Indonesia and 9 percent lower than Thailand (Viet Nam Finance, 2017). Furthermore, with the current technology used by ethanol plants in the country, the efficiency of the processing stage is low (8 440 MJ/tonne of dry cassava chips). These two factors, combined, lead to an overall low productivity of Cassava-based ethanol in Viet Nam (60 768 MJ/ha per year) and to a relatively high cost of production (0.032 USD/MJ).

Practices and policies to improve sustainability

To improve the efficiency and sustainability of the Cassava-based ethanol pathway in Viet Nam, the productivity of cassava should be improved, through the use of improved varieties, advanced cultivation techniques and good agricultural practices. At the same time, in order to increase the overall productivity of the supply chain and the energy/ethanol output per hectare, ethanol plants should make use of more efficient processing technologies. Policies and incentives would be needed to promote the adoption of the aforementioned measures to increase productivity at both farm and plant level. In addition to enhancing the efficiency and competiveness of the domestic Cassava-based ethanol sector, these policies would have a number of environmental and socio-economic co-benefits, such as improved land and natural resource management and increased income for cassava producers

Future monitoring

The computation of indicator 17 and the related analysis was mainly based on previous studies. Information related to this indicator, e.g. in terms of production cost, is readily available at ethanol plants. However, getting access to this information is difficult, due to its commercial sensitivity. In order to be able to access this information in the future, the direction and support of the Ministry of Industry and Trade would be needed. Furthermore, a dialogue and exchange of information could be established with relevant business associations, and confidentiality agreements could be signed with individual plants willing to cooperate.

Biogas

Approach used

For the measurement of Indicator 17 for the biogas value chain, secondary data were obtained from official national statistics (GSO website). To complement this, primary data were obtained from a survey conducted on 47 households in the Thanh Thuy and Tam Nong districts in the Phu Tho Province, two pig farms in the same province, and two cassava starch processing factories in the Tay Ninh Province.

Results

Animal manure is the feedstock most commonly used for biogas production in Vietnamese households, in addition to livestock farms of course. A total amount of 84.8 million tonnes of fresh manure is produced per year in the country. At industrial level, cassava starch wastewater is used to produce biogas. In Viet Nam, there are 102 plants, each producing an amount of wastewater varying from 243 000 m^3/year to 1 500 000 m^3/year. Thus, a large amount of feedstock is available for biogas production in the country.

For indicator 17.1, Viet Nam could produce 84.8 million tonnes of fresh livestock manure per year of which 26.33 million tonnes/year of fresh pig manure (General Statistics Office of Viet Nam, no date). The latter is the most common feedstock used for biogas production at household and farm level. A pig with average weight of 50 kg can produce 2.6 kg of fresh manure per day (LCASP, 2017 and SNV, 2011). Wastewater from cassava starch production is the main raw material used for biogas production at the industrial level. In Viet Nam, there are 102 cassava starch plants, each producing an amount of wastewater varying from 243 000 m^3/year to 1 500 000 m^3/year (i.e. 19.61 m^3 per tonne of cassava starch) (CASRAD, 2017).

Biogas can produce an amount of thermal energy equal to 1.165 MJ/kg of wet pig manure and 66.1 MJ/m^3 of wastewater. Total biogas output in Viet Nam is over 33 million GJ/year, of which around 28.5 million GJ/year from pig manure at household and farm level, and almost 5 million GJ/year from the wastewater of cassava starch plants (of which almost 3 million GJ/year used for cassava starch drying).

Biogas production cost from pig manure is 0.015627 USD/MJ at household level and 0.015835 USD/MJ at farm level. The cost of biogas production in cassava starch factories is 0.003108 USD/MJ, which is lower than the price of most other fuels, such as sawdust, rice husk, DO and LPG, while the production cost of biogas at household and farm level is lower than the price of LPG only.

Practices and policies to improve sustainability

The implementation of indicator 17 in Viet Nam confirmed the importance of monitoring the productivity at the level of raw materials, processing and production. Monitoring of this indicator is essential to assess the efficiency and competitiveness of the biogas sector and any other bioenergy industry.

Biogas may be an effective option to replace fossil fuels and other less efficient and sustainable biofuels. However, the cost of building ADs is still high, the payback period is long and the biogas surplus produced at farm level is a constraint, since no power production from biogas occurs so far at small and medium scale.

Therefore, policies should be adopted to help pig-raising households, livestock farms and cassava starch factories access the necessary capital to build ADs. Furthermore, adequate incentives should be provided for the supply of surplus electricity to the grid.

Future monitoring

Viet Nam is a country with a huge biogas potential, only part of which has been exploited so far. As the biogas sector continues to expand in Viet Nam, monitoring productivity is key to assess the efficiency of the sector. Furthermore, monitoring of production costs is important to assess the competitiveness of biogas compared to other fuels.

Regarding the production cost, data were obtained from a survey conducted on 47 households and two pig farms in the Phu Tho

Province, and two cassava starch processing factories in the Tay Ninh Province. For Future monitoring, a broader sample of households, farms and plants should be surveyed, and an information exchange should be promoted with relevant business associations.

REFERENCES

CASRAD. 2017. Survey data of households / livestock farms in Phu Tho province and in four cassava starch processing factories in Tay Ninh province. April 2017.

Dantri. 2016. Series of ethanol plants bankrupt because of Chinese technology ***(translated from Vietnamese)***. Available at: http://dantri.com.vn/kinh-doanh/hang-loat-nha-may-ethanol-pha-san-vi-cong-nghe-trung-quoc-20160402222221932.htm [Accessed: 8 Jan 2018].

EPRO. 2016. Consulting JSC. Biogas User Survey (BUS) 2014.Available at: http://biogas.org.vn/vietnam/getattachment/Thu-vien-phim,-anh/An-pham/Bao-cao-Khao-sat-nguoi-su-dung-cong-trinh-khi-sinh/Bus2014-report,-ENG.pdf.aspx

FAO. 2012. The low carbon agricultural support project (LCASP) in Viet Nam – Carbon balance appraisal with the ex-ante carbon balance tool. Available at: www.fao.org/fileadmin/templates/ex_act/pdf/case_studies/draft_aout2012-clear.pdf

GSO website. Statistical data: Agriculture, Forestry and Fishery. Available at: www.gso.gov.vn/default_en.aspx?tabid=778 [Accessed: 24 Jan 2018].

Ho Sy Chinh. 2013. Calculate to design ethanol distillation system with a capacity of 100 000 m³/year in bio-ethanol production from cassava. Graduation Thesis. The 52nd Machine and chemical technology equipment.

Institute of Agricultural Science for Southern Viet Nam. 2014. Cassava as raw material, biofuel *(translated from Vietnamese)*. Available online: http://iasvn.org/tin-tuc/San-lam-nguyen-lieu,-nhien-lieu-sinh-hoc-4492.html Accessed 08/01/2018.

LCASP. 2017. Handbook for construction and installation of large and medium biogas plant with HDPE technology Available at: http://lcasp.org.vn/uploads/kien-thuc/2017_03/so-tay-xay-dung-va-lap-dat-cong-trinh-khi-sinh-hoc-vua-va-cong-nghe-ho-phu-bat-hdpe.pdf

Loan T. Le, Justus Wesseler, Xueqin Zhu and Ekko C. van Ierland. 2013. Energy and greenhouse gas balances of Cassava-based ethanol in Viet Nam, pp 1-24.

MARD. 2016. Real situation and solutions for environmental treatment of livestock production. Department of Livestock Production.

MOIT. 2016. Circulars: Regulating the energy consumption performance in the steel industry (in Vietnamese). Available at: https://thuvienphapluat.vn/van-ban/Tai-nguyen-Moi-truong/Thong-tu-20-2016-TT-BCT-dinh-muc-tieu-hao-nang-luong-trong-nganh-cong-nghiep-thep-323190.aspx.

MOIT. 2017. FAO Regional workshop Nov.16-17 "Sustainable Bioenergy Production and Use in Southeast Asia: Lessons Learnt and Future Opportunities, The orientation in the production and use of biofuels in Vietnam, Dr. Do Xuan Dong, Department of Science and Technology. Available at: www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/AG2/Viet_Nam_project/Final_Mettings/Dong_Do-Xuan.pdf

Phat Hung Company. Comparison of Fuel Costs. *(translated from Vietnamese)*. Available at: http://cuitrau.vn/tin-tuc/91-so-sanh-chi-phi-nhien-lieu-chat-dot.html

RuDeC. 2017, Characteristics of Livestock Models. Workshop on "Characterization of livestock producers", on 30/6/2017 in Ha Noi, organized by Institute of Policy and Strategy for Agriculture and Rural development in collaboration with the Department of Livestock Production and Food and Agriculture Organization of the United Nations (FAO).

SNV. 2011. Biogas technology at household level. Available at: http://biogas.org.vn/english/getattachment/An-pham/2012/Domestic-biogas-technology-training-handbook.pdf.aspx [Accessed: 15 Jan 2018]

Thanh_tan weblog. 2014. Cassava and ethanol production from cassava chips in Viet Nam (Part 3) (translated from Vietnamese). Available at: http://thanhtan.net/kinhdoanh-kinhte/nganh-san-lat-va-san-xuat-con-nhien-lieu-tu-san-lat-viet-nam-phan-3.html. [Accessed: 8 Jan 2018].

Van Dinh Son Tho. 2017. Hanoi University of Science and Technology, Glance at Bioenergy in Viet Nam, biomass and residue to power production seminar 2017

Viet Nam Biogas Association. 2014. Prof. Dr. Bui Van Chinh, MSc Ho Thi Lan Huong, Dr. Do Ngoc Quynh, MSc Nguyen Ngoc Thai, Prof. Dr. Duong Nguyen Khang, Nguyen Ngoc Em, Guidebook on quality management of some household-size biogas digesters in Viet Nam.

Viet Nam Finance. 2017. Viet Nam Export Import Report 2016 (translated from Vietnamese). Available at: http://vietnamfinance.vn/upload/news/hoanghung_btv/2017/3/29/BC%20XNK%202016.pdf [Accessed: 8 Jan 2018]

4.18 INDICATOR 18: NET ENERGY BALANCE

Do Xuan Truong, Van Dinh Son Tho
Vietnam Japan International Institute for Science of Technology (VJIIST) at the Hanoi University of Science and Technology (HUST)

DESCRIPTION:

Energy ratio of the bioenergy value chain with comparison with other energy sources, including energy ratios of:
(18.1) feedstock production;
(18.2) processing of feedstock into bioenergy;
(18.3) bioenergy use; and/or
(18.4) lifecycle analysis.

MEASUREMENT UNIT(S):

(18.1) ratio
(18.2) ratio
(18.3) ratio
(18.4) ratio

4.18.1 Implementation of Indicator 18 in Viet Nam

For the implementation of indicator 18 in Viet Nam, secondary data from a literature review and primary data from surveys were used and compared.

a. Cassava-based ethanol

The analysis related to the Cassava-based ethanol pathway was disaggregated into the four stages of the value chain: cassava production; ethanol conversion; ethanol distribution and blending; and ethanol use. Secondary data available in literature were used. These were complemented and compared with data collected from three ethanol plants in Viet Nam between January and March 2017 (VJIIST, 2017).

b. Biogas

The measurement of indicator 18 for the biogas pathway focused on biogas production from pig manure at farm level. The following three stages of the value chain were considered: wet manure collection; biogas production; and biogas use. The net energy balance of biogas production from cassava starch wastewater was not calculated due to lack of data. Data were collected through a survey that was conducted in selected provinces of Viet Nam between January and March 2017 (VJIIST, 2017).

4.18.1 Key findings

Cassava-based ethanol

Table 99 shows the cassava yield in different areas of Viet Nam in 2015. Total harvested area of cassava was 567 thousand ha (GSO website). Gia Lai and Tay Ninh were the provinces with the largest harvested area and production of cassava, i.e. almost 22 percent of the country's total. Fresh cassava yield varies across regions, from 7.9 tonnes/ha in Ha Giang to 32.4 tonnes/ha in Tay Ninh.

In 2015, the weighted average yield of cassava in Viet Nam was about 18 tonne/ha and was calculated using the following equation:

$$y_{ave} = \frac{1}{\sum A} \sum A_i y_i$$

where A_i and y_i are the area and cassava yield of province i, respectively.

The Cassava produced in Viet Nam is mainly exported or used to supply cassava starch production plants. Only a small amount of cassava is addressed to ethanol production (around 1.53 percent in 2016). After the harvest, cassava is sliced and dried in the sun before being delivered to ethanol plants in the form of dry chips. From 1 tonne of fresh cassava, 0.4 tonnes of dry chips can be produced. **Table 99** shows dry cassava chip yields for the various cassava-producing regions of Viet Nam. The weighted average of cassava dry chip yield is 7.2 tonnes/ha.

Table 100 shows the energy inputs per litre of ethanol as reported by Loan *et al.* (2013) and based on a survey conducted within the present study in three ethanol plants (plant A, B and C) in Viet Nam (VJIIST, 2017). Plant A and B use coal to produce heat and electricity for own consumption, whereas plant C uses electricity from the grid and steam that it produces from woodchips and cashew shell as feedstock.

TABLE 99

CASSAVA YIELD IN DIFFERENT PROVINCES OF VIET NAM, 2015

	AREA (1000xha)	CAPACITY (1000xtonne)	FRESH CASSAVA YIELD (tonnes/ha)	DRY CASSAVA CHIP YIELD (tonnes/ha)
WHOLE COUNTRY	567	10 700	18.0*	7.2*
YIENBAI	15.8	305.0	19.3	7.5
SON LA	31.2	359.5	11.5	4.5
NGHE AN	17.4	410.0	23.6	9.2
QUANGNGAI	19.7	376.4	19.1	7.5
BINHDINH	13.6	335.5	24.7	9.6
PHU YEN	23.0	397.2	17.3	6.7
BINHTHUAN	30.9	510.8	16.5	6.4
KON TUM	39.5	590.2	14.9	5.8
GIA LAI	63.7	1 180.9	18.5	7.2
DAKLAK	34.0	666.5	19.6	7.6
BINHPHUOC	17.7	410.9	23.2	9.1
TAY NINH	57.6	1 868.3	32.4	12.6
DONG NAI	15.8	399.2	25.3	9.9

** weighted average*
Source: GSO website

The energy inputs per unit of chemicals – such as fertilizers, pesticides, NaOH, Urea, DAP and H_2SO_4 – used in feedstock production, and for electricity were taken from BioGrace (2017) and are listed in **Table 100**. The energy inputs of diesel and coal are provided based on their LHV, divided by their thermal efficiency, which is 92 percent for coal and 88 percent for diesel (Loan ***et al.***, 2013). The energy input of labour is 2.3 MJ/h (Loan ***et al.***, 2013).

The total energy input of Cassava-based ethanol reported by Loan ***et al.*** (2013) is 19.71 MJ/litre, which is significantly higher than the amount of energy input in plants A (13.77 MJ/litre), B (13.34 MJ/litre) and C (12.36 MJ/litre). However, Loan ***et al.*** (2013) did not report the energy credit for the by-product (dry cake). In the three ethanol plants considered, slurry from the bottom of the distillation column is separated from water and dried by using heat provided by the biogas plant coupled with the ethanol production plant, for producing dry cake. Dry cake is considered as the by-product of the ethanol plant and can be used as soil fertilizer, solid fuel or animal feed. The energy credit of dry cake in ethanol processing is about 2.67 MJ/litre. In ethanol plants, biogas is generated from the treatment of cassava wastewater. Biogas is used in the boiler for co-combustion with coal, and for drying the solid waste from the bottom of the distillation column. Therefore, biogas production and use lower the amount of external energy inputs.

The energy input reported by Loan ***et al.*** (2013) in the cassava cultivation phase is significantly lower than the one estimated in the context of this study (1.60 MJ/litre compared with an average of 4.1-4.3 MJ/litre for the three plants considered). On the other hand, the energy input for the feedstock conversion phase is higher than the one for plants A, B and C (17.69 MJ/litre compared with an average of 11.5 MJ/litre for the three plants).

Table 101 presents the results of indicator 18 calculated for the case described in Loan ***et al.*** (2013) and for the three plants considered.

2.25 kg of dry cassava chips are required for producing 1 litre of ethanol in plants A and

B, whereas an ethanol yield of 2.4 kg of dry cassava chips/litre is reported for plant C. As a consequence, 1 tonne of dry cassava chips can produce between 416.67 litres (plant C) and 444.44 litres (plants A and B) of ethanol. The ethanol yield of the ethanol plant reported in Loan *et al.* (2013) was assumed to be the same as that of plants A and B due to the use of a similar technology. The energy content of fresh and dry cassava are 6 670 MJ/tonne and 16 675 MJ/tonne, respectively.

The main outcomes of this study are shown in **Table 101** and can be summarised as follows:

(i) The efficiency of cassava production (Indicator 18.1) was higher in the case study analysed by Loan *et al.* (2013) than for the plants A, B, and C, and resulted in a Net Energy Ratio (NER) of about 23.5 and 9.23 (as an average of the three plants), respectively. This result is due to the use of high fertilizer input for cassava cultivation in cases A, B and C compared to the case analysed by Loan *et al.* (2013).

(ii) The efficiency of feedstock processing (Indicator 18.2) was higher in the ethanol plants A, B, C than in the study case analysed by Loan *et al.* (2013), with values ranging from 1.82 to 1.96 for plants A, B and C, and 1.19 in case of the study of Loan *et al.* (2013).

(iii) The NER of the entire Life Cycle (Indicator 18.4) of the ethanol pathway is about 1.07 in the study case analysed by Loan *et al.* (2013), and varies from 1.53 to 1.71 for the ethanol plants A, B, and C. The average NER of the Cassava-based ethanol pathway in Viet Nam was estimated at 1.61. On the other hand, the (fossil) energy input accounts for about 94 percent and 62 percent on average of the ethanol LHV for the case analysed by Loan *et al.* (2013) and for the ethanol plants A, B, and C, respectively.

TABLE 100

ENERGY INPUTS PER LITRE OF ETHANOL

Input	Unit	Energy input* (MJ/unit)	Reference (Loan *et al.* 2013)		Plant A		Plant B		Plant C	
			Consumption** (unit/l)	Energy input*** (MJ/l)	Consumption** (unit/l)	Energy input*** (MJ/l)	Consumption** (unit/l)	Energy input*** (MJ/l)	Consumption** (unit/l)	Energy input*** (MJ/l)
CASSAVA PRODUCTION										
FERTILIZERS AND PESTICIDES				0.75		3.37		3.37		3.37
N	KG	48.99	0.010	0.51	0.041	2.03	0.041	2.03	0.041	2.03
P_2O_5	KG	15.23	0.009	0.13	0.034	0.53	0.034	0.53	0.034	0.53
K_2O	KG	9.68	0.009	0.09	0.031	0.30	0.031	0.30	0.031	0.30
CAO	KG	1.97	-	-	0.179	0.35	0.179	0.35	0.179	0.35
PESTICIDES	KG	268.40	0.000	0.01	0.001	0.16	0.001	0.16	0.001	0.16
LABOUR	H	2.30	0.117	0.27	0.117	0.27	0.117	0.27	0.117	0.27
DIESEL FOR OPERATING TRACTORS	L	40.89	0.003	0.11	0.007	0.27	0.007	0.27	0.007	0.27
DIESEL FOR TRANSPORTATION	L	40.89	0.010	0.48	0.017	0.69	0.011	0.45	0.010	0.42
ETHANOL CONVERSION				17.69		11.43		11.62		10.74
CHEMICALS				0.14		0.14		0.32		0.21
NAOH	KG	10.22	0.003	0.03	0.003	0.03	0.0006	0.01	0.0034	0.04
UREA	KG	22.78	0.003	0.07	0.003	0.07	0.0025	0.06	0.0050	0.11
DAP	KG	8.60	0.003	0.03	0.003	0.03		0.00	0.0027	0.02
ENZYME	KG	15.00	0.001	0.02	0.001	0.02	0.0016	0.02	0.0020	0.03
DENATURANT (GASOLINE)	KG	46.70					0.0046	0.21	0.0002	0.01
H2SO4	KG	3.90					0.0037	0.01	0.0012	0.00
ELECTRICITY	KWH	5.65	0.281	1.59	0.000	0.00	0.000	0.00	0.1640	0.93
COAL	KG	20.53	0.600	15.96	0.550	11.29	0.550	11.29	0.0000	0.00
WOODCHIP	KG	10.88							0.6667	7.25
CASHEW SHELL	KG	17.57							0.1333	2.34
DRY CAKE CREDIT	KG	-15.57			0.172	-2.67	0.172	-2.67	0.172	-2.67
DISTRIBUTION AND BLENDING				0.41		0.677		0.301		0.226
DIESEL FOR TRANSPORTATION	L	40.89		0.39		0.673		0.297		0.222
ELECTRICITY FOR BLENDING	KWH	5.65		0.02		0.004		0.004		0.004
TOTAL				19.71		13.77		13.34		12.36

* Energy input per unit of chemicals, fuels and labour. Source: BioGrace, 2017
** Consumption per litre of ethanol.
*** Energy input per litre of ethanol. (3) = (1)*(2)

TABLE 101

RESULTS OF INDICATOR 18 FOR THE CASSAVA-BASED ETHANOL PATHWAY

		REFERENCE (Loan *et al.* 2013)	PLANT A	PLANT B	PLANT C
CASSAVA ENERGY CONTENT (MJ/TONNE OF DRY CASSAVA CHIPS)	a	16 675.00	16 675.00	16 675.00	16 675.00
ETHANOL YIELD (L/TONNE OF DRY CASSAVA CHIPS)	b	444.44	444.44	444.44	416.67
ENERGY INPUT IN CASSAVA PRODUCTION (MJ/TONNE OF DRY CASSAVA CHIPS)	c	711.11	1 926.64	1 817.75	1 693.30
ENERGY BALANCE OF CASSAVA PRODUCTION PHASE (MJ/TONNE)	a-c	15 963.89	14 748.36	14 857.25	14 981.70
INDICATOR 18.1 (RATIO)	**a/c**	**23.45**	**8.65**	**9.17**	**9.85**
AMOUNT OF ETHANOL ENERGY PRODUCED (MJ/TONNE OF DRIED CASSAVA CHIPS)	d	9 377.78	9 377.78	9 377.78	8 791.67
ENERGY INPUT IN FEEDSTOCK CONVERSION (MJ/TONNE)	e	7 862.22	5 081.24	5 166.02	4 475.69
ENERGY BALANCE IN FEEDSTOCK CONVERSION (MJ/TONNE)	d-e	1 515.56	4 296.54	4 211.76	4 315.98
INDICATOR 18.2 (RATIO)	**d/e**	**1.19**	**1.85**	**1.82**	**1.96**
TOTAL ENERGY INPUT IN FEEDSTOCK PRODUCTION AND PROCESSING, DRY CAKE CREDIT, ETHANOL BLENDING AND DISTRIBUTION (MJ/TONNE)	**f**	8 760.00	6 121.75	5 924.12	5 148.39
ENERGY BALANCE FOR THE ENTIRE CASSAVA-BASED ETHANOL PATHWAY (MJ/TONNE)	d-f	617.78	3256.03	3447.24	3641.33
INDICATOR 18.4 (RATIO)	**d/f**	**1.07**	**1.53**	**1.58**	**1.71**

Sub-indicator 18.3: ethanol use

Loan *et al.* (2013) presented experimental results concerning the fuel efficiency of blends with respect to gasoline. On the one hand, it is argued that the lower LHVs of blends cause higher fuel consumption than gasoline, while on the other hand, their higher octane values and compression ratios improve thermo-dynamic properties, thus resulting in reduced fuel consumption. However, fuel efficiency is not only affected by these properties but also by other factors such as vehicle speed and gear, vehicle models and road conditions. Duc *et al.* (2016) developed a new fuel system that enables used gasoline motorcycles to operate on 100 percent ethanol. The results show that using ethanol instead of gasoline causes improvements in engine performance and exhaust emissions. An average improvement of 19 percent in engine efficiency was reported.

In 2016, motorbikes accounted for almost 94 percent of the total number of vehicles in Viet Nam, as shown in **Table 102**. The number of motorbikes and cars in 2016 were 45 and 2.1 million, respectively. Of this, Honda constitutes 69 percent of the motorbike market, and Toyota makes up 37 percent of the car market, as shown in **Figure 52** and **Figure 53**, respectively.

TABLE 102

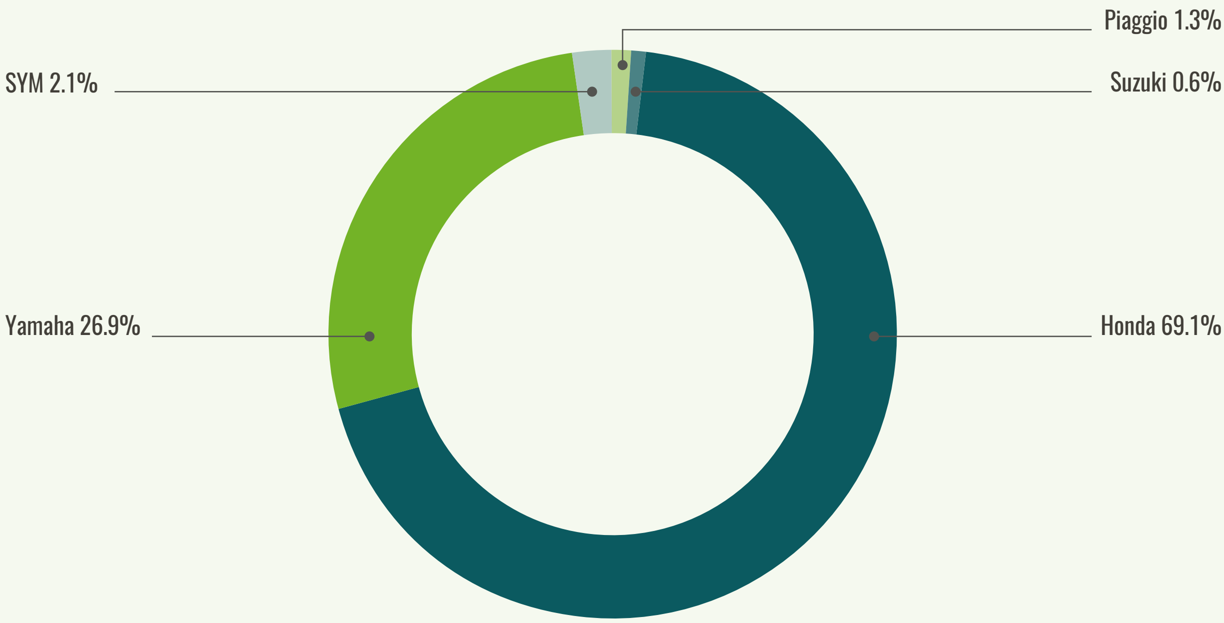
NUMBER OF VEHICLES IN VIET NAM, 2016

VEHICLE	MOTORBIKE	CAR (<9 SEATS)	CAR (>9 SEAT)	TRUCK	TOTAL
NUMBER (MILLION)	45	2.1	0.12	0.85	48.07
PERCENTAGE	93.6	4.4	0.2	1.8	100

Source: Vietnamnet.vn, 2016

FIGURE 52

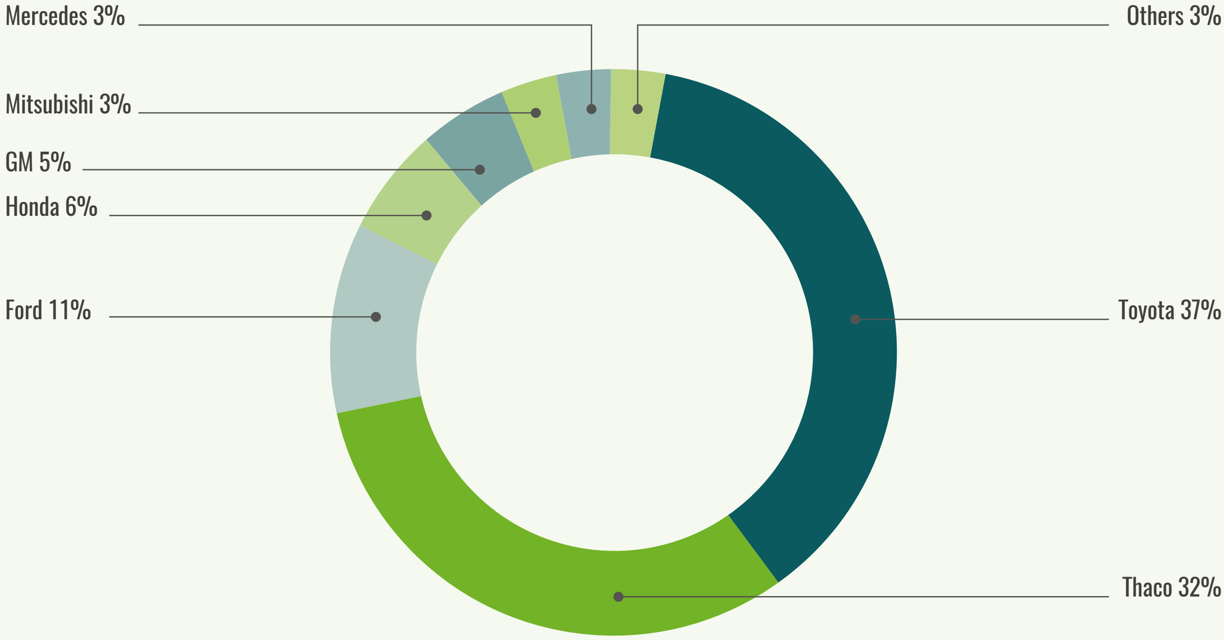
MARKET SHARE OF MOTORBIKES IN VIET NAM, 2016



Source: Newcare, 2016

FIGURE 53

MARKET SHARE OF CARS IN VIET NAM, 2016



Source: iNET, 2016

TABLE 103

ESTIMATION OF ETHANOL THERMAL EFFICIENCY

VEHICLE GASOLINE		THERMAL EFFICIENCY (percent)		
		E100	E5	
MOTORCYCLE	HONDA CONVENTIONAL ENGINE	25.0-27.5	29.8-32.7	-
	HONDA EXLINK ENGINE	29.5-32.0	35.1-38.1	-
CAR	TOYOTA ENGINE	38	45.2	-
CURRENT COMBUSTION ENGINE (ON AVERAGE)	-	40	-	40.4

Table 103 gives an estimate of the ethanol thermal efficiency for a sample of Honda motorbikes and Toyota cars, with the assumption that new engines using ethanol (E100) have a thermal efficiency 19 percent higher than those using gasoline.

On average, the efficiency of gasoline combustion in a current engine is about 40 percent. Therefore E5 can slightly improve the thermal efficiency of this engine to 40.4 percent (= 40 x (1 + 0.19 x 0.05). However, there are no empirical studies to prove this in Viet Nam and it is such a slight improvement that it is practically negligible. Because the thermal efficiency of gasoline and E5 engines is almost the same, the results of indicator 18.4 indicate that 1 MJ of fossil fuel is needed to produce 1.61 MJ of Cassava-based ethanol in Viet Nam.

Biogas

a. Biogas from pig manure at farm level

Biogas is mostly produced in Viet Nam through the anaerobic digestion of wet pig manure. Biogas is the main product and digestate is a by-product of the anaerobic digestion process. An open tank is used to store the digestate. **Table 104** presents the results of a survey conducted within this study in March 2017 with five pig farms located in the North of Viet Nam (VJIIST, 2017). Data related to number of livestock, feed consumption, energy consumption and wastewater production were collected from the surveyed farms.

No energy is consumed for collecting the wet manure and delivering it to the anaerobic digester. On the other hand, feedstock processing into biogas implies the consumption of around 0.1 MJ of heat and 0.02 MJ of electricity per MJ of biogas produced. The heat used in the biogas generation process is recycled within the system, while electricity is withdrawn from the grid. The remaining biogas (90 percent) is burned for other

TABLE 104

RESULTS OF SURVEY WITH PIG FARMS

FARM	NO. OF SOW (pig-head)	NO. OF PORK (pig-head)	FEED CONSUMPTION (tonne/y)	ELECTRICITY CONSUMPTION (kWh/y)	DIESEL CONSUMPTION (litre/y)	WASTEWATER m^3/Y
FARM 1	1 800	4 200	4 380.0	225 000		65 700
FARM 2		2 000	2 007.5	172 500		14 600
FARM 3	1 200	6 000	3 600.0	525 000	2 400	36 500
FARM 4	2 000	5 200		750 000		
FARM 5	1 200		1 314.0	562 500		54 750

Source: VJIIST, 2017

purposes and/or released as flue gas. The energy inputs per unit of labour, diesel and electricity are 2.30 MJ/h, 40.89 MJ/litre and 5.65 MJ/kWh, and are listed in **Table 105** (Loan *et al.*, 2013). The energy input of diesel is defined based on the LHV, with a thermal efficiency of 88 percent. The energy input to produce one kWh of electricity is 5.65 MJ (Loan *et al.*, 2013).

Table 105 shows the energy input per m^3 of biogas. 0.68 MJ of energy is used as input in the form of electricity for the production of 1 m^3 of biogas.

TABLE 105

ENERGY INPUT FOR 1 m^3 OF BIOGAS

INPUT	UNIT	ENERGY INPUT (MJ/unit)[a]	CONSUMPTION (unit/m^3)[b]	ENERGY INPUT (MJ/m^3)[c]
COLLECTION OF WET MANURE				0.00
LABOUR	h	2.30		0.00
DIESEL FOR OPERATING TRACTORS	litre	40.89		0.00
DIESEL FOR TRANSPORTATION	litre	40.89		0.00
BIOGAS PRODUCTION				0.68
ELECTRICITY	kWh	5.65	0.12[d]	0.68
HEAT (IN-SITU)	MJ	0.00	2.16[e]	0.00
BIOGAS TRANSPORT				0.00
DIESEL FOR TRANSPORTATION	litre	40.89		0.00
ELECTRICITY FOR TRANSPORTATION	kWh	5.65		0.00
TOTAL				0.68

(c) = (a)*(b)
(d) = (LHV of 1 m^3 biogas)(0.02)/3.6*
(e) = (LHV of 1 m^3 biogas)(0.1)*

TABLE 106

RESULTS OF INDICATOR 18 FOR THE BIOGAS PATHWAY

ENERGY CONTENT OF PIG MANURE ON A WET BASIS (MJ/KG)	2.800
BIOGAS YIELD (m^3/KG)	0.056
BIOGAS ENERGY (MJ/m^3)	21.6
ENERGY INPUT IN WET MANURE COLLECTION (MJ/KG)	0.000
ENERGY BALANCE FOR FEEDSTOCK PRODUCTION PHASE (MJ/KG)	2.800
INDICATOR 18.1 (RATIO)	**N/A***
BIOGAS ENERGY (MJ/KG WET MANURE)	1.21
ENERGY INPUT IN BIOGAS CONVERSION AND DISTRIBUTION (MJ/KG WET MANURE)	0.038
ENERGY BALANCE FOR FEEDSTOCK PROCESSING PHASE (MJ/KG WET MANURE)	1.17
INDICATOR 18.2 (RATIO)	**31.8**
ENERGY BALANCE FOR BIOGAS DISTRIBUTION PHASE (MJ/KG WET MANURE)	1.17
INDICATOR 18.4 (RATIO)	**31.8**

** Not Applicable: manure is just the waste of livestock production farms*

Table 106 presents the results of indicator 18 for the biogas pathway at farm level. According to the Biogas Program for the Animal Husbandry Sector in Viet Nam (MARD website), about 0.056 m^3 of biogas are produced from each kg of fresh manure. Since no energy consumption occurs in the collection and delivery of the wet manure to the anaerobic digester, the Net Energy Balance of feedstock production could be considered equal to the LHV of the wet manure (2.8 MJ/kg), while sub-indicator 18.1 cannot be calculated.

Each kg of pig wet manure can generate 1.21 MJ of biogas. Assuming that five percent of biogas is leaked during biogas conversion and considering that electricity consumption for processing 1 kg of wet manure is 0.038 MJ/kg, the energy balance of the processing phase is 1.17 MJ/kg, giving a ratio for sub-indicator 18.2 of 31.8.

No energy consumption occurs for collecting and delivering the wet manure to the anaerobic digester nor for distributing/delivering the biogas produced to the final users. Therefore, in the calculation of sub-indicator 18.4, the total energy input in the manure-based biogas pathway corresponds to the consumption of electricity in the feedstock processing (biogas production) phase and Indicator 18.4 is equal to indicator 18.2.

Biogas use

There is no literature on biogas thermal efficiency for cookstoves in Viet Nam. However, there are some reports comparing the thermal efficiencies of various stoves and fuels in other developing countries, as listed in **Table 107**. The thermal efficiency is very different among those reports. For the biogas stove reported by Tribhuwan University (2001), the thermal efficiency is in the range of 32.3-49.4 percent, depending on the controlled conditions. In Viet Nam, the uncontrolled biogas stove is the prevalent condition, therefore the thermal efficiency is about 32.3 percent. It is lower compared to the LPG and Kerosene stoves (from 40 to 60 percent) but higher than wood stoves (10 percent) or improved wood stoves (20 percent).

However, there are no detailed studies showing the difference in the thermal efficiency of a stove using biogas and fossil fuels such as LPG in Viet Nam. Under perfect controlled conditions, the thermal efficiency of a biogas stove (49.4 percent) is slightly lower than an LPG stove (53.2 percent). This may be due to the lower methane content in biogas compared to the gas hydrocarbons in LPG.

b. Biogas from cassava starch wastewater at industrial level

Table 108 reports data related to selected cassava starch production plants in Viet Nam collected through a survey performed within this study (VJIIST, 2017). Starch capacity varies from 10 800 tonne/y to 32 000 tonnes/year, while the consumption of fresh cassava varies from 40 000 tonnes/year to 128 000 tonnes/year. The cassava starch plant uses electricity mainly for

TABLE 107

THERMAL EFFICIENCY OF BIOGAS AND OTHER FUELS

SOURCE	SMITH ET AL., 2000	TERI WEBSITE	TRIBHUWAN UNIVERSITY, 2001
FUEL/STOVE	THERMAL EFFICIENCY (percent)		
BIOGAS STOVE	57.3	45	49.4 (Perfect controlled condition) 43.8 (Semi-controlled condition) 32.3 (Uncontrolled condition)
LPG STOVE	53.6	60	53.2
KEROSENE STOVE	50.0	43	38.2
WOOD STOVE	22.8	10	
IMPROVED WOOD STOVE		20	
ELECTRICITY STOVE		70	

TABLE 108

MAIN OUTCOMES FROM SURVEY CONDUCTED IN SELECTED CASSAVA STARCH PRODUCTION PLANTS IN VIET NAM

			Electricity consumption			Biogas			
Cassava starch plant location	Starch capacity (tonne/y)	Cassava feed (tonne/y)	kWh/y	kWh/tonne	Wastewater (m^3/yc)	m^3/y	m^3/tonne	m^3/m^3 wastewater	COD input (mg/litre)
PY	28 800	115 200	4 752 000	165.0	633 600	2 448 000	85	3.86	6 830
H	21 600	86 000	3 652 000	169.1	422 400	1 920 000	89	4.55	8 320
QN	21 600	82 000	3 672 000	170.0	453 600	1 188 000	55	2.62	5 660
HT	16 000	60 000	2 720 000	170.0	352 000	800 000	50	2.27	8 325
TH	24 000	90 000	3 960 000	165.0	552 000	1 200 000	50	2.17	6 850
QT	32 000	128 000	5 300 000	165.6	784 000	2 880 000	90	3.67	7 520
QN1*	11 000	40 000	2 856 000	259.6	187 000	605 000	55	3.24	9 125
QN2	30 000	120 000	5 730 000	191.0	690 000	3 000 000	100	4.35	7 520
NA	12 000	48 000	2 160 000	180.0	252 000	1 020 000	85	4.05	8 120
BD1*	16 800	67 000	5 350 000	318.5	302 400	1 000 000	60	3.31	6 430
BD2	30 000	120 000	5 040 000	168.0	600 000	-	-	-	8 000
TN1*	10 800	-	-	-	237 600	-	-	-	-
TN2*	11 700	-	-	-	175 500	-	-	-	-
AVERAGE				**171.5**			**67.10**	**3.06**	**7 461**

** data not available or very different from the others, therefore not used in calculating the average*

washing, cutting and milling machines, and heat totally from biogas. Wastewater from the plants have high COD indexes of, on average, about 6 715 mg/litre. Biogas yield varies from 2.17 to 4.55 m^3/m^3 of wastewater. The COD index of the output wastewater from the biogas digester is around 800 mg/litre. It is then pumped into the aerobic tanks to satisfy the COD requirement for its release.

Table 109 shows the amount of CH_4 produced annually by each biogas plant and the related amount of energy produced, in the form of heat and power. The amount of heat used in the starch drying process was calculated based on the initial and final moisture of starch (34 percent and 12 percent, respectively) and by assuming a heat efficiency of the drier of about 64 percent. **Table 109** also presents the share of biogas used for the drying process, which is in a range of 50-81 percent. The remaining heat from biogas combustion is released as flue gas of the cassava starch plants. Currently, in Viet Nam, there is no use of biogas for power generation. If the excess heat was used for power generation (using a gas engine with efficiency of about 33 percent), the potential electricity saving in ethanol plants could vary from 7.8 percent up to 66 percent in the BD2 and QT plants, resulting in substantial reductions (i.e. over a hundred thousand US dollars) of total cassava starch production costs. However, it is important to consider that the initial investment costs as well as maintenance costs for installing a biogas pre-treatment plant and a gas engine could be significant and could have long payback times.

TABLE 109

BIOGAS USE AND POTENTIAL IN STARCH CASSAVA PLANTS IN VIET NAM

Cassava starch plant location	Generated CH_4[a] (kg/y)	Generated energy[b] (GJ/y)	Heat used for starch drying (GJ/y)	Share of produced biogas used for starch drying (percent)	Potential power generation[c] (kWh/y)	Potential electricity saved[d] (percent)	Saving[g] (USD/y)
PY	1 107 976	55 399	34 500	62.28	1 915 725	40.31	135 029
H	921 170	46 058	25 875	56.18	1 850 154	50.66	130 407
QN	639 304	31 965	25 875	80.95	558 268	15.20	39 349
HT	768 152	38 408	19 167	49.90	1 763 752	64.84	124 317
TH	968 484	48 424	28 750	59.37	1 803 468	45.54	127 117
QT	1 527 859	76 393	38 333	50.18	3 488 799	65.83	245 907
QN1E	451 465	22 573	13 177	58.37	861 314	30.16	60 709
QN2	1 344 672	67 234	35 938	53.45	2 868 809	50.07	202 207
NA	534 946	26 747	14 375	53.74	1 134 126	52.51	79 938
BD1E	1 252 800	62 640	35 938	57.37	2 447 729	48.57	172 527
BD2	493 728	24 686	20 125	81.52	418 131	7.82	29 472
TN1E			12 938				
TN2E			14 016				
				58.16		48.17	

a (Generated CH_4) = (Wastewater flowrate)(COD input – COD output)*0.29/1000.*
b (Generated energy) = (Generated CH_4)LHV_{CH4}/1000.*
*c (Potential power generation) = ((Generated energy)–(Heat used for starch drying))*0.33*106/3600.*
d (Potential electricity saved)= (Potential power generation)/(electricity consumption).
e data not available or very different from the others, therefore not used in calculating the average.

4.18.3 Main conclusions and recommendations

a. Approach used

Two bioenergy pathways were investigated, i.e Cassava-based ethanol and Biogas from pig manure at farm level. An attempt was also made to analyse biogas produced from cassava starch wastewater, but the measurement could not be finalized because of lack of data.

Cassava-based ethanol

For Cassava-based ethanol, the study focused on three ethanol plants in Viet Nam that were surveyed within this study, and the outcomes were compared with data available in literature.

Biogas

For the analysis of biogas, a survey was conducted with pig farms in selected provinces of Viet Nam between January and March 2017 (VJIIST, 2017).

b. Results

Cassava-based ethanol

The main results of the measurement of Indicator 18 for Cassava-based ethanol from the three plants considered, expressed in terms of Net Energy Balance (NEB) and Net Energy Ratio (NER), are the following:

- LHV of dry cassava chip: 16 675 MJ/tonne
- Indicator 18.1: NEB = 14 862 MJ/tonne; NER = 9.23
- Indicator 18.2: NEB = 4 275 MJ/tonne; NER = 1.88
- Indicator 18.3 (Ethanol thermal efficiency – E5): 40.4 percent
- Indicator 18.4: NEB = 3 529 MJ/tonne; NER = 1.61

Biogas

The main results of the measurement of Indicator 18 for pig manure-based biogas, in terms of Net Energy Balance (NEB) and Net Energy Ratio (NER), are the following:

- LHV of wet manure: 2.8 MJ/kg
- Indicator 18.1: NEB: 2.8 MJ/kg; NER: Not applicable
- Indicator 18.2: NEB:1.17 MJ/kg; NER: 31.8
- Indicator 18.3 (Thermal efficiency of uncontrolled biogas stove): 32.3 percent
- Indicator 18.4: NEB: 1.17 MJ/kg; NER: 31.8

The main results of the measurement of Indicator 18 for biogas production coupled with cassava starch production plants, in terms of Net Energy Balance (NEB) and Net Energy Ratio (NER), are the following:

- Indicator 18.1: NER: N.A. because the initial feedstock is just a waste (cassava-starch wastewater)
- Indicator 18.2: not measurable because the amount of electricity used for biogas production from cassava wastewater is unknown
- Indicator 18.3: Share of produced biogas used for cassava starch drying: 58.16 percent
- Indicator 18.4: not measurable because the amount of electricity used for biogas production from cassava wastewater is unknown

c. Future monitoring

There are many cassava starch production plants and middle-size pig farms in Viet Nam. However, only a few plants and farms were considered in this analysis. Additional cassava starch plants and farms should be surveyed and studied in order to gather more robust information and get to more accurate results. If the energy input for biogas production from cassava wastewater at industrial level could be known in detail, the net energy analysis of this specific pathway could be completed.

REFERENCES

BioGrace. 2017. The BioGrace GHG calculation tool – version 4d. Available at: www.biograce.net/home [Accessed: 9 Feb 2018]

Duc, K.N., Tien, H.N., Duy, V.N. 2016. Performance enhancement and emission reduction of used motorcycles using flexible fuel technology. Journal of the Energy Institute.

Smith, K.R., Uma, R., Kishore, V.V.N., Lata, K., Joshi, V., Zhang, J., Rasmussen, R.A., Khalil, M.A.K. 2000. Greenhouse Gases from Small-scale Combustion Devices in Developing Countries, Phase IIa: Household Stoves in India. EPA-600/R-00-052, U.S. Environmental Protection Agency, Office of Research and Development, Washington, DC. Available at: http://ehsdiv.sph.berkeley.edu/krsmith/publications/00_smith_3.pdf [Accessed: 9 Feb 2018]

GSO website. Statistical data (06.Agriculture, Forestry and Fishing]. Available at: www.gso.gov.vn. [Accessed: Jan 2018]

iNET. 2016. "Miếng bánh thị phần ô tô Việt Nam, ai đang 'ăn' nhiều nhất?" (Vietnamese automobile market share, who is eating the most?) Available at: http://tintuc.vn/mieng-banh-thi-phan-o-to-viet-nam-ai-dang-an-nhieu-nhat-98442 [Accessed: 9 Feb 2018]

Loan, T.L., Wesseler, J., Zhu, X., and van Ierland, E.C. 2013. Energy and greenhouse gas balances of Cassava-based ethanol in Viet Nam. Biomass and Bioenergy 51:125–135. DOI 10.1016/j.biombioe.2013.01.011

MARD website. Statistics Pages. Available at: www.mard.gov.vn/en/Pages/statistics.aspx

NEWCARE. 2016. "Thị trường xe máy Việt Nam năm 2016: Nước chảy chỗ trũng" (Vietnam motorbike market in 2016: the water runs down the valley). Available at: http://autobikes.vn/thi-truong-xe-may-viet-nam-nam-2016-nuoc-chay-cho-trung-2237.html [Accessed: 9 Feb 2018]

TERI (The Energy and Resources Institute) website. 2017. Available at: www.teriin.org/renew/tech/biogas [Accessed: 10 Apr 2017].

Tribhuwan University. 2001. Technical report, Efficiency Measurement of Biogas, Kerosene and LPG Stoves, 2001

VJIIST. 2017. Survey carried out in March 2017 within this study, conducted on five pig farms located in the North of Viet Nam

4.19 INDICATOR 19: GROSS VALUE ADDED

Cassava based ethanol pathway: **Dao The Anh and Bui Quang Duan**
Biogas pathway: **Nguyen Thi Dieu Linh**

Centre for Agrarian Systems Research and Development (CASRAD) at Viet Nam Academy of Agricultural Sciences (VAAS)

DESCRIPTION:

Gross value added per unit of bioenergy produced and as a percentage of gross domestic product.

MEASUREMENT UNIT(S):

USD/MJ and percentage

4.19.1 Implementation of Indicator 19 in Viet Nam

Cassava-based ethanol

For measuring this indicator, a survey was submitted to 21 cassava-growing households from the Tay Ninh Province that sell fresh cassava to local traders and starch production factories.

Due to lack of data related to the ethanol processing stage, a detailed analysis could be conducted only for the cassava starch value chain. However, an estimate of the gross value added was made for Cassava-based ethanol as well.

Biogas

In Viet Nam, all products derived from the anaerobic digestion process (i.e. biogas and digestate) from households, farms and cassava starch factories are not sold to third parties. Therefore, the gross value added for the biogas value chain was measured by taking into account the cost sustained for producing biogas, as well as the savings derived from replacing the use of fossil fuels or other fuels and from replacing the use of fertilizers (assuming the digestate from biogas production is used instead).

For the measurement of this indicator for the biogas value chain, secondary data from EPRO (2016) were used. In addition, primary data were collected from two starch factories located in the Tay Ninh Province through a survey conducted April 2017.

4.19.2 Key findings

Cassava-based ethanol

a. Gross value added

outcomes from the survey conducted within this study confirmed that the Tay Ninh Province has one of the highest cassava yields in the country. The productivity of cassava across the 21 households that were surveyed varied from 10 to 47 tonnes/ha of fresh cassava, with an average of 31.7 tonnes/ha (Table 110). The cassava varieties used were KM89, KM94 and some new plant varieties such as HL-S10, HL-S11, KM94 (mutation variety) and KM505.

TABLE 110

CASSAVA PRODUCTIVITY OF SURVEYED HOUSEHOLDS IN THE TAY NINH PROVINCE

AREA AND NUMBER OF HOUSEHOLDS	PRODUCTIVITY (tonnes/ha)		
	MIN	MAX	AVERAGE
TAP HIEP COMMUNE - TAN CHAU DISTRICT (N=2)	30.00	40.00	35.00
HAO DUOC COMMUNE - CHAU THANH DISTRICT (N=6)	25.00	45.00	34.50
TAN LAP COMMUNE - TAN BIEN DISTRICT (N=13)	10.00	47.00	30.01
TOTAL	10.00	47.00	31.77

Source: CASRAD, 2017

Gross value added in the cassava production stage

Case 1: households buy propagation material of improved cassava variety and rent land for cassava cultivation. In this case, an average production cost of 1 685.38 USD/ha or 0.05 USD/kg of fresh cassava was reported by the surveyed households. Total revenues declared amounted to 1 889.55 USD/ha on average, with a profit of 204.17 USD/ha (**Table 111**).

Case 2: households use their own propagation material and own the land used for cassava cultivation. In this case, the average production cost declared by the surveyed households was 1 240.35 USD/ha, or 0.04 USD/kg of fresh cassava. Total revenues reported were equal to 1 889.55 USD/ha on average, with a profit of 649.20 USD/ha (**Table 111**).

In both of the above-mentioned cases, in order to reduce the production cost and increase profits, cassava producers often engage family labour in cassava production, e.g. for planting, harvesting and other related activities (CASRAD, 2017).

Collection and transport of fresh cassava to cassava starch factories

Total intermediate cost is 68.01 USD/tonne of fresh cassava. Total revenue per tonne is 76.21 USD/tonne and value added is 8.2 USD/tonne of fresh cassava (**Table 112**).

Cassava starch processing

Total intermediate cost is 323.18 USD/tonne of cassava starch. Total revenue is 337.39 USD/tonne

TABLE 111

GROSS VALUE ADDED OF CASSAVA CULTIVATION

INDICATORS	UNIT	CASE 1	CASE 2
PRODUCTIVITY (A)	TONNES/HA	31.77	31.77
PRODUCTION COST (B)	USD/HA	1 685.38	1 240.35
TOTAL REVENUES (D)	USD/HA	1 889.55	1 889.55
GROSS VALUE ADDED (E = D-B)	USD/HA	204.17	649.20

Source: CASRAD, 2017

TABLE 112

GROSS VALUE ADDED OF CASSAVA COLLECTION AND TRANSPORT ACTIVITIES

No	CONTENT	AMOUNT (USD/tonne)
1	TOTAL COSTS	68.01
	COST OF RAW MATERIALS (FRESH CASSAVA)	59.60
	COST OF LOADING	1.77
	SHIPPING COSTS TO THE FACTORY	6.64
2	TOTAL REVENUES	76.21
3	GROSS VALUE ADDED (PER TONNE OF FRESH CASSAVA)	8.20

Source: CASRAD, 2017

of cassava starch. Thus, value added is 14.21 USD/tonne of cassava starch (**Table 113**).

Gross value added of cassava starch production

Assuming that 3.5 kg of fresh cassava are needed to produce 1 kg of dry cassava starch, the total gross value added generated along the cassava starch value chain is 114.59 USD/tonne of dry cassava starch (**Table 114**).

Gross value added per unit of ethanol produced

the average selling price of E5 RON 92 gasoline was 17 025 VND/litre for 2017 (equal to 0.75 USD/litre – see Indicator 24). Meanwhile, the production cost of ethanol was 0.68 USD/litre (see Indicator 17.4). Thus, the gross value added was 0.07 USD/litre (equivalent to 0.0033 USD/MJ).

b. Percentage of gross domestic product

Cassava starch value chain

Case 1: The gross value added of cassava starch production is 65.45 USD/tonne of cassava starch. It is estimated that Viet Nam produces about

TABLE 113

GROSS VALUE ADDED OF CASSAVA STARCH PROCESSING

NO	CONTENT	AMOUNT (USD)
1	**TOTAL COSTS/TONNE OF FINAL PRODUCT**	**323.18**
	RAW MATERIALS (E.G. FRESH CASSAVA)	266.73
	OTHER INPUTS (E.G. ELECTRICITY)	43.07
	LABOR	11.53
	OTHER COSTS	1.84
2	**TOTAL REVENUE/TONNE OF PRODUCT**	**337.39**
	FROM THE MAIN PRODUCT (CASSAVA STARCH)	331.86
	FROM BY-PRODUCTS (CASSAVA RESIDUE)	5.53
3	**GROSS VALUE ADDED (PER TONNE OF PRODUCT)**	**14.21**

Source: CASRAD, 2017

TABLE 114

TOTAL GROSS VALUE ADDED IN THE CASSAVA STARCH VALUE CHAIN

No	PHASE OF THE CASSAVA STARCH VALUE CHAIN	CASE 1		CASE 2	
		GROSS VALUE ADDED	GROSS VALUE ADDED PER TONNE OF CASSAVA STARCH (USD/tonne)	GROSS VALUE ADDED	GROSS VALUE ADDED PER TONNE OF CASSAVA STARCH (USD/tonne)
1	CASSAVA PRODUCTION	204.17 (USD/ha)	22.54	649.2 (USD/ha)	71.68
2	CASSAVA COLLECTION AND TRANSPORTATION TO PLANT	8.2 (USD/tonne of fresh cassava)	28.7	8.2 (USD/tonne of fresh cassava)	28.7
3	CASSAVA PROCESSING IN STARCH PRODUCTION PLANTS	14.21 (USD/tonne of cassava starch)	14.21	14.21 (USD/tonne of cassava starch)	14.21
	TOTAL GROSS VALUE ADDED OF VALUE CHAIN		65.45		114.59

Source: CASRAD, 2017

1.2 million tonnes of cassava starch. Thus, the total gross value added generated by the cassava starch value chain amounts to USD 78.54 million per year. The GDP (in terms of purchasing power parity) of Viet Nam in 2016 was USD 595 billion (Vietnambiz, 2017). Thus, the cassava starch value chain contributed to 0.0132 percent of total GDP in that year.

Case 2: The gross value added of cassava starch production is 114.59 USD/tonne of cassava starch. Thus, the cassava starch value chain contributed USD 137.5 million (or 0.023 percent) to GDP in 2016.

Cassava-based ethanol value chain

In 2016, total national consumption of ethanol was 29 500 m^3, or 29.5 million litres (Dong, 2017). If a gross value added of 0.07 USD/litre is considered, the Cassava-based ethanol value chain contributed USD 2.065 million (or 0.000347 percent) to the country's GDP in 2016. With a country-wide E5 mandate for RON92 gasoline, the gross value added generated by the Cassava-based ethanol value chain would have equalled USD 18.75 million, or 0.00315 percent of GDP, in 2016.

Biogas

c. Gross value added per unit of bioenergy produced

Household level

The gross value added per unit of bioenergy at household level was measured using the data from EPRO (2016) shown in **Table 115**.

On average, an AD with a volume of 10.49 m^3 generated value added from savings on fuel, fertilizers and fish feed of USD 73.22. The gross value added per unit of biogas produced is very small, i.e. 0.00195 USD/MJ. Thus, the total gross value added generated by the 405 000 ADs currently in operation at household level was estimated at USD 18.97 million.

Farm level

Currently, biogas produced at farm level (MBP and LBP scale) is not used for the production of heat or electricity[17]. Therefore, the gross value added from biogas produced at this level was not calculated.

TABLE 115

GROSS VALUE ADDED OF BIOGAS VALUE CHAIN AT HOUSEHOLD LEVEL

NO.	CONTENT	UNIT	2014
1	**COST SAVINGS PER AD/YEAR**	**USD***	**73.22**
	- SAVINGS ON FUEL COSTS FOR COOKING	USD	58.08
	- SAVINGS ON ELECTRICITY COSTS	USD	2.06
	- SAVINGS ON FERTILIZER COSTS	USD	10.55
	- SAVINGS ON FISH FEED COSTS	USD	2.54
2	**PRODUCTION COST OF BIOGAS PER AD/YEAR**	**USD**	**26.39**
3	**GROSS VALUE ADDED PER AD**	**USD**	**46.83**
4	NUMBER OF ADS IN THE COUNTRY (90 PERCENT IN USE)	NUMBER OF PLANTS	405 000
5	**GROSS VALUE ADDED OF BIOGAS PRODUCED**	**USD**	**18 966 150**
6	TOTAL BIOGAS PRODUCTION AT HOUSEHOLD LEVEL	MJ	9 720 000 000
7	**GROSS VALUE ADDED PER UNIT OF BIOGAS PRODUCED**	**USD/MJ**	**0.00195**

Source: Elaborated from EPRO (2016)
* Exchange rate: 1 USD = 22 600 VND

[17] As explained under previous indicators (e.g. Indicator 17), biogas produced at farm level is used for cooking and lighting by a few hundred households living on the concerned farms. The same figures estimated above for the household level apply here, but to a much smaller set of households.

Industrial level

Gross value added per unit of biogas was estimated based on a survey of two cassava starch processing factories in the Tay Ninh Province. These plants use biogas to dry cassava starch, and part of the digestate produced is used as fertilizer. Therefore, biogas production and use enable savings in terms of energy cost for cassava drying and fertilizer cost. Regarding the former, biogas produced from cassava starch wastewater replaces coal and/or diesel oil (DO).

The gross value added of biogas production from cassava starch wastewater at industrial level is USD 0.0073135 per MJ of biogas. With a total of 102 cassava starch factories in Viet Nam, the gross value added of biogas from cassava starch wastewater can be estimated at almost USD 20,7 million (**Table 116**).

Percentage of gross domestic product

The Gross Value Added from the biogas value chain across all levels was almost USD 40 million, accounting for 0.0067 percent of the country's GDP.

TABLE 116

GROSS VALUE ADDED OF BIOGAS VALUE CHAIN AT INDUSTRIAL LEVEL

NO.	CONTENT	UNIT	HUNG DUY TRADING INDUSTRY TRANSPORT IM-EXPORT CO., LTD	THANH BINH CO., LTD
1	**COST SAVINGS FROM BIOGAS PLANT**	**USD**	**847 270.2**	**135 967.5**
	- SAVINGS ON THE COST OF FOSSIL FUELS	USD	839 305.6	135 967.5
	- SAVINGS ON THE COST OF FERTILIZER	USD	7 964.6	0.0
2	**PRODUCTION COST**	**USD**	**164 792.0**	**31 371.7**
3	**GROSS VALUE ADDED**	**USD**	**682 478.2**	**104 595.8**
4	BIOGAS PRODUCTION	MJ/PLANT/Y	84 169 933	16 024 078
5	**GROSS VALUE ADDED PER UNIT OF BIOGAS PRODUCED**	**USD/MJ**	**0.00810**	**0.006527**
6	**AVERAGE**	**USD/MJ**	**0.0073135**	
7	TOTAL BIOGAS PRODUCTION AT INDUSTRIAL LEVEL	MJ/Y	2 825 974 260	
8	**GROSS VALUE ADDED OF BIOGAS PRODUCED**	**USD**	**20 667 565**	

Source: CASRAD, 2017

4.19.1 Main conclusions and recommendations

Cassava-based ethanol

a. Approach used

In order to calculate the gross value added in the Cassava-based ethanol value chain in Viet Nam, secondary data were used, as well as the results of indicator 17. In addition, primary data were collected through interviews with 21 cassava producers and four cassava starch factories in the Tay Ninh Province.

b. Results

With a gross value added of 0.07 USD/litre, the Cassava-based ethanol value chain contributed USD 2.065 million (or 0.000347 percent) to the country's GDP in 2016. With a country-wide E5 mandate for RON92 gasoline, the gross value added generated by the Cassava-based ethanol value chain would have equalled USD 18.75 million, or 0.00315 percent of GDP.

c. Practices and policies to improve sustainability

To increase the gross value added per unit of ethanol, the production cost of cassava should be reduced, by improving the efficiency and productivity of the feedstock cultivation stage. In order to increase the ethanol output (and the associated value), improved processing technologies could be introduced as well.

d. Future monitoring

For an accurate measurement of this indicator in the future, it would be important to collect detailed information related to the ethanol processing stage. This would require coordination with the Ministry of Industry and Trade, with business associations active in the sector and with individual plants willing to cooperate, in order to facilitate the sharing of information.

Biogas

a. Approach used

In Viet Nam, biogas produced at all levels (i.e. household, farm and industrial) is used exclusively for own consumption. For this reason, the gross value added for the biogas value chain was measured based on the savings on the cost of fossil fuels and fertilizer made possible by biogas use, minus the production cost of this fuel.

Secondary data from EPRO (2016) were used. Furthermore, primary data were collected from two starch factories in the Tay Ninh Province.

b. Results

The Gross Value Added from the biogas value chain across all levels was almost USD 40 million (of which 18,97 million at household level and 20,67 million at industrial level), accounting for 0.0067 percent of the country's GDP.

c. Practices and policies to improve sustainability

Currently, only part of the biogas produced at household, farm and industrial levels is used, with the rest of it being flared or vented. A significant surplus of biogas is available especially at farm level, as well as at industrial level. Using this surplus to produce heat and electricity and supply the latter to the grid would greatly increase gross value added generation and the contribution of the sector to the country's GDP. Heat and power generation from biogas should be adequately supported in the context of sectoral policies such as the National Energy Policy and the Renewable Energy Policy.

d. Future monitoring

Collecting primary data for measuring indicator 19 at the industrial level is a challenge due to the commercial sensitivity of the part of the information required. In the context of this study, only 2 out of 102 cassava starch processing plants were interviewed. In the future, a broader sample of these plants should be surveyed.

REFERENCES

CASRAD. 2017. A survey data conducted on April 2017 in Phu Tho and in Tay Ninh provinces. For measuring Ind. 19 on cassava based ethanol the survey involved 21 cassava producers and four cassava starch factories in Tay Ninh province.

EPRO. 2016. Consulting JSC. Biogas User Survey (BUS) 2014. Available at: http://biogas.org.vn/vietnam/getattachment/Thu-vien-phim,-anh/An-pham/Bao-cao-Khao-sat-nguoi-su-dung-cong-trinh-khi-sinh/Bus2014-report,-ENG.pdf.aspx

Loan, T.L., Wesseler, J., Zhu, X. and van Ierland, E.C. 2013. Energy and greenhouse gas balances of Cassava-based ethanol in Viet Nam, Biomass and Bioenergy 51:125–135. DOI 10.1016/j.biombioe.2013.01.011

Dong, D.X. 2017. The orientation in the production and use of biofuels in Vietnam. Department of Science and Technology, MOIT. FAO, Sustainable Bioenergy Production and Use in Southeast Asia: Lessons Learnt and Future Opportunities, 16-17 November 2017, Hanoi. Available at: www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/AG2/Viet_Nam_project/Final_Mettings/Dong_Do-Xuan.pdf [Accessed: 13 Feb 2018]

Vietnambiz. 2017. Vietnam's economy and forecasts are full of surprises (translated from Vietnamese). Available at: http://vietnambiz.vn/kinh-te-viet-nam-va-nhung-du-bao-day-bat-ngo-16944.html

4.20 INDICATOR 20: CHANGE IN CONSUMPTION OF FOSSIL FUELS AND TRADITIONAL USE OF BIOMASS

Cassava based ethanol pathway: **Do Xuan Truong**[1]
Biogas pathway: **Nguyen Ngoc Mai**[2]

[1]Vietnam Japan International Institute for Science of Technology (VJIIST) at the Hanoi University of Science and Technology (HUST)
[2]Centre for Agrarian Systems Research And Development (CASRAD) at Viet Nam Academy of Agricultural Sciences (VAAS)

DESCRIPTION:

(20.1) Substitution of fossil fuels with domestic bioenergy measured by energy content (20.1a) and in annual savings of convertible currency from reduced purchases of fossil fuels (20.1b)
(20.2) Substitution of traditional use of biomass with modern domestic bioenergy measured by energy content.

MEASUREMENTS UNIT(S):

(20.1a) MJ per year and/or MW per year
(20.1b) USD per year
(20.2) MJ per year and/or MW per year

4.20.1 Implementation of Indicator 20 in Viet Nam

Cassava-based ethanol

For the measurement of indicator component 20.1, the required data was obtained from both national and international statistics, as well as from indicator 18. The following formula obtained from FAO (2011) was used for estimating the amount of fossil fuel energy, disaggregated by fossil fuel type, substituted by using modern bioenergy in Viet Nam:

$$[1]\quad E_{fossilsub\_i} = E_{bioenergydom} \times \left(1 - \frac{1}{NER\_i}\right)$$

Where:

- $E_{fossilsub\_i}$ is the amount of fossil fuel energy, disaggregated by fossil fuel type, substituted by domestic modern bioenergy in the country;
- $E_{bioenergydom}$ is the amount of domestically produced modern bioenergy consumed in the country; and
- NER_{dom_i} is the (national average) Net Energy Ratio for domestically produced modern bioenergy consumed in the country, disaggregated by fossil fuel type and calculated according to the methodology for Indicator 18 on Net energy balance, and using only fossil fuel inputs for the energy input term:

$$\text{Net Energy Ratio} = \frac{\text{Energy output}}{\text{Fossil fuel energy input}}$$

In Viet Nam, the NER for Cassava-based ethanol plants was calculated within sub-indicator 18.4 as an average of the NER of the three ethanol plants considered in this study and is equal to 1.61.

Component 20.2 was not found to be relevant in relation to the Cassava-based ethanol pathway in the current context of Viet Nam, as this fuel does not replace traditional biomass use.

Biogas

In Viet Nam, the final use of biogas, and thus its potential to replace other fuels, is strictly dependent on the scale at which it is produced and used.

Formula [1] used for measuring sub-indicator 20.1 in the case of the ethanol pathway was not applicable for measuring the capability of biogas to replace fossil fuel energy in Viet Nam due to lack of data. As a consequence, proxies were adopted, based on secondary and primary data collected for the scope of this study.

ADs in Viet Nam were classified depending on their scale/volume as follows: Small Biogas

Plants (SBP), Medium Biogas Plants (MBP) and Large Biogas Plants (LBP). The SBP have an average volume of 10 m^3, the MBP have an average volume of 500 m^3 and the LBP have an average volume of 2 000 m^3. Between household and farm levels, in 2015 there were 465 370 ADs in Viet Nam – 450 000 at household level (SBP) and the remainder at farm level, of which 14 370 were MBP and 1 000 were LBP. Around 90 percent of the existing ADs were operational (MARD, 2016).

In Viet Nam, biogas produced in the ADs either at household, farm and industrial level, is used ***in-house*** (i.e. for own consumption), for addressing different purposes.

At household level, according to EPRO (2016), 98 percent of biogas produced is used for cooking and heating.

At farm level, results from the survey carried out within this study in Phu Tho Province in April 2017 (CASRAD, 2017), highlighted that livestock farms with more than 100 heads, commonly feed ADs with animal manure (mainly from pigs) and use the produced biogas for cooking rice and lighting bulbs in the house, while the unexploited biogas, whose amount is unknown, is flared or vented. It emerged that, although pig farms consume a large amount of power for stable ventilation and warming, as well as for pumping water for cleaning the farm, the power supply for the farm currently comes entirely from the grid and no power or heat generation occurs from biogas. In Viet Nam, the NER for pig manure-based biogas production at farm scale, in which the only energy input is electricity from the grid, was calculated within sub-indicator 18.4 and is equal to 31.8.

In cassava starch industries, biogas is used to replace coal and DO in the production of steam and heat for drying cassava starch. Results from the surveys conducted within this study (CASRAD, 2017; VJIIST, 2017) show that the use of biogas for running generators and producing power, thus reducing the amount of electricity withdrawn from the grid, occurs only in a few cases, specifically when an AD is coupled with ethanol production plants. Even in these cases, the electricity produced is used for own consumption and no surplus electricity is produced and supplied grid to the grid. The NER for biogas produced at industrial scale could not be calculated due to lack of data on the electricity consumed in the AD process. As a consequence, it was not possible to calculate sub-indicator 20.1 for biogas from cassava-starch wastewater, although this sub-indicator is highly relevant in the case of the biogas pathway at industrial level, as there is the potential for significant savings in terms of fossil fuels.

As a consequence, the measurement of Indicator 20 in Viet Nam addressed only the biogas capability of displacing fossil fuel (i.e. LPG, sub-indicator 20.1) and traditional fuel (e.g. fuelwood, residues; sub-indicator 20.2) for cooking and heating purposes at household and farm levels.

4.20.2 Key findings

Cassava-based ethanol

a. Sub-Indicator 20.1

Ethanol consumption in Viet Nam decreased from 37 000 m^3/year in 2013 to 15 200 m^3/year in 2015, but increased again to 29 500 m^3/year in 2016, as presented in **Table 117**. As calculated in indicator 18, the total (fossil) energy input accounts for about 62 percent (1/1.61) of the LHV of Cassava-based ethanol. Therefore, only 38 percent of the volume of ethanol consumed in the country is actually displacing fossil fuels, i.e. 235 235 068 MJ in 2016, for a total value of around 1.7 million USD/y in 2016 (up from around 1.3 million USD in 2015).

Should the country-wide E5 mandate for RON92 gasoline be fulfilled in 2018, the amount of fossil fuel replaced by ethanol would be equal to 2.1 billion MJ/year. Based on the same 2016 oil price used for the above calculations, the resulting annual savings would be around 15.2 million USD/year.

b. Sub-Indicator 20.2

As explained above, indicator component 20.2 was not deemed relevant in the case of the ethanol pathway in Viet Nam.

TABLE 117

CHANGE IN CONSUMPTION OF FOSSIL FUELS IN VIET NAM, 2013-2016 AND 2018 (FORECAST)

	ETHANOL		FOSSIL FUELS SUBSTITUTED BY ETHANOL			
YEAR	m^3/y	MJ/y	MJ/y	Price $bbl_{fossilsub\_OIL}$	USD/MJ[c]	USD/y
2013	37 000	780 700 000	295 040 594	101.31	0.0170	5 004 909
2014	25 300	533 830 000	201 743 973	108.26	0.0181	3 657 048
2015	15 200	320 720 000	121 205 865	62.82	0.0105	1 274 922
2016	29 500*	622 450 000	235 235 068	42.43	0.0071	1 671 234
2018[b]	267 850	5 651 635 000	2 135 854 675	42.43	0.0071	15 174 234

Source: Viet Nam Petroleum Association, 2017
** Dong, 2017*
b Based on a country-wide E5 mandate for RON92 gasoline (MOIT, 2017).
c Content of 1 barrel = 5.97 GJ

Biogas

a. Sub-Indicator 20.1

BIOGAS FROM PIG MANURE

At household level

According to the Low Carbon Agricultural Support Project (FAO, 2012), an AD can produce 0.3 m^3 biogas/day for each m^3 of capacity. The energy content of the biogas produced is 0.0216 GJ/m^3 biogas (equivalent at 6 kWh/m^3 biogas). Therefore, the energy theoretically produced annually by one AD at household level (10 m^3) is equal to around 24 GJ. Given that only 90 percent of ADs originally built are currently operational (Department of Livestock Production - MARD, 2016), total energy output of ADs at household level is estimated at 9 720 000 GJ per year (405 000 bio-digesters x 24 GJ/year), equal to 232.3 KTOE.

At farm scale

In practice, large-scale farms with more than 100 pigs, also use only small digesters such as KT1, KT2, composite. Therefore, the amount of energy saved from substitution of fossil fuels and fuelwood on these farms can be calculated in the same way as households; the results are shown in **Table 118**.

Assuming an annual average of about 15 days for maintenance of the biogas plants (e.g. for repairing and fixing pipeline, repairing the digester tank, replacing the stove and removing sediment) and using the same FAO figures (2012) reported for the household level, the annual biogas output at MBP level (500 m^3) is 1 134 GJ/plant (0.3 x 500 x 0.0216 x (365-15)). Considering that the number of MBPs in Viet Nam is 14 370, 90 percent of which are currently operational, the total biogas output of the country at MBP scale is 14 666 022 GJ/year.

Using the same methodology, it can be estimated that the 900 LBP currently operating in the country can generate 4 082 400 GJ/year of thermal energy.

The total biogas production from pig manure at household and farm levels is 28 468 422 GJ/year (**Table 118**). Nevertheless, this amount is not what is actually consumed, with the major discrepancy between production and consumption occurring at farm scale (MBP and LBP). As a matter of fact, only a minimal share of biogas produced at farm level is actually consumed, while most of it is flared or vented. Therefore, in the case of biogas produced from pig manure, the measurement of parameter $E_{bioenergy\ dom}$ was not possible and sub-indicator 20.1 could not be calculated by adopting the GBEP methodology (FAO, 2011).

As a proxy for the measurement of sub-indicator 20.1, information on the traditional energy use of 47 households was collected in a survey in the Thanh Thuy and Tam Nong districts of Phu Tho Province. Unfortunately, many surveyed households could only quantify the traditional energy used by the family

TABLE 118

BIOGAS PRODUCTION FROM LIVESTOCK MANURE IN VIET NAM

PLANT SIZE (type)	VOLUME (m³)	ADS BUILT	OPERATIONAL ADS (90%)	BIOGAS PRODUCED PER AD (GJ/plant)	TOTAL BIOGAS PRODUCTION FROM LIVESTOCK MANURE (GJ/y)
SBP	10	450 000	405 000	24	9 720 000
MBP	500	14 370	12 933	1 134	14 666 022
LBP	2000	1 000	900	4 536	4 082 400
TOTAL		**465 370**	**418 833**		**28 468 422**

Source: Elaborated from MARD, 2016

TABLE 119

ENERGY CONSUMPTION FOR COOKING PER HOUSEHOLD

	UNIT OF MEASURE	WOOD	AGRICULTURAL RESIDUES	LPG	
NON-BIOGAS USE	KG FUEL/DAY	10.87	4.26	0.16	
HEATING VALUE OF FUEL	MJ/KG	15	12	41.0	
ENERGY CONSUMPTION				**220.73 MJ/DAY**	**80 566 MJ/YEAR**
FUEL SAVED WHEN USING BIOGAS	KG FUEL/DAY	9.23	2.55	0.04	
ENERGY SAVINGS				**170.69 MJ/DAY**	**62 301 MJ/YEAR**

Source: EPRO, 2016

in terms of value rather than amount. For this reason, the amount of fossil fuel and traditional energy displaced by using biogas at household and at farm level was calculated on the basis of data reported by EPRO (2016). Energy consumption at household level is varied and depends on several factors, such as the number of household members, local availability of biomass sources, cooking habits and affordability of LPG fuel, among others. The average energy consumption for cooking per household is approximately 80 566 MJ/year, as reported in **Table 119**.

According to EPRO (2016), and the results of indicator 24, biogas produced at household level can replace 77.3 percent of the consumption of wood fuel, agricultural residues and LPG for cooking. Households that have an AD (i.e. 418 833 households, including those using biogas from pig farms) use 25 percent less LPG, equal to 0.04 kg LPG/day (1.64 MJ/day), or 250 713 434 MJ/year in total (Ind. 20.1a). This is the equivalent of 6 115 tonnes of LPG per year. In October 2017, the retail price of LPG in some Vietnamese provinces was equal to around VND 361 000 per 12 kg bottle (30 083 VND/kg LPG). Thus, total savings due to the replacement of LPG by biogas at household level could be estimated at VND 184 billion (USD 8.14 million[18]).

BIOGAS FROM CASSAVA STARCH WASTEWATER

As measured within Indicator 17, with 102 cassava starch factories producing on average 720 750 m³/plant of wastewater, the estimated total amount of thermal energy potentially generated by ADs is equal to 4 859 146 GJ. Of this amount,

[18] Exchange rate 1 USD = 22 600 VND.

as stated in Indicator 18, only 58.16 percent is actually consumed in-house, replacing the use of coal and DO for producing steam and heat for drying cassava starch products. Therefore, $E_{bioenergydom}$ from cassava-starch production plant wastewater-based biogas was quantified as 2 826 080 GJ/year.

Lack of data prevented the calculation of sub-indicator 18.4 (Net Energy Ratio) in the case of biogas produced from cassava starch wastewater, therefore it was not possible to quantify sub-indicator 20.1 using the GBEP methodology (FAO, 2011) and a proxy approach was used.

It is known that biogas produced from cassava starch wastewater is used as a fuel to replace coal and/or DO for cassava starch driers. The LHV of DO (42.71 MJ/Kg) (MOIT, 2016) and its price in 2016 (12 380 VND/kg) were used to calculate the savings from substitution of DO by biogas. Assuming that 100 percent of biogas consumed by cassava starch plants was used to replace DO for producing heat and steam, 66 167 tonnes of DO were replaced by biogas and savings erere equal to VND 819 142 million (USD 36.25 million).

b. Sub-Indicator 20.2

BIOGAS FROM PIG MANURE

For SBP and MBP scales, biogas is mainly used for cooking, so savings from the purchase of LPG, fuelwood and rice straw were considered for these two scales. Biogas produced in LBP digesters is used for cooking and electricity generation, but there is no data on the amount of electricity generated from biogas (CASRAD, 2017).

The amount of traditional energy (i.e. wood and agricultural residues) saved by the use of biogas was calculated using the amount of energy consumed at household and farm level for cooking purposes on the basis of data reported by EPRO (2016). The type and amount of traditional energy used by households is strictly dependent on the economic conditions and characteristics of each household.

In Viet Nam, livestock raising occurs mainly at household level and the installation of an AD to treat livestock waste is not compulsory. Biogas produced from farm-scale biogas plants is used to replace LPG, fuelwood and agricultural by-products for cooking in households. According to EPRO (2016), households who used biogas saved 9.23 kg of fuelwood and 2.55 kg of agricultural residues per day, which is the equivalent of 169 MJ/day or 61 703 MJ/year (**Table 120**).

Therefore, the total amount of traditional energy savings by the 418 833 livestock-raising households using ADs is equal to 25.8 million GJ/year (Indicator 20.2). 1.4 million tonnes of fuelwood and 390 thousand tonnes of agricultural residues are saved by these households per year thanks to biogas.

TABLE 120

TRADITIONAL ENERGY SAVINGS PER HOUSEHOLD WITH AN AD

FUEL	Kg	LHV (MJ/Kg)	MJ/day	MJ/y
FUELWOOD	9.23	15	138.5	50 534
AGRICULTURAL RESIDUES	2.55	12	30.6	11 169
TOTAL TRADITIONAL ENERGY			169	61 703

Source: Elaborated from EPRO, 2016

4.20.3 Main conclusions and recommendations

Cassava-based ethanol

a. Approach used

Data from the Vietnam Petroleum Association on domestic ethanol consumption and the GBEP methodology (FAO, 2011) were used to calculate sub-indicator 20.1 for the Cassava-based ethanol value chain.

Sub-indicator 20.2 was not deemed relevant in the case of the ethanol pathway in Viet Nam, due to the fact that ethanol does not displace traditional biomass use.

b. Results

The capacity of all ethanol plants in Viet Nam is much higher than the current amount of ethanol consumption in the country. With the adoption of a country-wide E5 mandate for RON92 gasoline in 2018, this is likely to change. Sub-indicator 20.1 shows that, although the Net Energy Ratio is quite high (1.61), ethanol use only saved USD 1.7 million in 2016, due to the combination of low ethanol consumption and low oil prices. With the aforementioned E5 mandate, significantly higher savings (i.e. around USD 15 million) are estimated.

c. Future monitoring

The implementation in Viet Nam showed the importance of assessing the substitution of fossil fuels with biofuels and the resulting economic benefits, thus confirming the relevance of indicator component 20.1. The Future monitoring of this indicator in Viet Nam will be particularly important, in light of the recent adoption of a country-wide E5 mandate.

However, the wording of indicator component 20.1b appears to be tailored mainly to oil importing countries. In the case of oil exporting countries (as in the case of Viet Nam), it is more appropriate to assess the increase in exports rather than the import savings associated with the substitution of fossil fuels with biofuels. Therefore, a more neutral wording of indicator component 20.1b would be desirable in order to capture the full spectrum of substitutions and annual savings/revenues due to modern bioenergy trade.

Biogas

a. Approach used

Secondary data on the total number and type of ADs were retrieved from national statistics (Department of Livestock Production, MARD, 2016). Furthermore, a survey was conducted as part of this study (CASRAD, 2017). Results of Indicators 14, 17, 18 and 24 were also used as inputs for measuring both sub-indicators.

The measurement of indicator 20 was not carried out using the GBEP methodology due to lack of data regarding the amount of biogas actually consumed in the country ($E_{bioenergydom}$), especially at farm scale, and the unknown Net Energy Ratio (NER) of biogas production at industrial scale. This last parameter was not measured due to lack of data regarding the electricity consumption of ADs using cassava starch wastewater as feedstock.

b. Results

Biogas from pig manure

Total potential bioenergy production from the anaerobic digestion of livestock manure in Viet Nam was measured for ADs at small, medium and large scale and is equal to 28.5 million GJ. Due to lack of data on the actual bioenergy consumption at farm scale, the amount of fossil and traditional bioenergy replaced by using biogas in the country was used as a proxy based on EPRO (2016). It was estimated that the amount of fossil fuels (i.e. LPG) saved at household level by using manure-based biogas was equal to 250 million MJ/y (sub-indicator 20.1a), corresponding to 8.14 million USD/y (sub-indicator 20.1b).

Sub-indicator 20.2 is relevant in Viet Nam only at household level because at industrial level biogas is used only for replacing fossil fuels (i.e. coal and DO) and not traditional energy use. The amount of traditional energy saved by all households with ADs is equal to 25.8 million GJ/y or 25 800 million MJ/y (sub-indicator 20.2 at household level).

The total amount of energy saving by households using biogas is equal to 26.1 million GJ/y. This bioenergy is mainly used for cooking, lighting and heating at household level and not for electricity generation.

Biogas from cassava starch wastewater

Only 58.2 percent of the bioenergy generated from biogas from cassava starch wastewater at industrial level is consumed in-house for the production of steam and heat for drying cassava starch – an estimated 2 826 080 GJ/year ($E_{bioenergy\ dom}$). However, sub-indicator 20.1 could not be measured in case of biogas from cassava starch wastewater due to lack of data that prevented the assessment of sub-indicator 18.4 (and therefore the calculation of the NER).

c. Practices and policies to improve sustainability

There are a number of potential practices and policies that could improve the sustainability of the biogas value chain. One of the main problems with the current situation is that not all of the biogas produced is used – some is released inadvertently through leakages and improper management, and a proportion is also flared or vented.

In order to avoid leakages and the associated methane emissions, improvements should be made in the technology used for ADs.

Along with the development of appropriate technologies, policies should be put in place to promote investments in power generators for both own consumption and injection into the grid, thus reducing the amount of biogas flaring and venting. In addition to avoiding GHG emissions, this would also increase the amount of domestically produced modern bioenergy consumed in the country ($E_{bioenergydom}$), allowing for the displacement of fossil fuels, with further environmental and socio-economic benefits.

Incentives for the use of biogas at industrial level could reduce the use of fossil fuels for the production of cassava starch. Indicator 20.1 shows that biogas produced from cassava starch wastewater can be used to generate steam and heat for drying cassava starch, thus replacing a significant amount of coal and DO oil, with positive environmental and economic impacts.

Finally, in order to reduce biogas flaring and venting, options for the distribution of the surplus biogas to communities living close to cassava starch plants should be explored.

d. Future monitoring

To monitor and synthesize data such as digester size, biogas technology and labour indicators, MARD should should set up official statistical data monitoring on biogas from livestock at central and local levels.

REFERENCES

CASRAD. 2017. Survey data of households / livestock farms in Phu Tho province and in four cassava starch processing factories in Tay Ninh province. April 2017

Dong, D.X. 2017. The orientation in the production and use of biofuels in Vietnam. Department of Science and Technology, MOIT. FAO, Sustainable Bioenergy Production and Use in Southeast Asia: Lessons Learnt and Future Opportunities, 16-17 November 2017, Hanoi. Available at: www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/AG2/Viet_Nam_project/Final_Mettings/Dong_Do-Xuan.pdf [Accessed: 13 Feb 2018]

EPRO Consulting JSC. 2016. Biogas User Survey 2014. Available at: http://biogas.org.vn/vietnam/getattachment/Thu-vien-phim,-anh/An-pham/Bao-cao-Khao-sat-nguoi-su-dung-cong-trinh-khi-sinh/Bus2014-report,-ENG.pdf.aspx

FAO. 2012. The Low Carbon Agricultural Support Project (LCASP) in Vietnam: Carbon balance appraisal with the Ex-Ante Carbon balance Tool. Available at: www.fao.org/fileadmin/templates/ex_act/pdf/case_studies/draft_aout2012-clear.pdf

FAO. 2011. The Global Bioenergy Partnership Sustainability Indicators for Bioenergy. First Edition. ISBN 978-92-5-107249-3. Available at: www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/Indicators/The_GBEP_Sustainability_Indicators_for_Bioenergy_FINAL.pdf

MARD. 2016. Real situation and solutions for environmental treatment of livestock production. Department of Livestock Production.

MOIT. 2017. Directive No 11/CT-BCT, promulgated by MOIT on 22 Sept 2017.

Viet Nam Petroleum Association. 2017. www.hiephoixangdau.org/

VJIIST. 2017. Survey conducted within the present study on April 2017.

4.21 INDICATOR 21: TRAINING AND REQUALIFICATION OF THE WORKFORCE

Nguyen Ngoc Mai
Centre for Agrarian Systems Research and Development (CASRAD) at Viet Nam Academy of Agricultural Sciences (VAAS)

Description:

(21.1) Share of trained workers in the bioenergy sector out of total bioenergy workforce
(21.2) Share of re-qualified workers out of the total number of jobs lost in the bioenergy sector

Measurement unit(s):

Percentage per year

4.21.1 Implementation of Indicator 21 in Viet Nam

In Viet Nam, the measurement of indicator 21 focused on the household level biogas pathway. The findings presented below refer in particular to sub-indicator 21.1 and are mainly based on secondary data available in literature and official reports. Furthermore, the results of a survey conducted under this project among a small sample of biogas-using households in the Phu Tho province are discussed below (AITCV, 2017).

Indicator 21.2 was not measured, as no jobs appear to have been lost as a result of the establishment of the bioenergy pathways analysed, and thus this sub-indicator was not deemed relevant.

4.21.2 Key findings

As explained in Chapter two, over the past few decades, various programmes have been implemented in Viet Nam to support the adoption of anaerobic digesters (ADs) at household level, under the leadership of Ministry of Agriculture and Rural Development (MARD) and in cooperation with the Netherlands Development Organization - SNV, the Asian Development Bank and the World Bank. Thanks to this support, around 450 000 household level ADs have been installed in the country, of which 90 percent (i.e. 405 000) are in operation (MARD, 2016).

As reported in MARD (2016) and as already discussed under indicator 12, over 20 000 jobs have been generated in the household level biogas sector. The majority of these jobs (around three quarters) are skilled. More precisely, there are almost 10 000 skilled technicians working part-time at district and commune levels, and almost 11 000 masons and biogas equipment suppliers. Of these 11 000, around half are considered as ‘skilled’, thanks to the training they received (e.g. on the latest techniques to build ADs) through the biogas support programmes implemented by MARD in cooperation with the aforementioned organizations (MARD, 2016). As a matter of fact, capacity development was among the priorities of these programmes. In addition to technicians and masons, trainings were organised for households (on how to operate the ADs) and for team leaders as well, who play a key role in the development of the biogas supply chain.

According to the most recent Biogas User Survey (EPRO 2014), the training of biogas builders was rated at 2.56 on a maximum scale of 3. Among the 349 biogas-using households that responded to the survey, 328 (94 percent) were trained. Most of these households were trained ‘on the ground’ at the biogas plants (290/349 households, accounting for 83 percent).

Interesting indications also emerged from the survey that was conducted under this project among 47 pig farmers with ADs installed (AITCV, 2017). The survey took place in the Phu Tho province (Tam Nong and Thanh Thuy districts), where biogas support programmes were implemented and households, technicians and masons received training. All of the farmers interviewed reported that they are satisfied with the technology of the building workers. Most households know how to use or were instructed on how to use the biogas plant by extension agents or building workers.

4.21.3 Main conclusions and recommendations

Approach used

The measurement of this indicator used secondary data available in literature and official reports, along with the results of a survey conducted under this project among a small sample of biogas-using households in the Phu Tho province (AITCV, 2017).

Results

Due to the lack of official statistics related to work in the biogas sector or on the level of trained and requalified workforce in the sector, the calculation of this indicator was only conducted at project level. As reported in MARD (2016), over 20 000 jobs have been generated in the household level biogas sector, of which around three quarters are skilled. EPRO (2014) report that 94 percent of households surveyed in 2013 had been trained. Primary data collected as part of this survey also supports the hypothesis that households are trained on biogas plant use either by extension agents or biogas masons.

Practices and policies to improve sustainability

As described in this report, household level biogas systems have had a positive effect on a number of environmental and social variables. However, as discussed in Chapter two and in indicator 6 (‘Water quality’), problems have been reported as well and biogas digesters are often poorly managed (Vu *et al.*, 2015; Bruun *et al.*, 2014).

For instance, oftentimes too much water is put into the ADs. This reduces the efficiency of the digestion process and leads to an excessively diluted digestate, thus discouraging farmers from transporting it to the field to apply it to the soil19. As a result, the digestate from the ADs is generally discharged directly into the environment (e.g. into lakes, canals, rivers, soil) nearby farm houses, instead of being used as a fertilizer. Due to this, the potential positive effects that a proper management and application of digestate can have in terms of increased soil organic matter and fertility and reduced use of chemical fertilizers (with associated cost savings) are not exploited. One of the reasons behind the issues described above is lack of adequate training for farmers/households on the operation of ADs. Furthermore, in some cases, limited awareness about the nutritive value (such as N, P and K) of the digestate, as well as of its toxic elements (such as heavy metals) has been reported among farmers. Another issue that has been reported is that, at times, biogas is emitted from the system (i.e. leakage), leading to emissions into the atmosphere of methane (CH_4), which is a greenhouse gas with a global warming potential 25 times higher than the one of CO_2 (Forster *et al.*, 2007). The primary reasons for these emissions are cracks in the digesters or the intentional release of biogas when production exceeds demand (Bruun *et al.*, 2014).

In order to make sure that household level biogas systems deliver their potential, multiple benefits (both environmental and social), it is key to build capacities, create knowledge and raise the awareness of team leaders, technicians, masons and especially biogas-using households about the potential risks associated with the mismanagement of biogas systems. This would help avoid, or at least mitigate, the aforementioned issues.

Future monitoring

Given the importance of the household level biogas sector in Viet Nam and the strong government support, it will be important to continue monitoring its sustainability in the future, including in terms of capacity of the individuals working in the sector. Such monitoring can provide useful indications regarding the effectiveness of the biogas support programmes in place, especially in terms of trainings provided to biogas technicians and masons.

[19] For a proper management of the digestate, drying and/or composting should be carried out in order to reduce the volume and increase the nutrient content of the digestate before applying it to the soil.

REFERENCES

AITCV. 2017. Survey carried out in April 2017 within this study, conducted on 47 pig farms located in the Phu Tho province

Bruun S., Jensen L.S., Vu T. K. V., Sommer S. 2014. Small-scale household biogas digesters: An option for global warming mitigation or a potential climate bomb? Renewable and Sustainable Energy Reviews, Vol. 33, May 2014, 736-741

EPRO. 2014. Consulting JSC. Biogas User Survey (BUS) 2013. Available at: http://biogas.org.vn/english/An-pham/2014.aspx

Forster, P., Ramaswamy, V., Artaxo, P., Berntsen, T., Betts, R., Fahey, D.W., Haywood, J., Lean, J., Lowe, D.C., Myhre, G., Nganga, J., Prinn, R., Raga, G., Schulz, M. & Van Dorland, R. 2007. Changes in atmospheric constituents and in radiative forcing. In: Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M. & Miller, H.L. (eds.): Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York, NY, USA.

MARD. 2016. Department of Livestock Production. Real situation and solutions for environmental treatment of livestock production.

Vu T. K. V., D. Q. Vu, Jensen L. S., Sommer S. G., and Bruun S. 2015. Life Cycle Assessment of Biogas Production in Small-scale Household Digesters in Vietnam. Asian Australas. J. Anim. Sci. Vol. 28, No. 5: 716-729, May 2015 Ministry of Industry and Trade of Viet Nam (MoIT), 2013.

4.22 INDICATOR 22: ENERGY DIVERSITY

Do Tien Minh
Vietnam Japan International Institute for Science of Technology (VJIIST) at the Hanoi University of Science and Technology (HUST)

DESCRIPTION:

Change in diversity of total primary energy supply due to bioenergy

MEASUREMENT UNIT(S):

Index (in the range 0-1)
MJ bioenergy per year in the Total Primary Energy Supply (TPES)

4.22.1 Implementation of Indicator 22 in Viet Nam

In fuelling the economy, Viet Nam is facing twin challenges: the security of energy supply and environmental pollution caused by energy-related activities. To successfully cope with this situation, energy diversity with a focus on renewable energy, particularly bioenergy, is considered as a sustainable strategy. In a country such as Viet Nam, with a strong dependence on fossil fuels, the higher the diversity of the energy supply, the lower the dependency on non-renewable and polluting energy sources. In order to measure diversity of energy supply, the Herfindahl Index (HI) is used. This index is calculated by applying the following formula:

$$HI = \sum_{i=1}^{n} S_i^2$$

Where:S = Share of energy sources in TPES; and n = Number of energy sources in TPES.
The HI can range from 0 to 1. HI = 0 when n = ∞, HI = 1 when n = 1 (S = 100 percent)

Therefore, a smaller index, closer to 0, indicates higher energy diversity.

In order to calculate this indicator in Viet Nam, Total Primary Energy Supply (TPES) disaggregated by fuel was found from the Energy balance for non-OECD countries of the IEA (2017). Furthermore, information related specifically to bioenergy (both traditional and modern) were gathered from various national organizations and sources, such as the Vietnam Energy Association (VNA), Electricity of Vietnam (EVN), Petro Vietnam (PVN) Ministry of Industry and Trade (MOIT), Vietnam Food Association (VFA) and Ministry of Agricultural and Rural Development (MARD).

4.22.2 Key findings

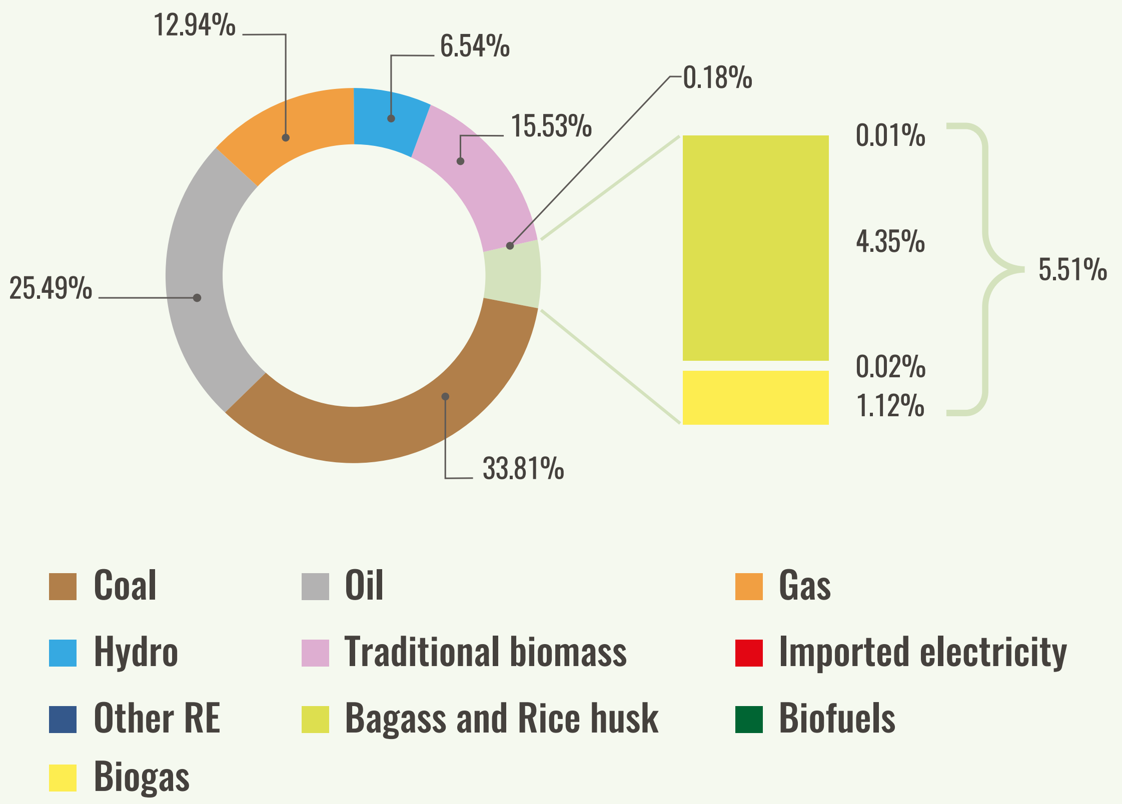
In Viet Nam, the Total Primary Energy Supply (TPES) in 2015 was equal to 73 804 ktoe (IEA, 2017). As shown in **Figure 1**, fossil fuels, including coal, oil and gas, play an important role in the TPES of the country. In 2015, the shares of these fuels were 33.81 percent, 25.49 percent and 12.94 percent respectively, making up 72.24 percent of the TPES. In Viet Nam, farming activities are quite prominent and widespread. Therefore, agricultural residues account for the second largest share, making up 21.01 percent of the TPES; this is further categorized by use: traditional biomass (15.53 percent) and modern bioenergy (5.51 percent).

Within this analysis, the traditional biomass used for cooking and heating is mainly constituted by fuelwood, rice straw and rice husk. It is not used for power generation and it is not considered as modern bioenergy because it is not used to produce energy in an efficient and safe way. In fact, according to the MECON project (2014), only 7.4 percent of households use improved biomass cookstoves for their daily cooking.

Modern bioenergy includes bagasse and rice husk for heat and power generation, biofuels for transportation and biogas. Bagasse and rice husk accounted for 4.35 percent of the TPES in 2015, followed by biogas (1.12 percent) and biofuels, i.e. liquid biofuels for transport (0.02 percent). The share of modern bioenergy in the TPES mix is still at a moderate level. This is partly due to the very low buying price set for biomass-based electricity (approximately USD 0.05-0.06 per Kwh), which means that investors are not motivated to invest in bagasse and rice husk-based co-generation. The second reason is the low oil prices recorded over the past few

FIGURE 54

SHARE OF ENERGY SOURCES IN TOTAL PRIMARY ENERGY SUPPLY (TPES), 2015



Sources: IEA, 2017; EVN, 2015; PVN 2017; VEA 2016; Indicators 14 & 18

years, which made biofuels less competitive. This, combined with the lack of a country-wide ethanol blending mandate, which was introduced only in January 2018, has led to a very low level of ethanol production and consumption in Viet Nam, with only two plants operating (as of December 2017) well below their capacity. The last reason is lack of adequate incentives to use the biogas produced by pig farms in an effective way, of which a significant volume is flared or vented.

Apart from fossil fuels and bioenergy, the shares of hydro, imported electricity, and other renewables accounted for 6.54 percent, 0.18 percent and 0.01 percent, respectively, in the TPES mix (**Figure 54**).

Based on the above data, the HI was calculated for two scenarios: one with modern bioenergy as part of the TPES (i.e. the current Vietnamese scenario) and one without modern bioenergy. In the second scenario, the share of TPES provided by each modern bioenergy source was shifted to the most likely alternative source, i.e. coal in the case of bagasse and rice husk, oil in the case of biofuels and gas in the case of biogas.

The two aforementioned scenarios and the associated HIs are shown in **Table 121** and are also represented in **Figure 55** and **Figure 56**.

In the current scenario (i.e. with modern bioenergy), a HI of 0.226 was calculated, while in the scenario without modern bioenergy, this Index was found to be higher (0.259). This shows the positive contribution of bagasse, rice husk, biofuels and biogas to the diversity and security of the energy supply in Viet Nam.

As requested in the methodology sheet of indicator 22, the ktoe per year of each bioenergy

TABLE 121

SHARE OF ENERGY SOURCES IN TOTAL PRIMARY ENERGY SUPPLY (TPES) WITH AND WITHOUT MODERN BIOENERGY, 2015

FUELS	FIRST SCENARIO: WITH MODERN BIOENERGY	SECOND SCENARIO: WITHOUT MODERN BIOENERGY
COAL	33.81	38.16
OIL	25.49	25.51
GAS	12.94	14.06
HYDRO	6.54	6.54
TRADITIONAL BIOMASS	15.53	15.53
IMPORTED ELECTRICITY	0.18	0.18
OTHER RE	0.01	0.01
BAGASSE AND RICE HUSK	4.35	0.00
BIOFUELS	0.02	0.00
BIOGAS	1.12	0.00
HERFINDAHL INDEX	**0.226**	**0.259**

FIGURE 55

TPES WITH MODERN BIOENERGY (FIRST SCENARIO)

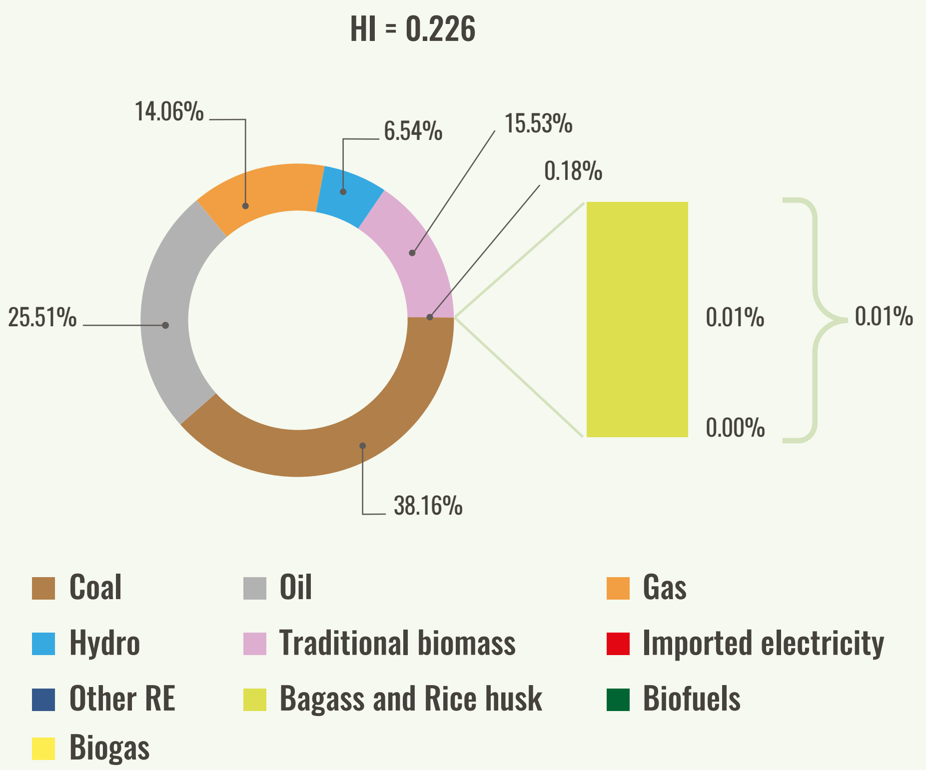
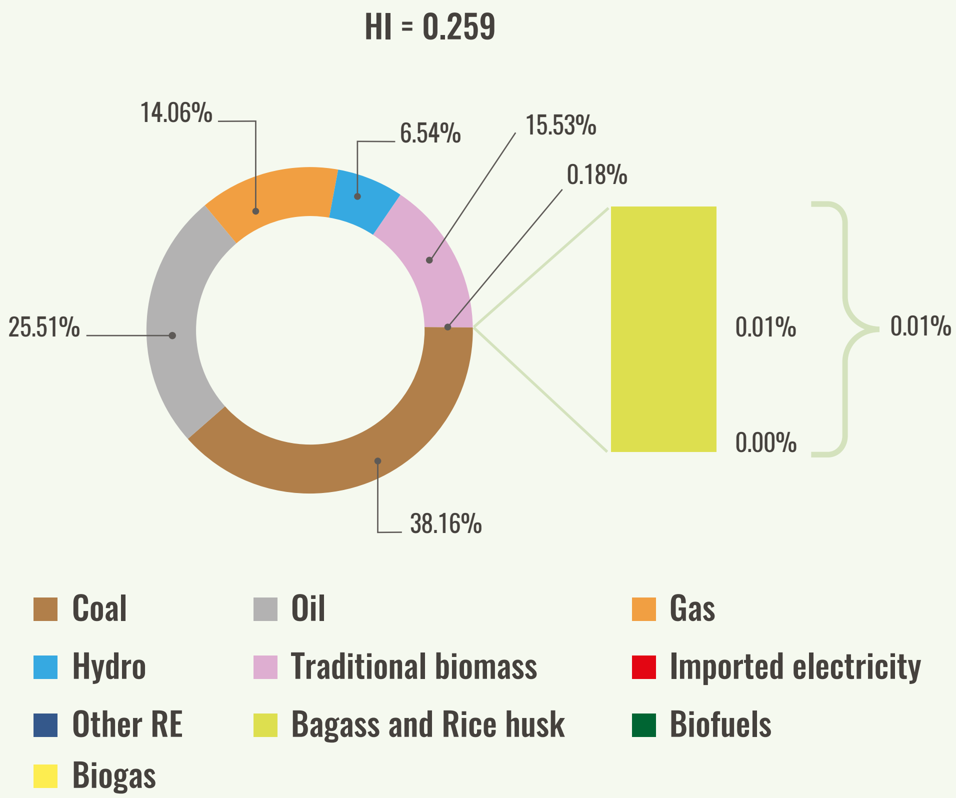


FIGURE 56

TPES WITHOUT MODERN BIOENERGY (SECOND SCENARIO)



source in the TPES are reported in **Table 122**. Values for bagasse and rice husk were taken from Electricity of Vietnam (EVN, 2015) and cross checked with the Vietnam Energy Association (VEA 2016). Values for biofuels (ethanol) were taken from Indicator 18 and refer to 2014, while the figure for biogas was calculated using the survey carried out by EPRO (2016) and information and results from Indicators 14 and 18.

TABLE 122

KTOE OF MODERN BIOENERGY PER YEAR IN TPES

ITEMS	TPES BY FUEL (KTOE)	SHARE OF TPES (percent)
COAL	24 954	33.81
OIL	18 813	25.49
GAS	9 549	12.94
HYDRO	4 827	6.54
TRADITIONAL BIOMASS	11 460	15.53
BAGASSE & RICE HUSK	3 211.5	4.35
BIOFUELS	14.9	0.02
BIOGAS	827.6	1.12
OTHER RE	10	0.01
IMPORTED ELECTRICITY	136	0.18
TOTAL	**73 803**	**100.00**

Sources: IEA, 2017; EVN, 2015; PVN 2017, VEA 2016; Indicators 14 & 18

4.22.3 Main conclusions and recommendations

a. Approach used

The Herfindahl Index (HI) was used for measuring the contribution of bioenergy to the diversity of the energy supply in Viet Nam. The HI was calculated for two scenarios: one with modern bioenergy as part of the TPES (i.e. the current Viet Nam scenario) and one without modern bioenergy. In order to compute this index, data on TPES was taken from IEA (2017), and complemented with various other national sources, especially in relation to bioenergy and its disaggregation into traditional and modern. To develop the alternative scenario, it was assumed that biomass (bagasse and rice husk), biogas and ethanol are replaced by coal, gas and oil, respectively.

b. Results

The result show that, in the current scenario (i.e. with modern bioenergy), HI is equal to 0.226, while in the scenario without modern bioenergy the Index was found to be higher (0.259). This indicates the positive contribution of bagasse, rice husk, ethanol, biodiesel and biogas to the diversity and security of the energy supply in Viet Nam. Furthermore, the ktoe per year of each bioenergy source in the Viet Nam TPES were reported: 3 211.5 for bagasse and rice husk; 14.88 for biofuels and 827.6 for biogas.

c. Practices and policies to improve sustainability

As mentioned above, due to the lack of adequate incentives, the modern bioenergy potential has not been fully exploited so far in Viet Nam. In particular, only a limited share of the ethanol production capacity has been used to date, even though this is likely to change following the introduction of the country-wide E5 mandate in 2018. Furthermore, significant volumes of biogas produced at farm level and industrial levels and not used for own consumption are flared or vented. By promoting heat and power generation from this surplus biogas, the contribution of modern bioenergy to the TPES would increase, along with the diversity of the energy supply.

d. Future monitoring

The importance of assessing the contribution of modern bioenergy to the diversity and security of the energy supply was confirmed during the measurement of indicator 22 in Viet Nam. With the adoption of a country-wide E5 mandate in January 2018 and the expected expansion in modern bioenergy supply, it will be important to monitor indicator 22 in the future and assess how modern bioenergy affects energy diversity and security.

REFERENCES

Electricity of Viet Nam (EVN). 2015. Annual report. Available at: www.evn.com.vn/UserFile/User/tcdl/BCTN%202015_Fi_Final.pdf [Accessed: 15 Apr 2017]

EPRO. 2016. Consulting JSC, Report on Biogas User Survey 2014.

GBEP. 2011. The Global Bioenergy Partnership Sustainability Indicators for Bioenergy. First Edition. ISBN 978-92-5-107249-3. Available at: www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/Indicators/The_GBEP_Sustainability_Indicators_for_Bioenergy_FINAL.pdf

IEA. 2017. Vietnam: Energy Balances for 2015. Available at: www.iea.org/statistics/statisticssearch/report/?country=Vietnam&product=balances [Accessed: 15 Apr 2017]

MECON Project. 2014. Household energy efficiency: a socio-economic Perspective. Available at: www.meconproject.com/wpcontent/uploads/report/[Task%203]%20Vietnam%20country%20report.pdf [Accessed: 15 Apr 2017]

PetroVietnam (PVN). 2017. Refinery, Petrochemical and Bio-fuel. Available at: http://english.pvn.vn/?portal=news&page=detail&category_id=42&id=3671 [Accessed: 15 Apr 2017]

Vietnam Energy Association (VEA). 2016. Revised National Master Plan for Power Development. Available at: http://nangluongvietnam.vn/news/en/policy-planning/adjusting-vietnam-national-power-development-planning.html [Accessed: 15 Apr 2017]

4.23 INDICATOR 23: INFRASTRUCTURE AND LOGISTICS FOR DISTRIBUTION OF BIOENERGY

Van Dinh Son Tho
Vietnam Japan International Institute for Science of Technology (VJIIST) at the Hanoi University of Science and Technology (HUST)

DESCRIPTION:

(23.1) Number and (23.2) capacity of routes for critical distribution systems, along with (23.3) an assessment of the proportion of the bioenergy associated with each.

MEASUREMENT UNIT(S):

(23.1) number
(23.2) MJ, m^3 or tonnes per year; or MW for heat and power capacity
(23.3) percentages

4.23.1 Implementation of Indicator 23 in Viet Nam

For the implementation of indicator 23 in Viet Nam, official reports at national level were used to collect relevant information regarding: the policy of the Government on ethanol fuel and the blending ratio; the infrastructure and logistics for the distribution of gasoline; the infrastructure of gasoline distribution systems and their ability to absorb ethanol fuel; and the projected future consumption of gasoline. Interviews and a literature review were conducted on the adequacy and diversity of key infrastructural components in order to assess the limitations of the ethanol fuel supply infrastructure.

This indicator requires the identification of the number and capacity of routes for critical distribution systems for ethanol. Information from two state-owned petroleum companies and an oil refinery was used: Petrolimex (Vietnam National Petroleum Import Export Corporation), PV oil (Petrovietnam Oil Corporation) and the Binh Son Petroleum refinery.

To calculate this indicator for feedstock transportation routes, interviews were conducted with local manufacturers and Google maps was used in order to estimate the distance over which cassava is transported from harvest areas to ethanol plants. To understand the critical supply/distribution routes of ethanol fuel from the plants to the petroleum distribution network, interviews were conducted with ethanol production companies and petroleum distributors to determine the transportation distance, the mode of transport and the route.

4.23.2 Key findings

Overview of gasoline market in viet nam

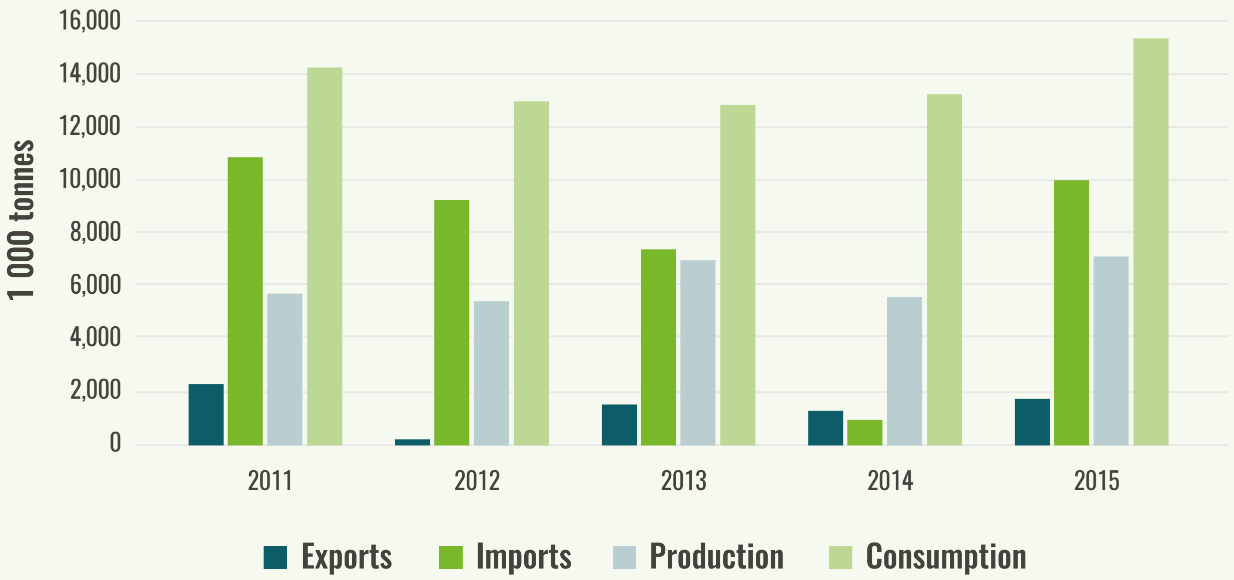
Although economic growth in Viet Nam from 2011 to 2017 was estimated at 5.6 percent per year on average, the growth in the consumption of oil and gas was even higher, around 7 and 11 percent, respectively. As shown in **Figure 1**, domestic consumption of petroleum decreased dramatically (by over 10 percent) in 2012, but in recent years (2014–2015) it has recovered its growth momentum and in 2015 it amounted to 15 million tonnes. In the medium and long term, the Ministry of Industry and Trade (MOIT) stated that the Viet Nam domestic demand will be 95 million tonnes of petroleum, which would be nearly eight times higher than in 2012. By 2018, thanks to the presence of the new Nghi Son refinery, the share of imports will decrease from about 65 to 30 percent of total domestic petroleum demand (Petrolimex, 2013).

a. Market management

The Government, represented by the MOIT and the Ministry of Finance (MOF), controls Viet Nam's petroleum market. The MOF manages the import tax rate and petroleum product prices while the MOIT controls the annual quota (the maximum volume of petroleum products that can be imported) to ensure supply to the domestic market. Petrolimex, a state-owned group, is the biggest petroleum importer and distribution

FIGURE 57

PRODUCTION, CONSUMPTION AND TRADE OF PETROLEUM IN VIET NAM



Source: Petrolimex, 2013

company, and holds more than 50 percent of the import quota.

The Government controls the market by Decree 84/2009/ND-CP, which defines price controls and facilities for import, wholesale and retail companies, including ports, terminals and distribution systems. The Decree clearly specifies that all Vietnam-based enterprises, regardless of the form of business, that engage in petroleum processing and production, are entitled to join the gasoline distribution market of Viet Nam as long as they comply with the above Decree. With the issuance of this Decree, the Government has partly opened the petroleum distribution market but has also imposed strict administrative measures on the trading of these products via its regulations on business operational criteria and the state's monopoly in the petroleum import-export business. The Decree effectively removed government subsidies and allowed import and wholesale companies to define their wholesale prices and adjust their retail prices according to global prices. Thus this Decree represents a move from a subsidized mechanism towards a market mechanism.

b. Main players

Domestic consumption of gasoline increased continuously over the past few years in Viet Nam, from 6.5 million m^3 in 2012 to around 8 million m^3 in 2016 (**Figure 58**).

Petrolimex and PV oil are the main players in this market, with a market share of 58.62 percent and 18.75 percent, respectively (**Figure 3**).

In Viet Nam, the gasoline price is set by the government, and the competition among petroleum companies is based on the distribution network and discount policy. The barriers for new entrants are very high for petroleum imports, while they remain at a medium level for the downstream stages of the supply chain.

FIGURE 58

DOMESTIC GASOLINE CONSUMPTION, 2012-2016

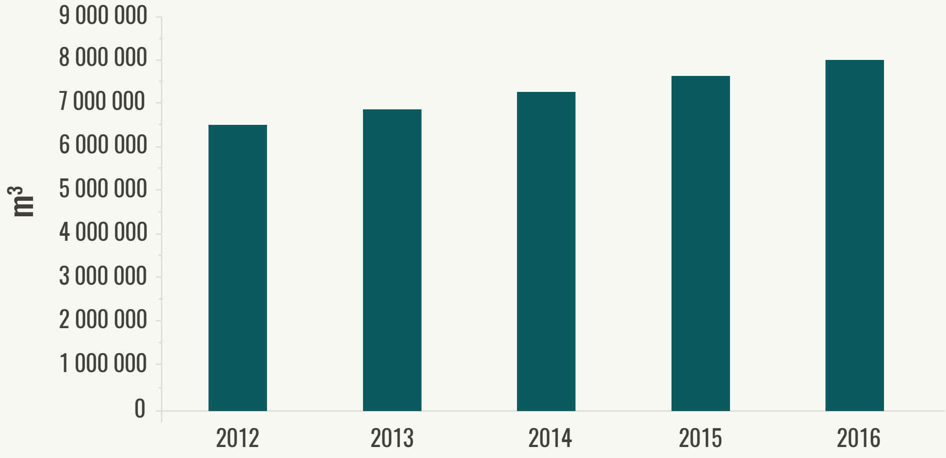
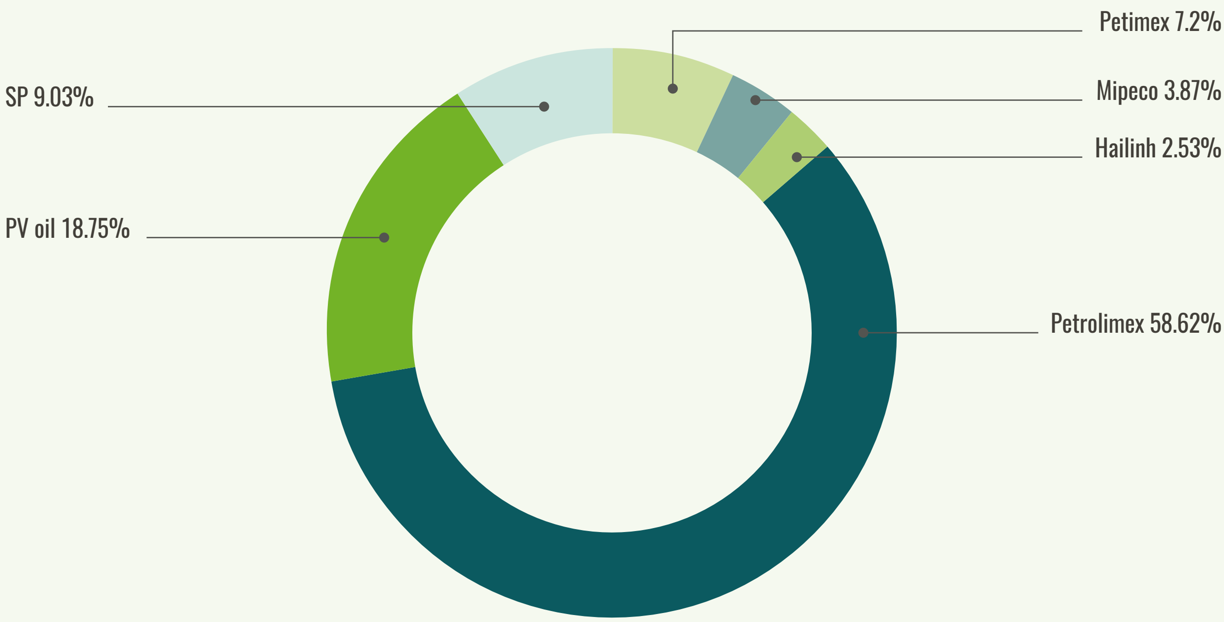


FIGURE 59

MARKET SHARE OF MAIN PLAYERS OF DOMESTIC GASOLINE MARKET, 2015



Source: PEC, 2014

Infrastructure for gasoline distribution in Viet Nam

The main ports for petroleum in Viet Nam are located in Hai Phong, Quang Ninh, Nghe An, Da Nang, Binh Dinh, Vung Ro, Ho Chi Minh city, Dong Nai and Vung Tau. Vietnamese petroleum ports can accommodate vessels of maximum 60 000 DWT. **Figure 60** shows the capacity of petroleum ports in each region. Currently, sea transportation is the main route for delivering gasoline from the Binh Son refinery (owned by PV oil) to the main gasoline terminals near the seaports. **Figure 61** shows the flow chart for gasoline imported by Petrolimex. The primary terminals in each seaport are shown: Quang Ninh (North), Hai Phong (North), Da Nang (Centre) Vung Ro (Centre), Nha Be (South/Ho Chi Minh), Dong Nai (South/Ho Chi Minh) or Ba Ria Vung Tau. The gasoline transportation then continues by truck to the secondary terminals on the mainland and finally to the gasoline distribution stations.

Ethanol production

a. Feedstock Logistics

Figure 6 shows the harvested areas of cassava in some of the largest provinces of Viet Nam. The Gialai Province has the largest cassava harvested areas (63 700 ha) and a yield of 7.2 tonnes/ha of dry chips. Tay Ninh has the second largest harvested area of cassava (57 600 ha) and the highest yield of dry cassava chips in the country (12.6 tonnes/ha).

According to our survey and interviews (VJIIST, 2017), there are currently five ethanol fuel plants in Viet Nam: three of them belong to Petro Vietnam and the other two belong to Tung Lam company. Four plants have been completed while one ethanol plant in the North was never finished due to bankruptcy. Three out of the four completed plants work intermittently (BRF-BF, Dai Tan and Tung Lam) because of the low ethanol demand in the domestic market. According to MOIT, as of December 2017, only two plants were operating, well below their capacity.

All ethanol plants use cassava produced in Viet Nam. Besides the limited demand for cassava for ethanol plants, a large amount of cassava is processed for starch or is exported to China. Due to the high demand for cassava, mainly for export and starch production, the price tends to be volatile. The survey conducted within this study showed that the cost of feedstock contributes 60-80 percent of the total ethanol production cost.

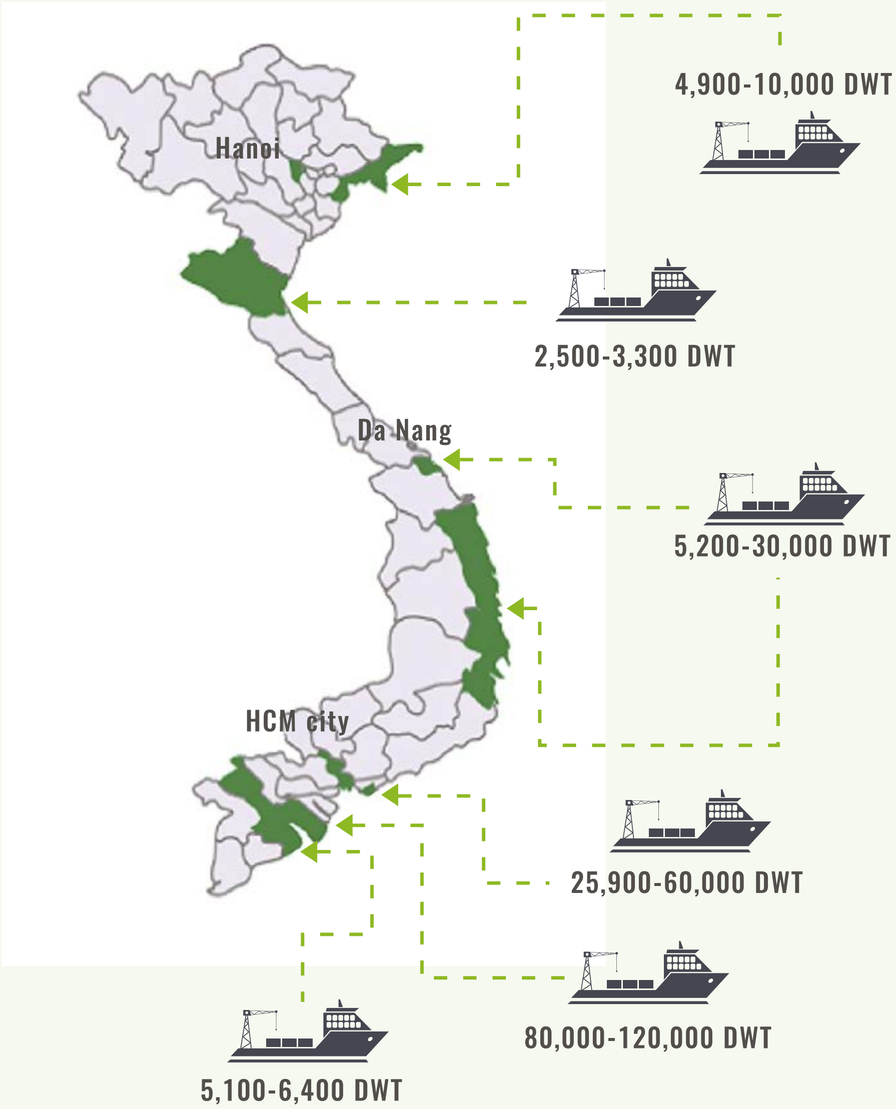
There are two scenarios for delivering feedstock to ethanol plants, each with advantages and disadvantages. In the first scenario, cassava is delivered directly by truck from harvest areas to the ethanol plant. In the second scenario, cassava is delivered to the ethanol plant from the main trading ports. The main advantage of the first scenario is the reduced transportation distance for cassava provision, which slightly reduces the cost of the feedstock. However, cassava provision directly from harvesting areas is not always reliable. This means that a certain amount of each company finance needs to be set aside for feedstock provision and that the feedstock needs to be purchased in advanced and stored; this has an impact on the ethanol plant cash flow. For the above mentioned reasons, ethanol production companies prefer to get the feedstock weekly, usually from a main port to the factory, in order to facilitate payment for the feedstock. Before 2017, this second scenario was preferred by ethanol production plants. However, with the introduction of the E5 mandate in 2018, the volume of produced ethanol fuel will increase and a large amount of cassava feedstock will be used for ethanol production. If this leads to an improvement in the reliability of delivery of feedstock directly from the harvesting areas, the ethanol plants might choose the shortest distance for transportation of cassava and thus shift to the first scenario. The scenarios for three ethanol plants are detailed below, and the average distances and energy consumption are summarised in **Table 123**.

a. Transportation of feedstock to the tung lam ethanol plant

In the first scenario considered, the transport of cassava is performed directly from the harvest areas to the ethanol factory by truck. In this scenario, in the case of the Tung Lam ethanol plant, feedstock production areas are

FIGURE 60

SEAPORTS FOR HANDLING AND TRANSFER OF PETROLEUM PRODUCTS, INCLUDING MAXIMUM DEADWEIGHT TONNAGE (DWT)



Source: VPBS, 2013

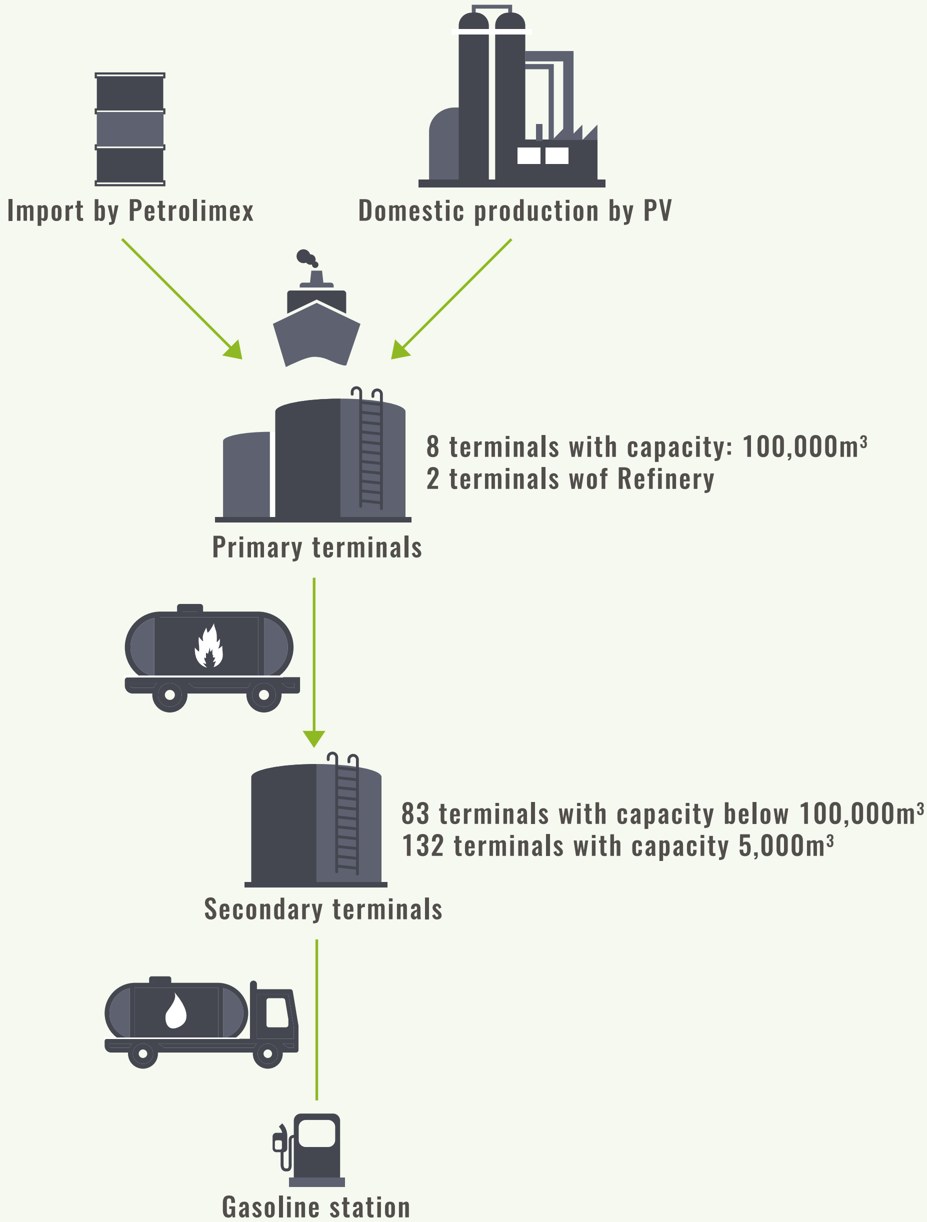
well connected to the ethanol plant by the main transportation road network of the country. There are two routes suitable for feedstock transportation, with an average transportation distance of about 212 km and a diesel consumption of approximately 113 MJ/tonne. In the second scenario, there are three routes for transporting the feedstock to the Cat Lai port and a further three routes for transferring it from Cat Lai port to the Tung Lam factory. The total transportation distance from the plantation area to the port and from the port to the plant is, on average, 234.3 km and it requires, on average, around 125 MJ/tonne. The main route for feedstock transportation from Tay Ninh and Binh Phuoc harvest areas to Cat Lai port is the National route No.22 while the National route No.1 is the main route from Cat Lai port to the Tung Lam ethanol plant. Both of these route are in very good condition.

b. Transportation of feedstock to the dai tan ethanol plant

In case of the Dai Tan ethanol plant, the first scenario includes only one route for delivering

FIGURE 61

GASOLINE DISTRIBUTION FLOW CHART



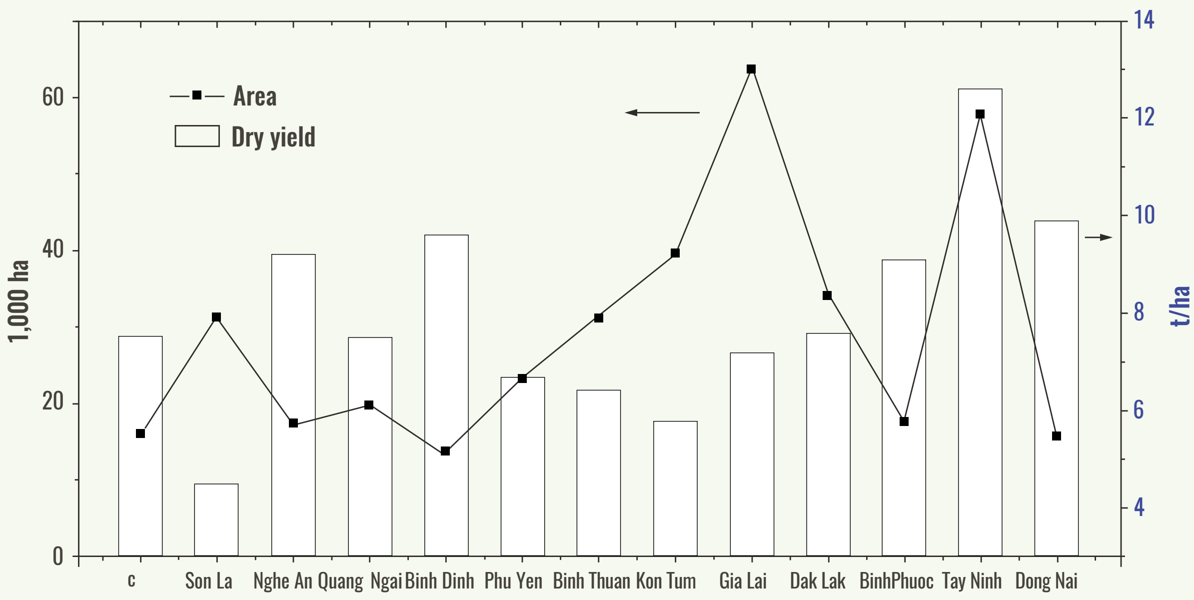
Source: GSO website

the feedstock to the plant, with a distance of about 262 Km and diesel consumption of almost 140 MJ/tonne. Given that there is only one route available, this represents a bottleneck for feedstock provision to the plant: if road transportation is interrupted along this route, then the logistics of feedstock supply to the plant would be impacted.

In the case of the second scenario, two different routes are used for transferring the feedstock from the harvest areas to the Quy Nhon port and four routes are available from the

FIGURE 62

CASSAVA HARVESTED AREA AND AVERAGE YIELD (DRY CASSAVA) IN VIET NAM



Source: GSO website

CASSAVA LOAD IS 40 TONNNES TRUCKS. DIESEL CONSUMPTION FOR A FULLY LOADED TRUCK IS 0.35 LITRES/KM AND FOR AN EMPTY TRUCK IS 0.245 LITRES/KM. HEATING VALUE OF DIESEL IS 43.1 MJ/KG AND ITS DENSITY IS 0.832 KG/LITRE. ENERGY CONSUMPTION FOR FEEDSTOCK TRANSPORTATION WAS CALCULATED AS FOLLOWS:

$$MJ/tonne \ \frac{\left[\frac{litre}{Km}\right]\left[\frac{MJ}{Kg}\right]\left[\frac{Kg}{litre}\right]}{[tonne]}$$

Quy Nhon port to the Dai Tan factory. The total transportation distance in this case is much further than in the first scenario: an average of 520 Km, requiring almost 277 MJ/tonne.

Transportation from the cassava production areas to the main port occurs from the three large harvest areas in the Center of Viet Nam (Dak Lak, Gia Lai and Kon Tum), which have a total harvested area of approximately 137 200 ha. Quy Nhon is the main port for exporting cassava from the Center of Viet Nam and all the cassava root is transported there. The cassava transportation route from Dak Lak to Quy Nhon port can be carried out by National route No 29 and National route 14C or route DT226. From Gia Lai to Quy Nhon port, cassava can be transported by National route No 19 or DT. 622 or DT.669. From Kon Tum to Quy Nhon port, cassava transport can be carried out on National route No 24 and DT.670.

Once the feedstock reaches the main port, there are then two routes for transportation from Quy Nhon port to the Dai Tan factory – National route 1A or National route 19 and AH17. Currently, feedstock transportation occurs weekly to Dai Tan ethanol plant on National route 1A.

c. Transportation of feedstock to the bsr-bf ethanol plant

In the case of the BSR-BF ethanol plant, the first scenario consists of three possible routes for feedstock transportation with an average distance of about 319 km and 170 MJ/tonne used.

The second scenario involves transportation from harvest areas to Quy Nhon port and subsequent transportation from the port to the BSR-BF plant. As in the case for the Dai Tan ethanol plant, the feedstock transportation to

TABLE 123

ENERGY CONSUMPTION FOR CASSAVA TRANSPORTATION TO ETHANOL PLANTS

ETHANOL PLANT	FIRST SCENARIO	SECOND SCENARIO
	HARVEST AREAS TO ETHANOL PLANT (MJ/tonne)	HARVEST AREAS TO MAIN PORT AND TO ETHANOL PLANT (MJ/tonne)
TUNG LAM	113	125
DAI TAN	140	277
BSR-BF	170	199

Quy Nhon port takes place over several routes from a number of harvest areas. From the Quy Nhon port to BSR-BF plant, there are then two possible modes of feedstock delivery, either on the National route 1A (about 212 km) or Route WL19 (about 368 km) by route No19 and No 24. The shortest total transportation route for the second scenario is about 374 km and implies an energy consumption of 199.5 MJ/tonne.

The many options for feedstock delivery in both scenarios mean that if one route was interrupted by incident, others route could be used.

d. Logistics for ethanol distribution

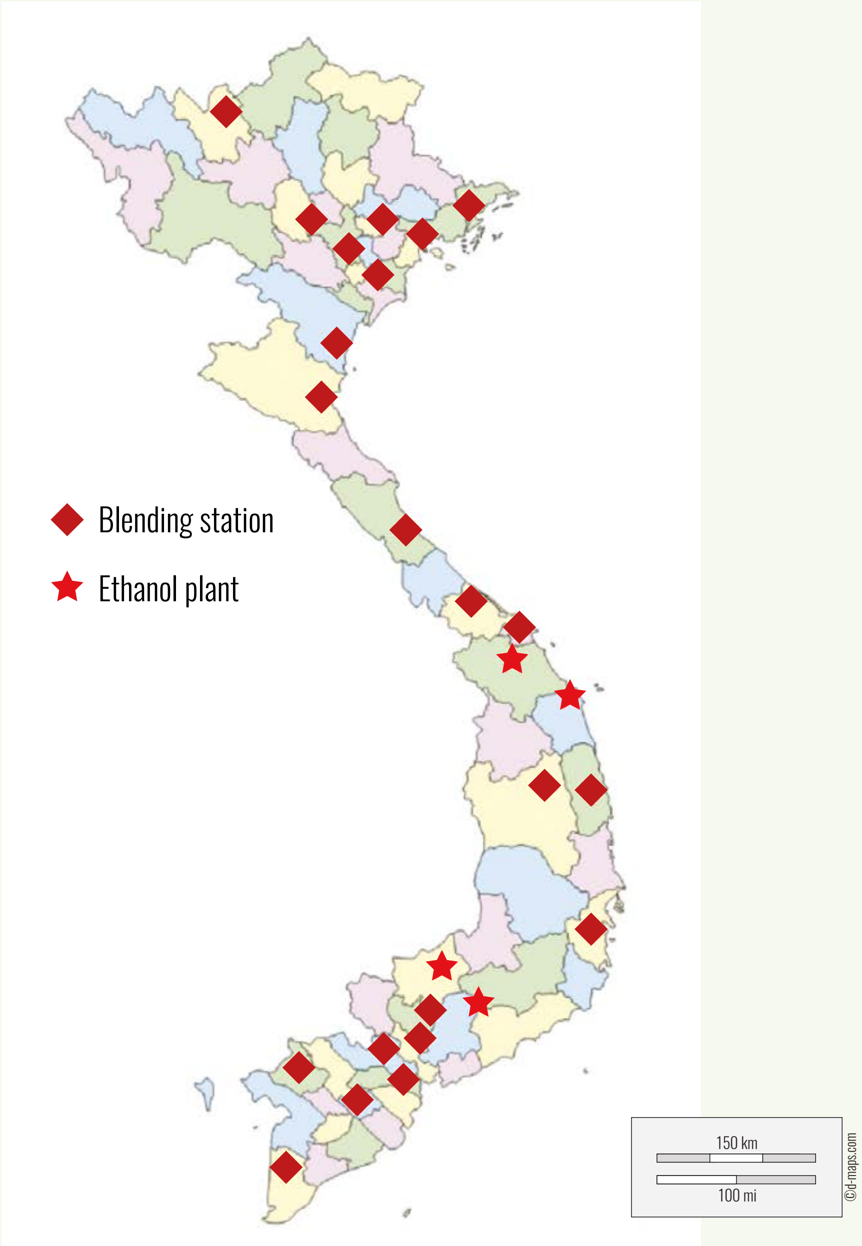
For blending ethanol with gasoline, the following methods can be used: in-tank recirculation, static mixer or in line blend. The first two methods require a tank for handling the ethanol fuel, while in the "in line blend" method, gasoline and ethanol are blended directly in line before being transferred by truck and ship to the gasoline station. All of the petroleum distribution companies choose the in line blend method and several blending systems have been installed so far across the country by Viet Nam National Petroleum Group (Petrolimex), PetroVietnam Oil Corporation (PV Oil), HCM City Oil and Gas Company (Saigon Petro), Military Petroleum Corporation and Nam Song Hau Trading and Investing Petroleum Joint Stock Company (**Figure 7**). Petrolimex currently has five E5 mixing stations in Ha Noi, Hai Phong, Da Nang, HCM City and Can Tho that use in line mixing technology with a total capacity of around 1.05 million m^3. Petrolimex plans to increase its number of mixing stations, as well as to invest in those in Ha Noi, Phu Tho, Quang Ninh, Ha Nam, Nghe An, Binh Dinh, Khanh Hoa and Ba Ria-Vung Tau. The total mixing capacity after the investment would reach 3 to 3.4 million m^3 a year. PV Oil has 12 mixing stations in nine cities and provinces with a total annual capacity of 1.06 million m^3. In addition to these, PV Oil has been investing in five mixing stations in Quang Ninh, Thai Binh, Ha Tinh and Can Tho provinces. It is also upgrading its current stations to bring the total capacity to 1.67 million m^3 a year. The total yearly capacity of E5 mixing stations from the seven petroleum traders could reach 6.2 - 6.7 million m^3/ year, thus satisfying the demand of E5 consumption in 2018.

Currently, the E100 transportation only occurs by truck, although it would be cheaper by train or ship. The regulation QCVN 09: 2012/ BCT *(National technical regulation of equipment, auxiliaries and means for blending, storing and transportation of ethanol, ethanol blended gasoline (E5, E10) at distribution terminals*), provides a very detailed description of all materials that should be used for building the storage system, pipes, pumps, valves and sealing. It recommends that, for storing and handling ethanol, new equipment should be installed. However, at the current stage, all the distribution systems are designed for gasoline and are not suitable for E100. This means that ships, trains or vehicles for transportation of gasoline cannot be used for delivering ethanol as well. Given the limited size of the domestic ethanol fuel market, investment in new trucks is the only viable alternative in the short term. With the further development of the ethanol fuel market, the demand for transportation will increase and new investment in ship and train transportation might be considered by petroleum companies.

Because of the lack of ethanol plants in the North of Viet Nam, ethanol delivered to the

FIGURE 63

ETHANOL PLANTS AND BLENDING STATIONS IN VIET NAM



Source: GSO website

North comes from BRS-BF and Dai Tan ethanol plants. The transportation distance and the related fuel consumption per unit of ethanol delivered are reported in **Table 124**. The distance for transportation of E100 to the North is about 876 – 1 028 Km.

In the Center of Viet Nam, there are two ethanol plants, therefore ethanol consumed within this area is provided directly by them and ethanol is transported over shorter distances compared to the North of the country. Ethanol is transported for about 50 km from the Dai Tan ethanol plant and about 118 km from the BSR-BF ethanol plant to the Zone 5 terminal.

For Southern Viet Nam, Tung Lam ethanol plant delivers its product to HCM, Dong Nai

TABLE 124

DISTANCE AND FUEL CONSUMPTION FOR ETHANOL TRANSPORTATION IN VIET NAM

ETHANOL PLANT STATION	DESTINATION		DISTANCE (km)	MJ/TONNE	COST (USD/m³)
	DISTRIBUTOR	TERMINAL			
NORTH					
ETHANOL DAI TAN AND BSR-BF	ZONE 1	Đ□C GIANG - HÀ N□I	887	539	**66.4**
	ZONE 3	TH□□NGLÝ- H□IPHÒNG	991	603	**73.8**
	HÀS□NBÌNH	Đ□XÁ- HÀ N□I	876	533	**57.4**
	B12	TERMINAL K130	1 028	625	**76.6**
		TERMINAL K132	996	606	**69.5**
CENTER					
ETHANOL DAITAN AND BSR-BF	ETHANOL DAITAN	ZONE 5- ĐÀN□NG	50	30	**5.0**
	BSR-BF	ZONE 5- ĐÀN□NG	118	72	**9.8**
SOUTH					
ETHANOL TUNG LAM	ZONE 2	NHÀ BÈ- TP HCM	130	79	**12.7**
	CAN THO	MI□NTÂY - C□NTH□	310	189	**27.3**
	Đ□NGNAI	KHO BIÊN HÒA	100	61	**10.6**
	VŨNGTÀU	K2	150	91	**16.5**

and Baria Vung Tau and Can Tho province. Transportation of ethanol from Tung Lam to HCM and Dong Nai blending locations is almost 100 km, while it is approximately 300 km from Tung Lam to Can Tho and 200 km for transportation from Tung Lam to Baria Vung Tau.

4.23.3 Main conclusions and recommendations

a. Approach used

For the implementation of indicator 23 in Viet Nam, official reports at national level were used to collect relevant information, e.g. regarding the infrastructure and logistics for the distribution of gasoline and the ability of this infrastructure to absorb ethanol fuel, and the projected future consumption of gasoline. In addition, interviews and a literature review were conducted on the adequacy and diversity of key infrastructural components in order to assess the limitations of the ethanol fuel supply infrastructure. For the identification of the number and capacity of routes for critical distribution systems for ethanol, information from two state-owned petroleum companies and an oil refinery was used. Furthermore, to calculate this indicator for feedstock transportation routes, interviews were conducted with local manufacturers and Google maps was used in order to estimate the distance over which cassava is transported from harvest areas to ethanol plants. Finally, interviews were conducted with ethanol production companies and petroleum distributors to determine the transportation distance of ethanol fuel from the plants to the distribution network, the mode of transport and the route.

b. Results

Feedstock transportation

In the South and Center of Viet Nam, cassava is cultivated in very large areas and it is used for starch processing, cassava chip production (mainly for export) exporting and ethanol production. The transportation networks used for supplying the agrochemical products to the field and to connect the harvest areas with processing or exporting facilities are well developed and in a good state. There are several options for cassava feedstock transportation to ethanol plants and no bottlenecks have been found that affect this step of the value chain.

The second scenario considered in this analysis (where cassava feedstock is transported from the harvesting areas to main ports and then from the ports to the ethanol plants) is assumed to be the current situation, given that the reliability of feedstock delivery outweighs the extra costs of longer transportation distances.

For Dai Tan and BRS-BF ethanol plants, the cassava feedstock is mainly produced in the Central Highland of Viet Nam (e.g. Kon Tum, Gia Lai, Dak Lak) and is transported by truck on the national road network to Quy Nhon port by National route No 19. 52 percent of total cassava production for domestic use and exports is transported through this road in Viet Nam. For transportation of cassava from the Quy Nhon port to ethanol plants located in the Center of Viet Nam, the National route 1A is the main road. The national road network is efficient both for the transport of cassava to the port and to the ethanol plant. On average, it takes 199 MJ/tonne and 277 MJ/tonne for feedstock transportation to Dai Tan and BRS-BF ethanol plants, respectively.

For the Tung Lam ethanol plant, the cassava feedstock is transported through Binh Phuoc and Tay Ninh to the Cat Lai port on the National route 22 and is further transported on National route 1A to the plant. Total transportation implies an energy consumption of 125MJ/tonne on average.

Ethanol transportation

Ethanol is transported by truck through two possible transportation routes: National route 1A and National route 1B. Efficiency of ethanol transport depends on the region of destination.

The ethanol fuel supplied to the Northern provinces of Viet Nam (Hanoi, Hatay, Hai Phong), is transported from the two ethanol plants located in Center of the country (Dai Tan and BSR-BF). This is because the proposed ethanol plant in Phu Tho was never completed. In this case, ethanol transportation takes place over a long distance and implies high costs in terms of energy (533 to 625 MJ/tonne) and money (57.4 to 76.6 USD/m^3), which is not cost effective. The lack of ethanol plants in the North of the country and the need for transporting ethanol from the Center of Viet Nam, thus spending a lot of energy and money, constitutes a bottleneck for ethanol use in the North. If the situation remains as it is now, the Northern of Viet Nam might face shortages of ethanol fuel in the future.

For supplying ethanol fuel to the Central provinces of Viet Nam (Da Nang, Hue, Quang Nam, Bac Tay Nguyen), energy consumption varies from 50 to 359 MJ/tonne. The cost for ethanol fuel transport also vary accordingly, from 5.0 to 44.5 USD/m^3.

The energy consumption and costs for supplying ethanol from the plant in the South (Tung Lam plant) are relatively low. For supplying ethanol from Tung Lam plant to HCM City, energy consumption is about 79 MJ/tonne and the cost for transportation is 12.7 USD/m^3. For supplying ethanol from Tung Lam plant to Baria Vung Tau and Can Tho, energy consumption ranges between 91 and 189 MJ/tonne and the transportation cost is 16.5 USD/m^3 to Baria Vung Tau and 27.3 USD/m^3 to Can Tho.

c. Practices and policies to improve sustainability

Currently, the feedstock is transported over long distances before reaching the ethanol plants, because first it is delivered to ports rather than being delivered directly to the plants from the harvesting areas (second scenario). As consumption of ethanol will increase in the near future due to the introduction of the E5 mandate, feedstock delivery directly from the harvesting areas will likely become more reliable and the first scenario considered in this analysis will likely become quite common. In this scenario, transport distance is much shorter, thus reducing energy consumption, transportation cost and related GHG emissions.

Currently ethanol fuel transportation is mostly carried out by truck, with ethanol travelling over long distances in order to be delivered to the gasoline distribution network (especially in Northern Viet Nam). Other means of transport, such as train or vessel, should be considered to increase the amount of fuel delivered and reduce the related energy consumption. As the sector grows over the coming years, thanks the E5 mandate, larger investments in ships and trains for ethanol transport could become more feasible.

d. Future monitoring

Infrastructure and logistics for the distribution of bioenergy can significantly affect the development of the sector. In 2016, only 29 500 m^3 of ethanol fuel were consumed nationwide. In 2018, ethanol consumption is projected to increase, following Directive No 11/CT-BCT, promulgated by the Ministry of Industry and Trade on 22 September 2017, which introduced a country-wide five percent ethanol blending mandate for RON92 gasoline. The ethanol plants and petroleum distributors will need to optimize their infrastructure and logistic systems to deal with this increased demand. Therefore the measurement of this indicator in the future is very important to determine potential bottlenecks and to understand where efficiency savings can be achieved.

REFERENCES

GSO website. Statistical data (06.Agriculture, Forestry and Fishing). Available at: www.gso.gov.vn/default.aspx?tabid=717 [Accessed: Sept 2017]

Kruyt, B., van Vuuren, D.P., de Vries, H.J.M. and Groenenberg, H. 2009. Indicators for energy security. Energy Policy 37, Issue 6, 2166–2181. Available at: https://doi.org/10.1016/j.enpol.2009.02.006

Nguyen, N.H. 2013; VietinbankSc Industry Report: Petroleum Distribution in Vietnam; APEC Energy Demand and Supply Outlook – 5th Edition: Vietnam

PEC, C. T. 2014. Quy hoạch phát triển hệ thống dự trữ dầu thô và các sản phẩm xăng dầu của Việt Nam đến năm 2025, tầm nhìn đến năm 2035- Báo cáo tổng hợp

Petrolimex, T. c. 2013. Dự án triển khai phối trộn và kinh doanh xăng E5.

VJIIST. 2017 Survey conducted within this study in April 2017.

VPBS. (2013) Báo cáo ngành dầu khí Việt Nam, VPBS.

4.24 INDICATOR 24: CAPACITY AND FLEXIBILITY OF USE OF BIOENERGY

Van Dinh Son Tho
Vietnam Japan International Institute for Science of Technology (VJIIST) at the Hanoi University of Science and Technology (HUST)

DESCRIPTION:

(24.1) Ratio of capacity for using bioenergy compared with actual use for each significant utilization route
(24.2) Ratio of flexible capacity which can use either bioenergy or other fuel sources to total capacity

MEASUREMENT UNIT(S):

Ratios

4.24.1 Implementation of Indicator 24 in Viet Nam

Cassava-based ethanol

For the implementation of indicator 24 (and in particular sub-indicator 24.1) in Viet Nam for the Cassava-based ethanol value chain, three scenarios were considered: actual ethanol consumption/blending between 2013 and 2016; a 3.5 percent ethanol blending (with gasoline) in 2018; and a 5 percent ethanol blending in 2018, i.e. the fulfilment of the blending mandate recently introduced in Viet Nam. For these three scenarios, a 10 percent 'blending wall', i.e. the maximum level of ethanol blending that can be tolerated by the existing motorcycle and car fleet without retrofitting, was assumed. The data and information required for the elaboration of the aforementioned scenarios were collected from national statistics, official reports and other studies, and through direct communications with government representatives.

Biogas

For the implementation of indicator 24 for the biogas pathway in Viet Nam, a survey was conducted with a few cassava starch factories, focusing on their potential biogas production and on the use of this fuel for meeting the factories' heat demand. Interviews were carried out with selected large livestock farms located in Northern Viet Nam as well. For household level biogas, data from national statistics or available in literature was used. In order to calculate the ratio of capacity for using bioenergy compared with actual use, biogas production and use (both potential and actual) at household, farm and industrial levels were estimated, based on a number of parameters, e.g. volume of feedstock/residues available, number of biogas plants, and energy demand for cassava starch drying.

According to the Department of Livestock Production (MARD, 2016), more than 465 000 biogas plants (or ADs) have been built so far in Viet Nam, 90 percent of which are operational. 450 000 of these plants have been built for meeting the energy demand of households and have an average volume around 10 m^3. Biogas produced in these types of plant is mainly used on-site for cooking purposes.

At the industrial level, various industries (e.g. food processing, beer, sugar, and cassava starch) generate co-products, waste or wastewater with high organic content and suitable for the anaerobic treatment process and biogas production. Biogas production from the wastewater of cassava processing is successfully applied in Viet Nam and all starch factories produce biogas that they use as fuel for steam production and for drying starch, but no power is produced. The results of the survey indicate that power is produced only when biogas plants are coupled with ethanol production plants, even though it was not possible to estimate the amount of power produced by such plants, due to lack of data.

4.24.2 Key findings

Sub-Indicator 24.1

a. Cassava-based ethanol

The first ethanol support policy in Viet Nam was adopted in 2007. However, a country-wide E5 mandate was introduced only in January 2018. Due to this and to the low oil prices over the past few years, domestic ethanol production and consumption have been quite limited.

For 2016, the total domestic consumption of ethanol was around 29 500 m^3, which contributed only marginally to the gasoline Mogas 92 market and was much lower than the capacity for using ethanol in the country, i.e. the so-called 'blending wall'. Therefore, the capacity ratio for ethanol use in 2016 was only 0.04 (**Table 125**). This means that the volume of ethanol sold in 2016 in the country corresponded to just 4 percent of the maximum volume of ethanol that could have been blended with gasoline and used in the domestic road transport sector without retrofitting the existing car and motorcycle fleet, which was assumed to be equal to 10 percent. As shown in the table below, the capacity ratio for ethanol use fluctuated considerably between 2013 and 2016, due to the high volatility of the ethanol market in Viet Nam.

In September 2017, the Ministry of Industry and Trade promulgated Directive No. 11/CT-BCT on strengthening the implementation of the 2012 Roadmap and introducing a nation-wide E5 mandate for RON92 gasoline starting from January 2018. According to the MOIT representatives consulted within this study, realistically only a 3.5 percent ethanol blending should be reached in 2018 (VJIIST, 2017). In this case, a capacity ratio for ethanol use of 0.35 was estimated for 2018. Should the E5 blending mandate be fulfilled already in 2018, the capacity ratio would increase to 0.5 (**Table 126**).

TABLE 125

RATIO OF CAPACITY FOR USING ETHANOL COMPARED WITH ACTUAL USE, 2013-2016

YEAR	DOMESTIC CONSUMPTION OF GASOLINE (m^3)	DOMESTIC CONSUMPTION OF ETHANOL (m^3)	CURRENT ETHANOL BLENDING LEVEL (PERCENT)	CAPACITY FOR USING ETHANOL (m^3) (*)	CAPACITY RATIO (percent)
	A	B	C = (B/A)*100	D = A*0.1	E = (B/D)
2013	5 847 000	37 000	0.63	584 700	0.063
2014	6 149 000	25 300	0.41	614 900	0.041
2015	6 494 000	15 200	0.23	649 400	0.023
2016	7 400 000	29 500	0.40	740 000	0.04

Source: Elaborated from PEC (2014) and Dong (2017)

TABLE 126

RATIO OF CAPACITY FOR USING ETHANOL COMPARED WITH ACTUAL USE, 2018

YEAR	DOMESTIC CONSUMPTION OF GASOLINE (m^3)	ETHANOL BLENDING LEVEL (percent)	DOMESTIC CONSUMPTION OF ETHANOL (m^3)	CAPACITY FOR USING ETHANOL (m^3) (*)	CAPACITY RATIO
	A	B	C = (A*B)/100	D = A*0.1	E = (C/D)
2018	7 652 000	3.5	267 820	765 200	0.35
2018	7 652 000	5	382 600	765 200	0.5

Source: VJIIST, 2017

a. Biogas

Biogas from cassava starch wastewater

In order to measure sub-indicator 24.1 for the biogas pathway at industrial level, a survey was conducted in April 2017 among cassava starch factories. **Figure 64** shows the processing capacity of these plants and their heat and power consumption (VJIIST, 2017). The power consumption of the majority of the plants included in the survey ranges between 156 and 180 kWh/tonne starch, with the exception of the QN1 and BD1 plants, which reported significantly higher levels of power consumption. No data could be obtained from plants TN1 and TN2.

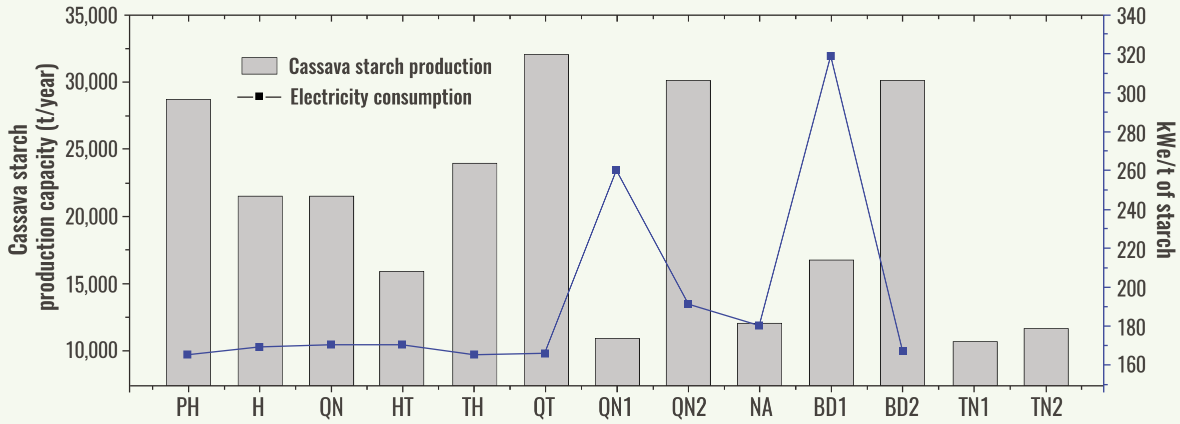
The drying process is the stage that accounts for the largest share of energy consumption in cassava processing, with an average of 171.5 kWh/tonne of starch. In most cassava starch processing plants, biogas produced from the wastewater replaces the use of coal and DO for the drying process (VJIIST, 2017).

As shown in **Figure 65**, typically around 50-60 percent of the biogas produced in these plants (58.2 percent, on average) is utilized on site for meeting their heat demand[20]. In particular, in case of QN, BD1 and TN2 plants, more than 80 percent of biogas produced is used for heat production. All the cassava-starch plants surveyed produce a surplus of biogas that could be used for power generation.

Table 127 shows data related to a company (PY) interviewed during this study. The factory has an annual capacity of 28 800 tonnes of starch. It is equipped with several facilities for root washing, centrifuging, rasping and extraction, among others, and has a total power consumption of about 4 752 MWh/year. The electricity used by this plant comes from the national grid.

FIGURE 64

PROCESSING CAPACITY AND POWER CONSUMPTION OF SELECTED CASSAVA STARCH PLANTS IN VIET NAM

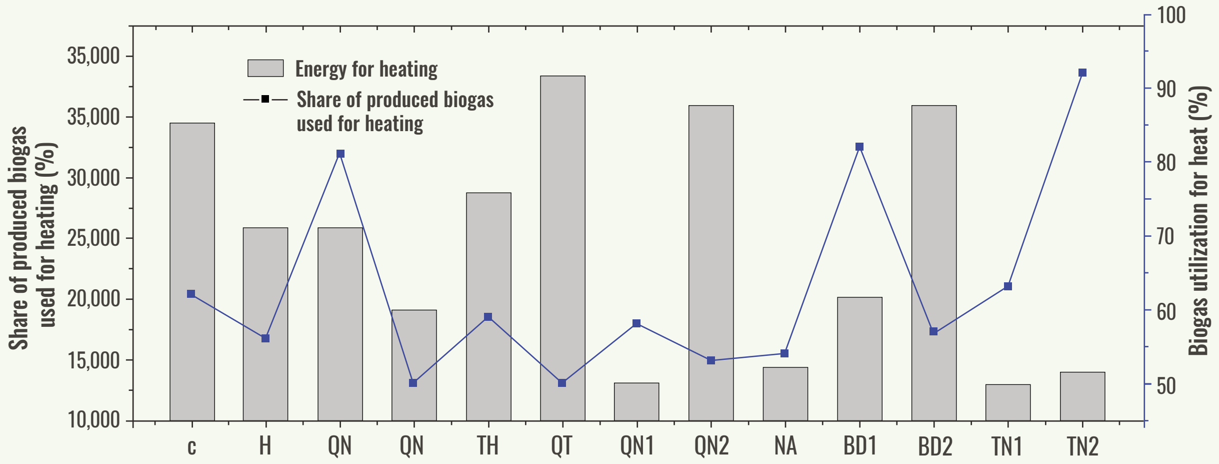


Source: VJIIST, 2017

[20] In order to estimate the potential biogas production and the amount of biogas used on site for heat production, the initial and the final starch water content, and the theoretical heat required for obtaining this reduction (in water content) during the drying process were considered in the calculation. By comparing the theoretical value of COD of wastewater and energy for drying starch, the biogas utilisation ratio for heating demand could be quantified.

FIGURE 65

BIOGAS UTILIZATION FOR STARCH DRYING IN SELECTED CASSAVA STARCH PLANTS IN VIET NAM



Source: VJIIST, 2017

Based on the COD of the wastewater, it was estimated that this plant could produce 1 107 976 m^3 of biogas per year. Currently, a covered lagoon is used for the anaerobic digestion process, and the company is not equipped with plants for co-generation of heat and power (CHP) from biogas. All biogas is burned directly without any further purification and the heat produced is used for drying starch, thus allowing savings of 34 500 GJ/year. This amount of heat is equal to 62.3 percent of the heat that could be generated by the biogas produced.

In order to come up with national level figures for the cassava starch industry as a whole, the potential volume of biogas produced, calculated as above, and its ratio of conversion into heat were assumed to be equal to the national average value (see Indicator 18). Biogas production from the wastewater of cassava starch processing in Viet Nam amounts to around 4 859 440 650 MJ/year, 58.16 of which is used for the starch drying process. This means that over 40 percent of the biogas produced by cassava starch plants is not utilized. No power generation is taking place from this surplus biogas, which is either flared or vented. For biogas at industrial level, a capacity ratio for using biogas compared with actual use (for heating) of 1 was calculated, meaning that all of the biogas that could be used – in the form of heat – for dying cassava starch – is actually utilized.

TABLE 127

BIOGAS PRODUCTION AND USE IN PY CASSAVA PROCESSING FACTORY

CASSAVA STARCH PRODUCTION	28 800 tonne/year
ELECTRICITY CONSUMPTION	4 752 MWH/YEAR
BIOGAS PRODUCTION (BASED ON COD OF WASTEWATER SYSTEM)	1 107 976 m^3/YEAR
POTENTIAL HEAT GENERATION FROM BIOGAS	55 399 GJ/YEAR
BIOGAS USE FOR STARCH DRYING	34 500 GJ/YEAR
SHARE OF PRODUCED BIOGAS USED FOR STARCH DRYING	62.3 PERCENT

Source: VJIIST, 2017

TABLE 128

CAPACITY RATIO OF BIOGAS USE FOR HEAT AND POWER GENERATION IN CASSAVA PROCESSING INDUSTRY

CONTENT	VALUE	UNIT
TOTAL WASTEWATER VOLUME	720 750	m^3/PLANT/YEAR
BIOGAS PRODUCTION PER CASSAVA STARCH PLANT	47 641 575	MJ/PLANT/YEAR
TOTAL NUMBER OF CASSAVA STARCH PLANTS	102	PLANT
TOTAL BIOGAS PRODUCTION	4 859 440 650	MJ/YEAR
SHARE OF PRODUCED BIOGAS USED FOR CASSAVA STARCH DRYING	58.16	PERCENT
AMOUNT OF PRODUCED BIOGAS USED FOR STARCH DRYING	2 826 250 682	MJ/YEAR
RATIO OF CAPACITY FOR USING BIOGAS COMPARED WITH ACTUAL USE (FOR HEATING)	1	RATIO

Source: VJIIST, 2017

b. Biogas from pig manure

As already discussed under previous indicators, pig manure is the most common feedstock used for biogas production at household and farm levels in Viet Nam.

According to FAO (2012), 1 m^3 of wastewater from animal husbandry can generate 0.3 m^3 biogas per day and burning 1 m^3 of biogas (LHV) can release 21.6 MJ of heat (FAO, 2012).

Using these figures, the biogas output at household / SBP scale (10 m^3) is 24 GJ/plant/year (0.3 x 10 x 0.0216 x 365). Total biogas output of the country for all SBPs is (24 x 405 000) = 9 720 000 GJ/year of thermal energy.

Regarding the farm level, based on the same FAO figures, the biogas output at MBP scale (500 m^3) is 1 134 GJ/plant/y (0.3 x 500 x 0.0216 x (365-15[21])). Assuming that the share of operating digesters is equal to 90 percent, the total biogas output of the country at MBP scale is 14 666 022 GJ/year. Using the same methodology, it can be estimated that, at LBP scale (2000 m^3), the total thermal energy generated by biogas in the country could reach 4 082 400 GJ/year. The total potential biogas production at all scales is reported in Table 129.

In Viet Nam, biogas produced from pig manure is used exclusively at household level, mostly for cooking. This is true not only for SBPs installed within pig-raising households, but for MBPs and LBPs operating in pig farms as well. In this latter case, only a small fraction of the produced biogas is utilized, resulting in a significant surplus of biogas, which is either flared or vented.

Energy consumption at household level is varied and depends on several factors, such as the number of household members, local availability of biomass sources, cooking habits

TABLE 129

TOTAL BIOGAS PRODUCTION AT HOUSEHOLD AND FARM LEVELS

TYPE	QUANTITY	NUMBER OF PLANTS (90%in use)	BIOGAS PRODUCED IN GJ/plant/y	TOTAL BIOGAS PRODUCTION (GJ/y)
HOUSEHOLD: SBP (10 m^3)	450 000	405 000	24	9 720 000
FARM: MBP (500 m^3)	14 370	12 933	1 134	14 666 022
FARM: LBP (2 000 m^3)	1 000	900	4 536	4 082 400

Source: MARD, 2016

[21] An average of 15 days a year for maintenance of a biogas plant was assumed.

and affordability of LPG fuel, among others. The average household energy consumption for cooking is approximately 80 566 MJ/year (EPRO, 2016). On average, biogas produced from pig manure replaces 77.3 percent of the consumption of wood fuel, agricultural residues and LPG used at household level for cooking purposes. Thus, the ratio of capacity for using biogas compared with actual use is 0.773. In the case of households living nearby pig farms producing biogas, this fuel meets 100 percent of the heat demand for cooking and the capacity ratio is 1.

Sub-Indicator 24.2

a. Cassava-based ethanol

At the moment, there are no flex-fuel vehicles circulating in Viet Nam. Therefore the flexible bioenergy capacity, as defined in the GBEP methodology sheet of indicator 24, and the associated flexibility ratio is equal to zero for bioethanol.

b. Biogas

In Viet Nam, biogas stoves cannot run on other fuels without retrofitting. Thus, the flexible bioenergy capacity is equal to zero in the case of Biogas from pig manure used at household level. However, as already explained in the social indicators, most households in Viet Nam (including those with ADs) tend to use more than one technology and fuel for cooking. This means that, in case of a shortage of biogas, most of the households relying primarily on this fuel for cooking, should be able to switch to an alternative fuel. Similarly, at industrial level, most cassava starch plants producing biogas from wastewater and using it for the cassava starch drying process should be able to switch to other fuels such as DO and coal, in case of need.

4.24.3 Main conclusions and recommendations

Approach used

a. Cassava-based ethanol

For the implementation of indicator 24 (component 24.1) for the Cassava-based ethanol value chain in Viet Nam, three scenarios were considered: actual ethanol consumption/ blending between 2013 and 2016; a 3.5 percent ethanol blending (with gasoline) in 2018; and a 5 percent ethanol blending in 2018, i.e. the fulfilment of the blending mandate recently introduced in Viet Nam. For these three scenarios, a 10 percent 'blending wall', i.e. the maximum level of ethanol blending that can be tolerated by the existing motorcycle and car fleet without retrofitting, was assumed. The data and information required for the elaboration of the aforementioned scenarios were collected from national statistics, official reports and other studies, and through direct communications with government representatives.

b. Biogas

For the implementation of indicator 24 for the biogas pathway in Viet Nam, a survey was conducted with a few cassava starch factories, focusing on their potential biogas production and on the actual use of this fuel for meeting the factories' heat demand. Selected large livestock farms located in Northern Viet Nam were interviewed as well (VJIIST, 2017). For small-scale biogas at household level, data from national statistics and literature was used. Finally, biogas production and use at household, farm and industrial levels were estimated, based on various parameters.

Results

a. Cassava-based ethanol

The capacity ratio for ethanol use fluctuated considerably between 2013 and 2016, due to the high volatility of the ethanol market in Viet Nam. In 2016, the volume of ethanol sold in 2016 in the country corresponded to just 4 percent of the maximum volume of ethanol that could have been blended with gasoline and used in the domestic road transport sector without retrofitting the existing car and motorcycle fleet, which was assumed to be equal to 10 percent. This means that the capacity ratio was equal to 0.04.

An E5 mandate has been introduced in January 2018 in Viet Nam. Assuming that only a 3.5 percent ethanol blending level will be reached in 2018, the capacity ratio for ethanol use would be equal to 0.35. Should the E5 mandate be fulfilled already in 2018, this ratio would increase to 0.5.

Regarding sub-indicator 24.2, the flexible bioenergy capacity, as defined in the GBEP methodology sheet of indicator 24, and the associated flexibility ratio are equal to zero for ethanol, as there are no flex-fuel vehicles circulating in Viet Nam.

b. Biogas

Concerning sub-indicator 24.1, for biogas at industrial level, a capacity ratio for using biogas compared with actual use (for heating) of 1 was calculated, meaning that all of the biogas that could be used – in the form of heat – for dying cassava starch – is actually utilized. A significant biogas surplus is available as well. No power generation is taking place from this surplus biogas, which is either flared or vented.

On average, biogas produced from pig manure replaces 77.3 percent of the consumption of wood fuel, agricultural residues and LPG used at household level for cooking purposes. Thus, the ratio of capacity for using biogas compared with actual use is 0.773. In the case of households living nearby pig farms producing biogas, this fuel meets 100 percent of the heat demand for cooking and the capacity ratio is 1.

Regarding sub-indicator 24.2, in Viet Nam biogas stoves cannot run on other fuels without retrofitting, meaning that the flexible bioenergy capacity is equal to zero. However, most households in Viet Nam (including those with ADs) tend to use more than one technology and fuel for cooking. This gives them the flexibility of switching from one fuel to another, depending on circumstances. Similarly, at industrial level, most cassava starch plants using biogas from wastewater for starch drying should be able to switch to other fuels such as DO and coal, in case of need.

Practices and policies to improve sustainability

As discussed above, pig farms produce large volumes of biogas, most of which is not utilized. Over 40 percent of the biogas produced by cassava starch plants (from the wastewater) is not used either. This surplus biogas is either flared or vented, leading to the release of significant emissions of methane (CH_4), which is a very powerful GHG. Incentives should be put in place by the Government to promote power generation from biogas in the agricultural sector, which would have a number of environmental and socio-economic benefits in addition to climate change mitigation.

Future monitoring

As modern bioenergy production and use continue to expand in Viet Nam, monitoring the capacity ratio and the flexible capacity related to the different biofuels and technologies used will be extremely important.

REFERENCES

Binh Son refinery. 2016. Report.

Dong, D.X. 2017. The orientation in the production and use of biofuels in Vietnam, Department of Science and Technology, MOIT, FAO, Sustainable Bioenergy Production and Use in Southeast Asia: Lessons Learnt and Future Opportunities, 16-17 November 2017, Hanoi. Available at: www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/AG2/Viet_Nam_project/Final_Mettings/Dong_Do-Xuan.pdf [Accessed: 13 Feb 2018]

EPRO. 2014. Biogas User Survey 2013. Available at: www.biogas.org.vn/english/getattachment/An-pham/2014/BIOGAS-USER-SURVEY-2013/Biogas-User-Suvey-Report-2013_eng.pdf.aspx [Accessed: 15 Apr 2017]

EPRO. 2016. Biogas User Survey (2014).

FAO. 2012. The Low Carbon Agricultural Support Project (LCASP) in Vietnam, Carbon balance appraisal with the Ex-Ante Carbon balance Tool, 2012. Available at: www.fao.org/fileadmin/templates/ex_act/pdf/case_studies/draft_aout2012-clear.pdf

FAO and IFAD. 2001. A review of cassava in Asia with country case studies on Thailand and Viet Nam. Status of cassava in Viet Nam: implications for future research and development. Available at: www.fao.org/docrep/009/y1177e/Y1177E05.htm [Accessed: 13 Feb 2018]

MARD. 2016. Real situation and solutions for environmental treatment of livestock production.

PEC, C. T. 2014. Quy hoạch phát triển hệ thống dự trữ dầu thô và các sản phẩm xăng dầu của Việt Nam đến năm 2025, tầm nhìn đến năm 2035- Báo cáo tổng hợp

Sorapipatana, C. and Yoosin, S. 2011. Life cycle cost of ethanol production from cassava in Thailand. *Renewable and Sustainable Energy Reviews* 15 (2011) 1343–1349

SPIN project. 2014. VNCPC, Sản xuất sạch hơn ngành tinh bột sắn. Available at: http://spin-e.vn/e-library [Accessed: 9 Feb 2018]

Thitruongsan website. Available at: http://thitruongsan.com/chao-gia-san-lat-cua-viet-nam-sang-thi-truong-trung-quoc-tang-theo-chieu-thang-dung-do-luong-san-lat-ton-kho-hien-o-muc-rat-thap_5269.html [Accessed: Feb 2018]

Trading economics website. Available at: https://tradingeconomics.com/vietnam/gasoline-prices [Accessed: 9 Feb 2018]

VJIIST. 2017. Surveys conducted within this study on April 2017 in feedstock production areas in Phu Tho, Tay Ninh province, ethanol plants, transportation activities mapping (including vehicles for cassava chips, ethanol and biofuel transportation) and E5 stations.

CHAPTER 5

CHAPTER

5

CONCLUSIONS AND RECOMMENDATIONS

Andrea Rossi, Tiziana Pirelli
Food and Agriculture Organization of the United Nations (FAO)

5.1 PROJECT OUTCOMES

In line with its intended outcome, the project that FAO implemented in cooperation with the Vietnam Academy of Agricultural Sciences (VAAS) - on behalf of the Ministry of Agriculture and Rural Development (MARD) - contributed to enhance the capacity of the country to assess bioenergy sustainability via the GBEP indicators. In particular, the project provided useful evidence to inform decision-making, within the broader context of low-carbon development, in relation to key bioenergy pathways in Viet Nam, i.e. Cassava-based ethanol and biogas.

In the implementation of the project, FAO worked in close cooperation with relevant national Centers of excellence, providing technical guidance and back-stopping to them, i.e.:

- The Institute of Agricultural Environment (IAE) and the Centre for Agrarian Systems Research and Development (CASRAD) at VAAS, which took the lead on the environmental indicators and measured part of the economic indicators as well;
- The Vietnam Japan International Institute for Science of Technology (VJIIST) at the Hanoi University of Science and Technology (HUST), which had the primary responsibility over the economic indicators; and
- The Asian Institute of Technology Centre in Vietnam (AITCV), which led the measurement of the social indicators.

In order to strengthen the capacity of the country to monitor bioenergy sustainability, trainings were organized, for key experts from the aforementioned Centers and from relevant national institutions, on selected methodologies to assess the impacts of bioenergy. These methodologies are relevant for – and could be applied to - the agricultural and energy sectors in general and thus could inform the development and implementation of policies to promote low-carbon development in these broader sectors beside bioenergy specifically.

The project also contributed to set the basis for the constitution of a national platform for the long-term monitoring of bioenergy sustainability. In particular, through the Multi-Stakeholder Working Group that was established in the country, the project promoted inter-ministerial coordination and fostered a constructive dialogue among policy-makers, private sector and academia. Furthermore, it raised the awareness of each of these stakeholders about the main sustainability issues associated with the selected bioenergy pathways and about the importance of monitoring the impacts of bioenergy production and use over time.

Furthermore, the project promoted the exchange of information, experiences and good practices among the aforementioned national stakeholders and at the regional level as well. With regard to the latter, a regional workshop was organized in Viet Nam, leading to fruitful discussions between policy-makers from different countries in the ASEAN region, and paving the way for possible future cooperation opportunities.

Finally, the implementation of the GBEP Sustainability Indicators for Bioenergy in Viet Nam provided useful lessons about how to apply the indicators as a tool for sustainable development and how to enhance the practicality of the tool. These lessons were incorporated in the Implementation Guide that was developed under the GBEP Working Group on Capacity Building in order to accompany the Sustainability Indicators for Bioenergy.

5.2 SUSTAINABILITY OF CASSAVA-BASED ETHANOL AND BIOGAS VALUE CHAINS IN VIET NAM: KEY RESULTS AND RECOMMENDATIONS

As explained in Chapter 1, in consultation with the Multi-Stakeholder Working Group, two priority bioenergy pathways were identified in Viet Nam. They were chosen based on their spread (e.g. household-level biogas), their relevance in terms of decision-making (e.g. Cassava-based ethanol), and the need for further evidence and analysis regarding their sustainability and competiveness. The following pathways and the related sustainability issues represented the main focus of the project:

- Cassava-based ethanol; and
- Biogas at household, farm and industrial levels.

The main results emerging from the implementation of the GBEP indicators for these two value chains and the related recommendations are discussed below.

5.2.1 Cassava-based ethanol value chain

For the Cassava-based ethanol value chain, two scenarios were analyzed under the various sustainability indicators implemented in Viet Nam:

- Domestic ethanol consumption as of 2016 (assumed to be equal to domestic production) vs. a baseline that was set in 2007, i.e. the year of introduction of the first ethanol support policies in the country; and

- Domestic ethanol consumption to meet a hypothetical E5 mandate for RON92 gasoline in 2016 vs. the aforementioned 2007 baseline.

For the feedstock production stage, two different cultivation systems were considered: on flat land and on sloping land.

As of December 2017, only two out of five fuel ethanol plants were operational in Viet Nam. Furthermore, the volume of production of these two plants was only a small fraction of their capacity. At the same time, over the past few years, only minor volumes of ethanol were blended with gasoline in the country, with less than 30 thousand m^3 of domestic ethanol consumption in 2016. These low levels of ethanol production and consumption recorded to date in Viet Nam are due to a number of factors.

Even though the first ethanol support policies date back to 2007, a nation-wide E5 blending mandate (for RON92 gasoline) was introduced only in January 2018. This, combined with low gasoline prices between 2014 and 2017 and an inadequate ethanol pricing policy, has led to very low ethanol blending levels over the past few years.

As emerged from the results of the implementation of the GBEP indicators, the competitiveness of the Cassava-based ethanol industry is hindered as well by low levels of productivity and efficiency along the supply chain and especially in feedstock production. As described under Indicator 17, with an average yield of 18 tonnes/ha, cassava productivity in Viet Nam is relatively low in comparison to other countries with similar agro-ecological conditions. To improve the efficiency and sustainability of the Cassava-based ethanol pathway in Viet Nam, the productivity of cassava should be improved, through the use of improved varieties, advanced cultivation techniques and good agricultural practices. At the same time, in order to increase the overall productivity of the supply chain, ethanol plants should make use of more efficient processing technologies. Policies and incentives would be needed to promote the adoption of the aforementioned measures to increase productivity at both farm and plant level. In addition to lowering the production cost of ethanol and enhancing the efficiency and competiveness of the domestic Cassava-based ethanol sector, these policies would have a number of environmental and socio-economic co-benefits as well, such as improved land and natural resource management, increased GHG emission savings compared to gasoline[22], and increased income for cassava producers.

In order to further improve the sustainability of the Cassava-based ethanol value chain and achieve higher GHG emission savings, as described under Indicator 1, the reliance of ethanol plants on coal for their energy needs should be reduced, in favor of less carbon intensive options such as biogas or other renewables. Furthermore, the logistics of the supply chain should be improved and the transportation distances of both feedstock and ethanol should be reduced, with positive effects in terms of both cost and emission savings. As explained under Indicator 23, currently in Viet Nam the feedstock is transported over long distances before reaching the ethanol plants, because first it is delivered to ports rather than being delivered directly to the plants from the harvesting areas. As reported by industry representatives, this may result in the lack of a reliable supply of affordable feedstock, which is a challenge that ethanol plants have been facing at times in Viet Nam and which has contributed to the volatility of the ethanol market over the past few years. Regarding ethanol, transportation is mostly carried out by truck, with the fuel travelling over long distances in order to be delivered to the gasoline distribution network, especially in Northern Viet Nam, where currently there are no ethanol plants in operation. Other means of transport, such as train or vessel, should be considered to increase the amount of fuel delivered and reduce the related energy consumption.

[22] According to the results of Indicator 1, in Viet Nam, ethanol production and use (for transportation) result in total GHG emissions of 57.5 – 59.2 $gCO_{2e}q$/MJ of product, which is a 37-39 percent (depending on where cassava is cultivated) GHG emission savings in comparison to gasoline.

The recent adoption (January 2018) of a country-wide E5 blending mandate represents an interesting opportunity for the growth of the domestic ethanol industry and market in Viet Nam. However, in the lack of measures to protect the domestic industry, addressing the challenges described above and improving the efficiency of the Cassava-based ethanol value chain will be key, in order for domestically produced ethanol to be able to compete (price-wise) with the ethanol coming from the international and regional markets. Furthermore, significant investments will be required, e.g. to improve the capacity and efficiency of ethanol storage and blending.

To date, the environmental, social and economic impacts of the Cassava-based ethanol value chain have been limited, due to the low level of ethanol consumption and the limited share of cassava used for the production of this fuel. For instance, only minor income and employment effects were reported under indicators 11 and 12, together with a negligible impact on the consumption of fossil fuels (indicator 20) and a minor contribution of ethanol to the energy diversity of the country (indicator 22). Furthermore, as discussed under the indicators 7, 8, 9 and 10, to date the demand for Cassava-based ethanol does not appear to have put significant pressures on land / land use, biodiversity, land tenure and food security.

In case the E5 blending mandate introduced in January 2018 will be met (mainly or exclusively) domestically, leading to a significant and rapid increase in the volume of ethanol produced in the country[23], the aforementioned pressures might increase and thus should be closely monitored. However, as emerged from the results of the analysis of the scenario with the E5 mandate, the large surplus of cassava in Viet Nam, with exports absorbing the vast majority of domestic production, is likely to mitigate these pressures. Nonetheless, in order to reduce the risk of competition with other uses of cassava and of trade-offs with exports, a sustainable intensification of cassava cultivation should be promoted. This way, the expansion in the cassava demand for the ethanol market could be met through an additional supply of this crop resulting from a yield increase.

Two issues deserve particular attention in the Future monitoring of the sustainability of the Cassava-based ethanol value chain:

- The impact of cassava cultivation and harvesting on soil erosion (indicator 2), in case the E5 mandate triggers an increase in cassava production on sloping lands, where the risk of erosion is elevated and where sustainable agricultural practices should be identified and promoted; and
- The impact of ethanol blending and of the resulting decrease in gasoline consumption on the Government's revenues and budget, in light of the important contribution to the National Fund of taxes and fees on gasoline products.

5.2.2 Biogas value chain

Biogas systems, especially at household level, have been in place for a few decades in Viet Nam. This study analyzed three different types and scales of biogas systems in Viet Nam: household (from pig manure), farm (also from pig manure), and industrial (from cassava wastewater). For the assessment of the sustainability of the biogas pathway under the various GBEP indicators, the situation as of 2016 (with biogas) was compared with a scenario without biogas.

At household level, around 450 000 Anaerobic Digesters (ADs) - 90 percent of which are currently operational - have been installed in Viet Nam, thanks to the support of the Government and of international and regional entities as well, such as the Netherlands Development Organization (SNV), the Asian Development Bank and the World Bank.

Among the 405 000 households with operational ADs, biogas provides most of the energy for cooking and is used for heating and lighting as well, displacing traditional biomass and fossil fuels, with multiple environmental and socio-economic benefits, including: reduced household energy expenditures on energy (indicator 11); increased access to modern energy

[23] It is important to consider that, in parallel with the increase in the share of ethanol blending in gasoline, gasoline consumption has been rapidly increasing in Viet Nam, and this trend is expected to continue over the coming years.

services (indicator 14); reduced time spent collecting fuelwood (indicator 13); and reduced exposure to indoor air pollution and to the related health risks (indicator 15).

The positive effects of biogas extend beyond biogas-using households. For instance, despite its relatively low labor requirements, the biogas sector in Viet Nam has generated demand for a number of skilled jobs linked to the construction and operation of ADs, such as masons and technicians. These workers were trained in the context of the biogas support projects mentioned above and especially by SNV (indicators 12, 21).

However, ADs are often poorly managed, reducing some of the benefits described above and giving rise to a number of issues. In particular, oftentimes too much water is put into the ADs, as discussed under indicators 6 and 21. This reduces the efficiency of the digestion process and leads to an excessively diluted digestate, thus discouraging farmers from transporting it to the field to apply it to the soil[24]. As a result, the digestate from the ADs is generally discharged into the environment (e.g. into lakes, canals, rivers, soil) nearby farm houses, instead of being used as a fertilizer. Due to this, the potential positive effects that a proper management and application of digestate can have, for instance in terms of reduced use of nitrogen-based fertilizers (with associated cost and emission savings), are not exploited. Furthermore, the discharge of digestate into the environment leads to negative impacts on water and soil quality, due (among other things) to the heavy metals found in digestate.

As reported under Indicator 21, one of the reasons behind the issues described above is lack of adequate training for farmers/households on the operation of ADs. Furthermore, in a few cases, limited awareness about the nutritive value (such as N, P and K) of the digestate, as well as of its toxic elements (such as heavy metals) has been reported among farmers. Another practical reason that limits the application of digestate (as well as manure) to the soil is that not all pig-raising household and farms (especially large scale ones) have and/or manage cropland.

Other challenges are the potential biogas leakages due to cracks in the ADs, and the intentional release (or venting) of surplus biogas, which can result in significant emissions of methane (CH_4), which is a greenhouse gas with a high global warming potential. These problems are being exacerbated by the growing size and intensification of livestock production units. Increased input into an AD designed for smaller livestock production may increase the risk of leakages. Furthermore, it may lead to a decrease in retention time and in the efficiency of the digestion process. If the increased input of manure leads to a higher biogas output, households are likely to release into the environment the biogas that exceeds their energy needs.

At farm level, ADs are mainly used as a waste management strategy, i.e. to reduce odour and emissions from pig manure. Only a small fraction of the produced biogas is used (for cooking, heating and lighting by the households living on the farm and its surroundings), while most of it is flared or even vented. This leads to significant methane emissions, and is a missed opportunity in terms of renewable energy generation (e.g. indicators 1, 18, 24). Power generation, including for injection into the grid, from agricultural and livestock residues, should be promoted, as it is already done for landfill biogas. Furthermore, opportunities to further distribute biogas to local communities should be explored.

At industrial level, biogas is produced mainly from the wastewater generated from cassava starch processing. Part of this biogas is used by cassava starch plants to meet their energy (heat) needs, while the rest of it is flared or vented (e.g. indicators 18, 24). Also in this case, power generation from this surplus biogas should be promoted. This way, the methane emissions associated with biogas flaring and especially venting would be avoided, and renewable energy could be generated, leading to the displacement of fossil fuels and to further GHG emission savings, in addition to various other environmental and socio-economic benefits.

The implementation of the GBEP indicators provided also interesting insights into the

[24] For a proper management of the digestate, drying and/or composting should be carried out in order to reduce the volume and increase the nutrient content of the digestate before applying it to the soil.

potential for the further development of the biogas sector in the country and on the related barriers. Overall, biogas may be an effective option to replace fossil fuels and other less efficient and sustainable biofuels. However, the cost of building ADs is still high and the payback period is long. For this reason, the biogas sector still needs policy support in Viet Nam. As mentioned above, promoting power generation from surplus biogas at farm and industrial levels would be key in order to ensure higher returns for investments in ADs. At household level, micro-financing schemes could be established to support the installation of ADs.

As discussed under various indicators, the following barriers to the adoption of biogas and to its efficient production and use have been reported in Viet Nam: inability to manufacture appliances and digesters locally; lack of technical skills in the private sector to install and maintain digesters; poorly developed biogas-based energy conversion equipment, with low heat conversion efficiency; lack of large appliances capable of using biogas; and limited awareness of available digestate applications and of the related benefits.

Another important issue hindering the growth of the biogas sector in Viet Nam is the lack of institutional coordination among the various national and local entities which have competence over biogas-related issues; and between these entities and international donors. At national level, stronger coordination and cooperation would be needed, in particular, among the Ministry of Agriculture and Rural Development, the Ministry of Natural Resources and Environment, the Ministry of Construction, the Ministry of Transportation, the Ministry of Science and Technology, the Ministry of Investment and Planning, and the Ministry of Finance. In addition, local and provincial agencies, especially in the agricultural sector, should be engaged in decision-making related to biogas. The private sector and NGOs should be involved and consulted as well, in order to identify and share best practices, jointly mobilize resources, apply new technologies, and develop the technical workforce.

5.3 RECOMMENDATIONS FOR FUTURE MONITORING OF BIOENERGY SUSTAINABILITY IN VIET NAM

As explained above, the project set the basis for the constitution of a national platform for the long-term monitoring of bioenergy sustainability, through the establishment of a Multi-Stakeholder Working Group (MSWG), bringing together representatives of relevant national ministries and agencies, private sector and academia.

Taking advantage of the momentum created by the project, it would be important to institutionalize the MSWG, turning it into a permanent, official body and formally appointing to it representatives of the aforementioned stakeholder groups. In order to ensure a participatory process, in the future it would be important to open up the MSWG to representatives of civil society as well.

The MSWG could play a key role in debating issues regarding modern bioenergy development and its sustainability, and it could provide guidance and advice to decision-makers. The MSWG could also act as custodian of the GBEP indicators, and it could oversee the monitoring of the environmental, social and economic impacts of bioenergy production and use through these indicators.

With the establishment of a long-term framework for the monitoring of bioenergy sustainability, it would be possible to assess the contribution of modern bioenergy to climate change mitigation and sustainable development and thus to the implementation of the Nationally Determined Contributions (NDCs) and of the Sustainable Development

Goals (SDGs). Furthermore, by monitoring the sustainability of modern bioenergy production and use, important indications could be obtained regarding the effectiveness of bioenergy support policies and the achievement of the related objectives (e.g. GHG emission reductions, increased energy diversity and access, etc.), in addition to the identification of any unintended effects that such policies might have. The results of the monitoring could then be used to inform possible revisions and adjustments to these policies.

Monitoring the environmental, social and economic sustainability of bioenergy production and use on a regular basis may be costly. Therefore, a financial commitment by the Government is necessary. However, monitoring costs should be relatively low, as the national Centers of excellence that applied the GBEP indicator methodologies in the country (and some of which are public and respond more or less directly to the Government) could be contracted. Furthermore, for the various GBEP indicators, baseline values were already established for the Cassava-based ethanol and biogas value chains in Viet Nam. Using these baseline values, the future impacts of these bioenergy pathways could be monitored.

Under this project, only the most relevant bioenergy pathways were analysed. In addition, for these pathways, it was only possible to count on partial data sets in most cases. For Future monitoring, it would be important to broaden the scope of the analysis to additional pathways. Furthermore, additional data should be compiled or collected, especially for the bioenergy pathways that are expected to experience a significant growth (e.g. Cassava-based ethanol) and for those that are considered to be particularly strategic.

Regarding secondary data, every relevant government institution represented in the MSWG should be committed to provide all necessary information. Access to data owned by the private sector is key as well for a thorough monitoring of the selected bioenergy value chains. Part of the information could be of a commercially sensitive nature (or could be perceived as such by operators) and thus should be treated as confidential. The cooperation of business associations, ideally as part of the MSWG, could play a key role in this regard. Where necessary, confidentiality agreements could be signed as well with private companies.

Concerning primary data, the size and geographical coverage of the field surveys carried out during the project were pretty limited, due to time and resource constraints. In order to get an accurate picture of the effects of modern bioenergy development in the different regions of Viet Nam, it is recommended to collect additional data. Priority should be given to the areas that are most relevant in terms of volume of production and use of the selected bioenergy pathways and/or in terms of prominence of the various sustainability issues addressed by the GBEP indicators.

In order to promote sustainable bioenergy development, the exchange of good practices, experiences and lesson learnt is fundamental, at both national and international level. The MSWG established under the project represents an excellent means to foster this exchange among relevant national stakeholders. Furthermore, a regional workshop was organized in Viet Nam, leading to fruitful discussions between policy-makers and experts from different countries in the ASEAN region, and paving the way for possible future cooperation opportunities. In order to exploit these opportunities, it would be important to maintain an active regional dialogue on issues related to sustainable bioenergy development, including through the organization of similar events in the future, ideally on a regular basis.

The Global Bioenergy Partnership (GBEP) has produced a set of twenty-four indicators for the assessment and monitoring of bioenergy sustainability at the national level. The GBEP indicators are intended to inform policymakers about the environmental, social and economic sustainability aspects of the bioenergy sector in their country and guide them towards policies that foster sustainable development. FAO, which is among the founding members of GBEP, implemented the indicators in Viet Nam, under the leadership of the Vietnam Academy of Agricultural Sciences (VAAS), on behalf of the Ministry of Agriculture and Rural Development (MARD).

This report presents the results of the implementation of the GBEP indicators to two key bioenergy pathways in Viet Nam: cassava-based ethanol and biogas at household, farm and industrial levels. The environmental, social and economic impacts of these two pathways are discussed, and recommendations are provided on how to improve their sustainability, efficiency and competitiveness. This work provided Viet Nam with an understanding of how to establish the means of a long-term, periodic monitoring of its domestic bioenergy sector based on the GBEP indicators. Such periodic monitoring would enhance the knowledge and understanding of this sector and more generally of the way in which the contribution of the agricultural and energy sectors to national sustainable development could be evaluated. The implementation of the GBEP indicators in Viet Nam also provided a series of lessons learnt about how to apply them as a tool for sustainable development and how to enhance their practicality.

Climate and Environment Division (CBC) Publications

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS (FAO)
WWW.FAO.ORG

ISBN 978-92-5-130504-1 ISSN 2226-6062

9 789251 305041
I9181EN/1/04.18