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MARKET ANALYSIS OF BIOCHAR PRODUCED BY SMALL-SCALE PYROLYSIS UNITS IN VIETNAM

April 2021

Acknowledgments

UNIDO has been supporting the development of small-scale pyrolysis from agro-waste in Vietnam for several years, with the support of the Swiss State Secretariat for Economic Affairs (SECO), in collaboration with technology and manufacturing partners in Europe and Vietnam. In this context, this study analyses the market and demand for biochar from small-scale pyrolysis of agro-waste in Vietnam.

The report was prepared by:

Heloise Buckland, Carolina Rius, Federico Tempestilli, Buysman, E., (HUSK), Nguyen T., (Vietnam Cleaner Production Centre, VNCPC) Truc, N. T, Alessandro Flammini (UNIDO) with inputs from Thi Dieu Linh Hoang, Peter Smalley (UNIDO), Giada Papi (UNIDO), Grishma Jain (Sofies), under the overall supervision of Akos Koszegvary (UNIDO) and the technical supervision of Hannes Zellweger (Sofies)

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Abbreviations and Acronyms

AC	Activated carbon
ACR	America Carbon Registry
ADB	Asian Development Bank
AMAF	ASEAN Ministers Meeting on Agriculture and Forestry
AMS	Approved Methodology for Small-scale CDM project activities
BAU	Business as usual
BIFFA	Binh Dinh Fertilizer and Services
BR	Biennial report
CDM	Clean Development Mechanism
CEC	Cation exchange capacity
CER	Certified Emission Reduction
CIF	Cost, insurance, and freight
COFE	Cambodian Organic Farm Enterprise
CORC	CO_2 Removal Certificate
CSR	Corporate social responsibility
CTC-N	Climate Technology Network and Centre
EBC	European Biochar Certificate
EC	Electrical conductivity
ESCO	Energy Service Company
EU	European Union
FTIR	Fourier Transform Infrared Spectroscopy
GAP	Good Agricultural Practice
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Greenhouse gas
GLASOD	Global Assessment of Human-induced Soil Degradation
GS	Gold Standard
IAE	Institute for Agricultural Environment
IBI	International Biochar Initiative
IPCC	Intergovernmental Panel on Climate Change

LDCs	Least Developed Countries
LPG	Liquified Petroleum Gas
MARD	The Ministry of Agriculture and Rural Development
MBI	Market based instruments
NAMA	Nationally Appropriate Mitigation Action
NC	National communication
NDC	Nationally Determined Contribution
NGOs	Non-Government Organisations
NUE	Nitrogen use efficiency
PAH	Polycyclic aromatic hydrocarbon
PCB	Polychlorinated biphenyl
PCDD	Polychlorinated dibenzo-p-dioxins
PDD	Project design document
PGS	Participatory Guarantee Systems
PMR	Partnership for market readiness
SB	Stabilized biomass
SCC	Social cost of carbon
SDGs	Sustainable Development Goals
SEM	Scanning Electron Microscopy
SNMI	Sustainable Nitrogen Management Index
TGA	Thermogravimetric analysis
TNUS	Thai Nguyen University of Sciences
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organisation
USAID	U.S. Agency for International Development
USDA	U.S. Department of Agriculture
USEPA	U.S Environmental Protection Agency
VAAS	Vietnam Academy of Agriculture Sciences
VBCF	Vietnam Business Challenge Fund
VCM	Voluntary Carbon Market

VNCPC	Vietnam Cleaner Production Centre
VCS	Voluntary Carbon Standard
VER	Voluntary Emission Reductions
VNUA	Vietnam National University of Agriculture
VOC	Volatile Organic Compounds
WASH	Water, Sanitation and Hygiene
WHC	Water Holding Capacity

Executive Summary

Biochar is the highly porous carbonaceous material that is produced when biomass is heated to high temperatures in an oxygen-starved environment using pyrolysis technology. Alongside biochar, this technology also converts the biomass into a source of heat which can be used for drying and a pyroligneous acid liquid known as "wood vinegar". The commercial opportunities for biochar have been analysed in order to better understand the barriers and opportunities to scale the uptake of this technology and the potential of the biochar market in Vietnam.

This report comprises three main parts. The first part is a market analysis undertaken through the lens of four potential commercial pathways for biochar: agriculture, wastewater treatment, activated carbon and carbon markets. These commercial pathways were analysed for Vietnam, neighbouring countries Thailand, Cambodia and Laos and European markets. In the second part, the authors reviewed the biochar policy landscape in Vietnam and in the third part reviewed the status of compliance and certification standards developed to date for biochar.

In terms of commercial viability, the key conclusions from this study are as follows:

- Vietnam is by far the largest potential market in Southeast Asia for biochar –based fertilizers.
- Biochar-based products marketed as organic fertilizers provide the most immediate opportunity in Vietnam, however, adopters of the pyrolysis technology would need to develop marketing capacity in order to penetrate the market for agro-inputs.
- Potential early adopters of small-scale pyrolysis units could be agriculture cooperative that can benefit from the thermal energy along the food processing value chain and their members can use the biochar for their own plots of land or as an additive to feed their cattle.
- Biochar applications as a water filtration medium are still in their infancy however there is potential for growth, particularly for industrial wastewater treatment.
- Given high logistics costs, export is only viable if the biochar is processed to create value-added products in Vietnam.
- While the market for activated carbon is growing in the region, the connections between biochar producers and activated carbon manufacturers have not yet been developed.
- Carbon markets can be accessed once a biochar producer is certified as a carbon sink. Income from this source could be relevant in the business model.

Introduction

Introduction

The following report aims to assess the local market and demand for biochar from small-scale pyrolysis of agro-waste in Vietnam. In particular, this study analyses the potential market for adopters of small-scale pyrolysis systems (able to process between 30-100 kg dry matter per hour, producing 10-30 kg of biochar per hour.) designed to add value to agricultural waste by converting it into three main outputs: heat which can be used for drying agricultural crops such as coffee husk or paddy rice, biochar and a pyroligneous liquid known as wood vinegar which can be commercialised as a natural pesticide.

As one of the outputs of pyrolysis of agro-waste, biochar is gaining traction in several sectors. If investors in small-scale pyrolysis can tap into biochar markets, they will have an economic incentive to adopt the technology more broadly and contribute to more sustainable management of agro-waste in Vietnam and other countries.

The geographical scope of the analysis focuses on three regions, first and foremost Vietnam, the target location of the UNIDO work and the location where the small-scale pyrolysis technology was successfully transferred. Today, these small-scale industrial pyrolysis systems, such as the PPV300[1], are also manufactured in Vietnam. Vietnam is also the country with the most advanced industrial manufacturing sector in the region. A brief analysis is also made for each of the four biochar pathways in neighbouring countries Thailand, Cambodia, and Laos as potential destinations for Vietnam to export their biochar.

Four different pathways have been analysed for biochar, each with varying degrees of maturity and each from the perspective of the production capacity small-scale pyrolysis. The first pathway analysed is that of agricultural applications which range from pure biochar to animal feed in order of economic value. The second pathway is that of water treatment, where the focus is on wastewater treatment using biochar as a means of removing organic and inorganic contaminants from water sources. The third pathway is activated carbon, a value-added product of biochar that has multiple applications in niche markets. The final pathway studied is that of carbon markets, with a consideration of both regulatory and voluntary mechanisms, as a potential source of income for pyrolysis.

A review has also been completed of existing policies on the promotion of biochar application from the public sector as well as relevant projects, studies and research on biochar implemented by NGOs, Universities, the private sector, and other players in Vietnam.

A review of potential opportunities for export to the European Union has been undertaken to assess the willingness of companies in the European Union to import biochar from Vietnam and/or companies willing to invest in co-processing biochar in Vietnam.

Finally, this study considers the feasibility to comply with existing biochar certification schemes for biochar and provide insights and clear recommendations on how to facilitate product standardization.

1 The system has been designed by Oekozentrum in Switzerland. PP refers to the model, V to the country (Vietnam) and 300 to the capacity (30 kg of biochar per hour). A short video on this technology and on UNIDO's past work in Viet Nam in the coffee sector can be seen at https://youtu.be/UQnLd_TGUpk

The analysis was undertaken in three steps:

The first step was a technical review of the technology. The review was carried out during a site visit to a pyrolysis unit manufacturer, Viet Hien Ltd., and the users of the first PPV300 installed in Vietnam, Binh Minh Cooperative in Dak Lak Province. In addition, a review of the second installation of the PPV300 in the region was carried out at the Cambodian Organic Farm Enterprise (COFE), in Phnom Penh. This installation is run by the impact driven business HUSK, registered as a private company in Spain and Cambodia[2]. These visits aimed to validate the production capacity and operational costs of both units in order to offer comparable data from different biomass sources, coffee husk and rice husk.

Desk research was conducted in the second step of the analysis to better understand the parameters of each of the four pathways analysed for the biochar as well as to analyse the results of projects and research already undertaken in Vietnam. Eleven biochar related projects carried out in Vietnam were summarised and the results can be found in Annex 1. In order to give a quantitative aspect to the analysis of the market potential of Vietnam, Thailand, Laos and Cambodia and Europe for Vietnamese biochar for each of the four pathways, a series of key performance indicators were identified.

The final part of the analysis identified and interviewed stakeholders from government, civil society, academic and private sector organisations who have been directly involved in Vietnam's biochar legacy. A selection of individuals from international biochar companies and certifying agencies were also interviewed. A total of 18 interviews were carried out.

2 For more information about HUSK please visit www.huskventures.com and a video of their production unit in Cambodia here. https://www.youtube.com/watch?v=Wnyq9Shbrro

Market Analysis

Chapter 1

Market Analysis

The following section presents four commercial pathways for biochar produced by small scale pyrolysis units in Vietnam, **and specifically the PPV300**. These pathways are agriculture, wastewater treatment, activated carbon and the carbon market. For each pathway, we highlight the most viable applications considering the production capacity and economics of operations of the PP Ökozentrum pyrolysis system.

For the first three pathways, agriculture, water treatment and activated carbon, we describe the potential applications, analyse a series of market demand indicators, and finally identify the opportunities for this pathway in Vietnam, neighbouring countries, and Europe.

In the context of potential export of biochar from Vietnam, the table below outlines an estimate of logistics costs. These calculations show that the density of biochar is key to access to the EU markets. Exports of Vietnamese coffee biochar could match the prices wholesalers accept to pay for unprocessed biochar.

The costs have been calculated considering a shipment in a 40ft container (dimensions: 12,029m x 2,350m x 2,392m [3]) using standard Euro Pallets (dimensions: 1,2m x 0,8m x 0,144m [4]).

Table 1 Logistics cost estimates for export of biochar from Vietnam

	Density (kg/m^3)	Pallets / Container	Kg / Pallet	Kg / Container	Estimated load value[5] (USD)
Rice Husk Biochar	221[6]	20	477	9.540	3.339
Coffee husk Biochar	500[7]	20	1.079	21.580	7.553

Shipment Costs for Coffee Husk Biochar (World Freight Rates, 2019)	
From Da Nang (Vietnam) to Rotterdam (Netherland)	From Da Nang (Vietnam) to Algeciras (Spain)
Cost per container: 3.126 USD - 3.455 USD	Cost per container: 2.618 USD - 2.893 USD
Cost per Tonne CIF Rotterdam: 525 USD	Cost per Tonne CIF[8] Algeciras: 497 USD

3 Containers standard dimensions: https://www.searates.com
4 Euro Pallets standard dimensions: https://www.epal-pallets.org/eu-en/load-carriers/epal-euro-pallet/
5 Estimated price of Biochar: 350 USD / ton
6 European Biochar Certificate
7 Data provided by Binh Minh Coffee Cooperative during field visit in June 2019.
8 Cost, insurance and freight

Shipment Costs for Rice Husk Biochar (World Freight Rates, 2019)	
From Sihanoukville (Cambodia) to Rotterdam (Netherland)	From Sihanoukville (Cambodia) to Algeciras (Spain)
Cost per container: 2.664 USD - 2.944 USD	Cost per container: 2.123 USD - 2.347 USD
Cost per Tonne CIF Rotterdam: 711 USD	Cost per Tonne CIF Algeciras: 650 USD

For the final pathway analysed, carbon markets, we have taken a global approach to the analysis with a review of the existing markets and methodologies followed by a detailed exploration of the different scenarios for coffee husk and rice husk respectively. The conclusions from the market analysis are summarised in the final section on recommendations.

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1.1 Agricultural Applications

International biochar experts Albert Bates and Kathleen Draper estimate that biochar as a soil amendment will only ultimately represent 5% of the global market for biochar in the future (Albert & Kathleen, 2019), however in Vietnam, and Southeast Asia it is still the predominant pathway for biochar. Below we outline the currently available solutions.

Benefits of biochar application as a soil conditioner

Unprocessed biochar applied as a soil amendment for coffee, pepper, and horticulture crops or as a means of restoring degraded land for agricultural purposes.

Technological - No additional processing required for both coffee and rice husks, coffee husks have a significantly higher carbon content (80%) than rice husk; however, rice husk has higher porosity (191m^2/g). High porosity and carbon content of 60-70% are beneficial for the soil (Lehmann, 2007).

Environmental - Benefits around nutrient efficiency, reduced nitrogen leaching, better water retention and improved soil structure are widely documented. In Vietnam, the improvement of degraded soils is perceived as having the most value and this is also becoming an increasing concern in Europe.

Economic - The market price in Vietnam is between 250 - 430 USD / T[9] however farmers also produce their own on a small scale at between 130 - 200 USD / T. Prices are significantly higher in Europe around 600 - 700 USD / T for biochar certified to European standards (The European Biochar Certificate (EBC), 2019).

Social - While there is a general level of awareness that biochar is beneficial for the soil, due to the long-standing tradition of biochar production, there is a lack of knowledge and consensus on the specific applications and impact on different crops of unprocessed biochar for agriculture in Vietnam. Producers have a far clearer understanding of the nutrient values (NPK) of traditional fertilizers whereas the more complex benefits of biochar are less well understood (e.g. water retention & nutrient uptake, increased microbial activity, liming potential, soil structure). Additionally, benefits are not always immediately visible (depending on application), which is also considered a barrier for uptake.

Benefits of biochar use in biofertilizers

A blend of biochar and other nutrients commercialised as a new generation agro-input with benefits of soil conditioning and fertilizer, with biochar content typically making up 20 - 40% of the blend.

Technological - Fertilizer processing installations required with significant infrastructure costs. Currently only a small number of established companies offer biofertilizers with biochar, e.g. BIFFA, Vietgap, Mai Anh Dong Thap (Vietnam), BioAgroChem (produced in Singapore and imported to Cambodia).

Environmental - Additional benefits of increased crop yields due to the "charging" effect of blending the biochar with nutrients.

Economic - The market price of organic fertilizer in Vietnam is between 170 - 200 USD / T which is a challenge to meet with the relatively high production costs of biochar. Prices for organic fertilizers are higher in Cambodia, produced by Green Mountain at 500 USD / T, or imported from Vietnam by Hoanglong Mekong Company, VIP LW ICH St at 400 USD / T. Biofertilizers are a growing and established market in Europe, although subject to stronger regulations from the ministries of agriculture compared to Vietnam.

Social - The reliance and trust in synthetic NPK fertilizers in Vietnam are widespread and there is considerable resistance to changing agricultural practice.

Benefits of use of wood vinegar (a biochar by-product) as a biopesticide (wood vinegar)

Distilled vapours or fractionated volatile gases from the pyrolysis process known as pyroligneous acid can be commercialised as an organic pesticide.

Technological - The PPV300 is considerably more effective at separating the tars from the vinegar than most traditional batch style biochar kilns; the production is 16 litres per tonne with the recommended dilution rates of 1:200.

9 Price information from leading Vietnamese biochar producers Binh Dinh Cooperative, BIFFA, Mai Anh Dong Thap

Environmental - Used as a fertilizer, pesticide, soil improver to combat disease, seed soaker, compost accelerator, preservative, and flavour enhancer. Increases effectiveness of biochar to revitalise soils and increase crops.

Economic - The global market for wood vinegar is expected to grow at a rate of 7% to 2025 (TMR Research, 2018), with government endorsement for wood vinegar in Cambodia and Thailand and growing markets in Australia, New Zealand, and the US (Verdilife, 2019.).

Social - Contains over 200 chemicals including formaldehyde which can be harmful if not administered correctly, dilution rates vary between 1:200 and 1:500. No international regulation or standardization exists for this product.

Benefits of use of biochar as a feed supplement

Biochar used as an additive for cattle and chicken feed to increase weight gain and health and it is being marketed as a supplement to fish feed for similar benefits.

Technological - Pure biochar added as a supplement to feed at approximately 1g per kg of animal weight or 1% of the feed. Growing scientific evidence of health benefits.

Environmental - Benefits include improved pasture quality and reduction in antibiotics and associated wastewater contamination. Livestock accounts for 80% of the global antibiotic market with increased concerns for human health and antibiotic resistance.

Economic - The growing market in Europe with market prices starting at 1.000 USD / T for the biochar feed supplement and higher retail prices for growing niche markets including horses, goats, sheep, and domestic animals. The global animal feed additives market is forecast to reach $30Bn by 2025.

Social - Favourable regulatory climate and growing market in Europe since 2010, not yet permitted in the US and still unknown as a product in SE Asia.

Market demand analysis

The following analysis is based on the market demand indicators as presented in Annex 3, as well as interviews with key stakeholders, and shows three stages of market development.

Application rates of biochar for agriculture vary considerably depending on the crop, existing soil quality and farmers capacity to pay for inputs. Recommendations for applications of biochar for rice range from 2 t to 20 t of biochar per hectare; therefore, neither unit is focussing on this sector at this stage. For horticulture crops, the recommendation of pure biochar application is 1 kg/m2 (i.e. 10 t per hectare), per cycle until production peaks, which will also vary according to crop and existing soil quality and application. In Cambodia, small scale vegetable producers plot sizes may be on average 500 m2 which means that one producer could potentially consume 1.5 t in the first year of application, based on applying 1 kg/m2 for 3 crop cycles. This means one small scale pyrolysis unit could supply around 100 vegetable farmers if applying pure biochar at these rates. To increase the potential impact of one unit, the development of biochar-based products (mixed with other nutrients or organic matter) is key.

Vietnam and Thailand – growing organic sector

A key issue for soil threats in Vietnam is that 75% of agricultural soil in Vietnam is degraded or infertile; 50% low in N, 87% in P, 80% in K, 72% in Ca, 48% in Mg. Moreover, desertification, degradation, contamination, and saltwater intrusion has become more and more serious over the last few years. In this context in both Vietnam and Thailand, there is a growing supply and demand for organic agricultural inputs and mechanisms such as the PGS and GAP certification provide potential market entry points for biochar as a complementary input for sustainable agriculture. Biochar's benefits to agriculture include nutrient efficiency which is particularly relevant for certified organic producers who have to limit their inorganic nitrogen input and the overuse of chemical fertilizers and pesticides is of increasing concern to consumers in Vietnam. As highlighted by indicator 1.1 Thailand has the greatest surface area of certified organic production in the region; however, by the percentage of total Europe far outweighs SE Asia.

In Vietnam, organic fertilizers have a low market price at 170 USD / T which means that it is difficult for biochar producers to compete. However, there is an emerging market of biochar-based products described as ¨biofertilizers¨ in Vietnam. Thailand has a more developed sector for biochar and biochar-based products are available from several online retail platforms. The country also has a considerably larger landmass under organic production. The increasing price of rice husk (at 70 USD / T) with an established market for other uses, such as combustion in rice husk furnaces for paddy drying and industrial biomass plants requiring steam or brick factories, means that it is expensive to make biochar from rice husk. In addition, the abundance of low quality, low-cost rice husk ash from combustion potentially distorts the market as it is sold as ¨biochar¨ at low prices and has an inconsistent and lower impact on yields compared to good quality and low ash content biochar produced from pyrolysis technology. This may have influenced the low level of understanding and trust from producers on the impact of biochar, worsened by the absence of standards and certification.

The Ministry of Agriculture and Rural Development (MARD) in Vietnam has developed policies to promote organic agriculture which will provide a framework for biochar use and increase demand for more sustainable alternatives to peat and sludge as inputs for organic fertilizers (MARD, 2018).

An additional factor for Vietnam, Cambodia and Laos is the increasing pressure from donors and international funding agencies to promote sustainable agriculture, and in particular climate-smart practices to reduce GHG emissions which provides a potential opportunity for biochar producers.

Cambodia and Laos - an opportunity for early adopters

In lower-income countries such as Cambodia and Laos, farmers have less capacity to pay for agricultural inputs. There are fewer competitors for biochar or organic fertilizers, as these tend to be imported at higher prices. In Cambodia, 4 M USD of organic fertilizers were imported into the country with over 50% (2,2 M USD) from the Netherlands (UN Comtrade | International Trade Statistics Database, n.d.).

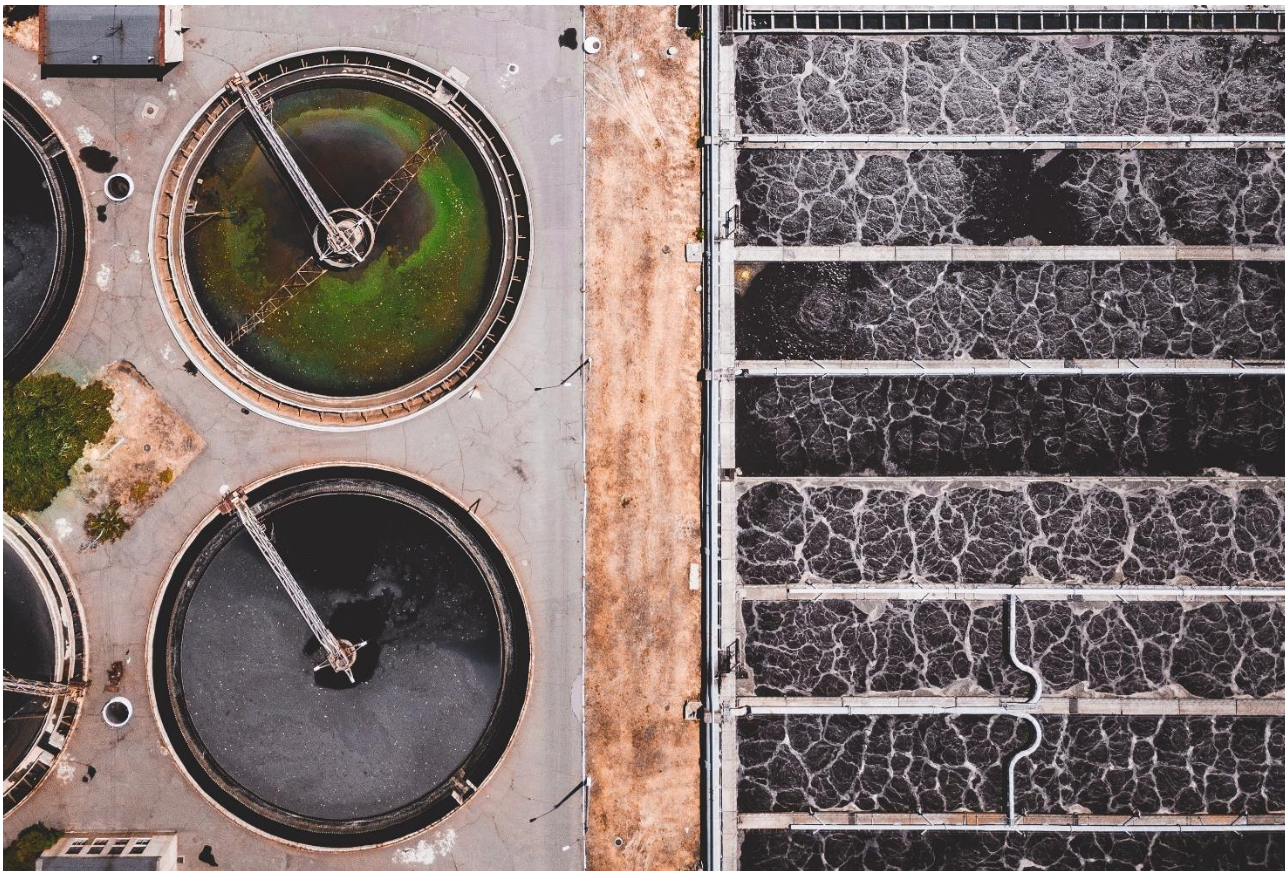
In Cambodia, only 20% of rice husk is used for paddy drying as many mills lack this gasification infrastructure. This means there is a large volume rice husk in the market, and as a result, it has a low value between 20 and 30 USD per ton depending on the season. The main reason this price remains so low compared to other countries is that Cambodia still uses wood as a principal source of fuel for industry. In Vietnam this is not the case, so the price of rice husk has risen to around 70 USD. The low cost of rice husk makes biochar more viable to produce from this biomass in Cambodia.

In both countries, development aid could play a relevant role in promoting low carbon agriculture by providing financial support for early-stage biochar producers and adopters. Significant opportunities exist especially where international NGOs are focussed on improving the horticulture value chains, regenerative agriculture and carbon sequestration projects related to agriculture.

Europe - high competition and quality control

Europe has a sophisticated and highly competitive market for agro-inputs with a large and growing organic sector and an increasing number of biochar producers meeting the voluntary standard, the European Biochar Certificate. The European Biochar Certificate is one of the two globally recognised standards for biochar. The main barrier to exporting biochar to Europe as a basic soil conditioner is the cost of logistics (The European Biochar Certificate (EBC), n.d.). Therefore, if trying to access the European market, it is advised that value-added products such as biofertilizer or animal feed supplements or powdered or pelletized biochar is exported. However, technical barriers to trade may exist for these value-added products as a considerable knowledge of regulations, standards, and trade tariffs[10] is required.

10 In the case of Vietnam, 30th June 2019 FTA was signed between Vietnam and EU where EU will liberalise 71% of its imports from Vietnam from day one and 99% will enter duty-free after seven years.



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1.2 Wastewater Treatment

Based on the research and interviews carried out we consider household water filters, industrial wastewater treatment applications and aquaculture filtration as the most promising applications for biochar.

Benefits of biochar application in household water filters

Household, village, or community level filtration systems using biochar as part of a biofiltration system to capture chemical contaminants in water sources, neutralise odours and improve taste and water quality.

Technological - The most common application is for a series of filters, firstly gravel to remove solid material; secondly, a biologically active sand filter to remove particulates and contaminants; and finally, a biochar layer to adsorb bacteria, contaminants, heavy metals, and chemicals.

Environmental - Significant reduction in toxins, chemical contaminants, most filtration systems focus on pathogens, biochar reduces chemical contaminants, pesticides, pharmaceutical residues, and industrial effluents.

Economic - Households can save money by using biochar filtering instead of buying bottled water and medication for the treatment of diseases from water-borne pathogens. Although some simple, affordable domestic filters exist using a combination of ceramic and biochar, a key barrier to uptake is the cost of distribution to rural communities.

Social - Although biochar can provide an affordable medium for small scale water filtration the sector is underdeveloped with only a handful of players active in this space. In countries such as Cambodia and Laos that still lack drinking water in many rural areas, last-mile distribution is costly.

Benefits of biochar application in industrial wastewater treatment

Biochar as a bio-sorbent and filtration media to treat industrial wastewater through adsorption of a wide range of organic and inorganic pollutants, including agrochemicals and heavy metals.

Technological - Surface area is considered one of the indicators for the effectiveness of water filtration capacity. Prototypes analysed show rice husk biochar having a surface area of 191m2/g and coffee husk biochar 70m2/g, providing a large hydrophobic surface for contaminants. Filtration capacity is estimated at 16,000 times the volume of biochar used in a filter (Schmid, 2019). Activated carbon has a higher surface area, between 600 and 2000m2/g however recent research shows that for certain contaminants biochar can be as effective (Alhashimi et al., 2019)[11].

Environmental - Biochar has a significantly lower energy demand to produce compared to traditional wastewater treatment technologies[12] including activated carbon. Surface adsorption and precipitation with biochar can also mitigate plant uptake of heavy metals including cadmium, lead, copper, zinc, and arsenic. It can also significantly adsorb toxic polyaromatic hydrocarbons and contaminants such as chlorine, chloramines, and VOC from water.

Economic - The adsorption cost of biochar was lower than activated carbon to remove chromium and zinc. Adsorption cost for lead and copper is comparable, and there is evidence that biochar could be at least as effective as activated carbon, and significantly cheaper to produce.

Social - Cadmium, mercury, lead, and arsenic are the heavy metals most harmful to human health and biochar can significantly reduce these from water sources and stabilise them within carbon and magnetized biochar is proven even more effective to immobilize metals (Alhashimi et al., 2019).[13]

11 Alhashimi et al (2019).
12 These include chemical precipitation, ion exchange, chemical oxidation, membrane technology, reverse osmosis, and adsorption by activated carbon, filtration and membrane technology (separation).
13 Alhashimi, H. et al (2019).

Benefits of biochar application in aquaculture water filtration

Used to filter water for fish farming, fishponds, and shrimp farms in combination with sand filters to remove heavy metals and other contaminants.

Technological - Varied levels of application from simple biochar bags soaked in ponds to more sophisticated applications.

Environmental - Biochar has been proven to reduce ammonia, contaminants, and heavy metals in fishpond aquaculture systems.

Economic - Small scale trials in Dak Lak, Vietnam have shown an increase in survival rate for shrimps from 50% to 100% using biochar submerged in bags in the water (Viet Hlen Ltd, 2019).

Social - The adsorption levels of heavy metals in aquaculture can have significant benefits on human health, by avoiding the uptake of heavy metals by the fish organs.

Market demand analysis

Biochar for wastewater treatment is an area of growing potential and the research carried out for this study shows three levels of development across the countries analysed.

Where there are lower levels of access to clean water, we assume a higher demand for affordable domestic and community water filtration systems with potential financial resources for implementation from Water and Sanitation Hygiene focussed NGOs and international development agencies. The data gathered indicates that this could be the case for Cambodia and Laos; however, Thailand and Vietnam have a much higher penetration of drinking water services. In the case of Europe, with near to 100% of the population having access to drinking water, domestic water filtration is not based on the need for drinking water safety but rather aspects of quality and taste.

If there is private sector involvement in water and sanitation it is assumed that there is a higher capacity to pay for urban wastewater treatment plants and potentially a more mature industrial wastewater treatment sector. In countries with larger aquaculture sectors, it is assumed there is a potential market for biochar as a medium for water filtration.

Cambodia and Laos - basic needs unmet

Small scale, household and community level biochar-based water filtration projects offer an affordable solution to many of the rural areas of Cambodia and Laos that lack access to clean water. Both countries have a mature WASH sector with several NGOs and development organisations working towards improving access to clean water and some examples of expertise and training on the use of biochar in this landscape. Hydrologic for example uses rice husk biochar in their clay water filters in Cambodia and Terraclear is a social enterprise offering biofilter solutions at the community level in Laos.

Thailand and Vietnam - more active private sector

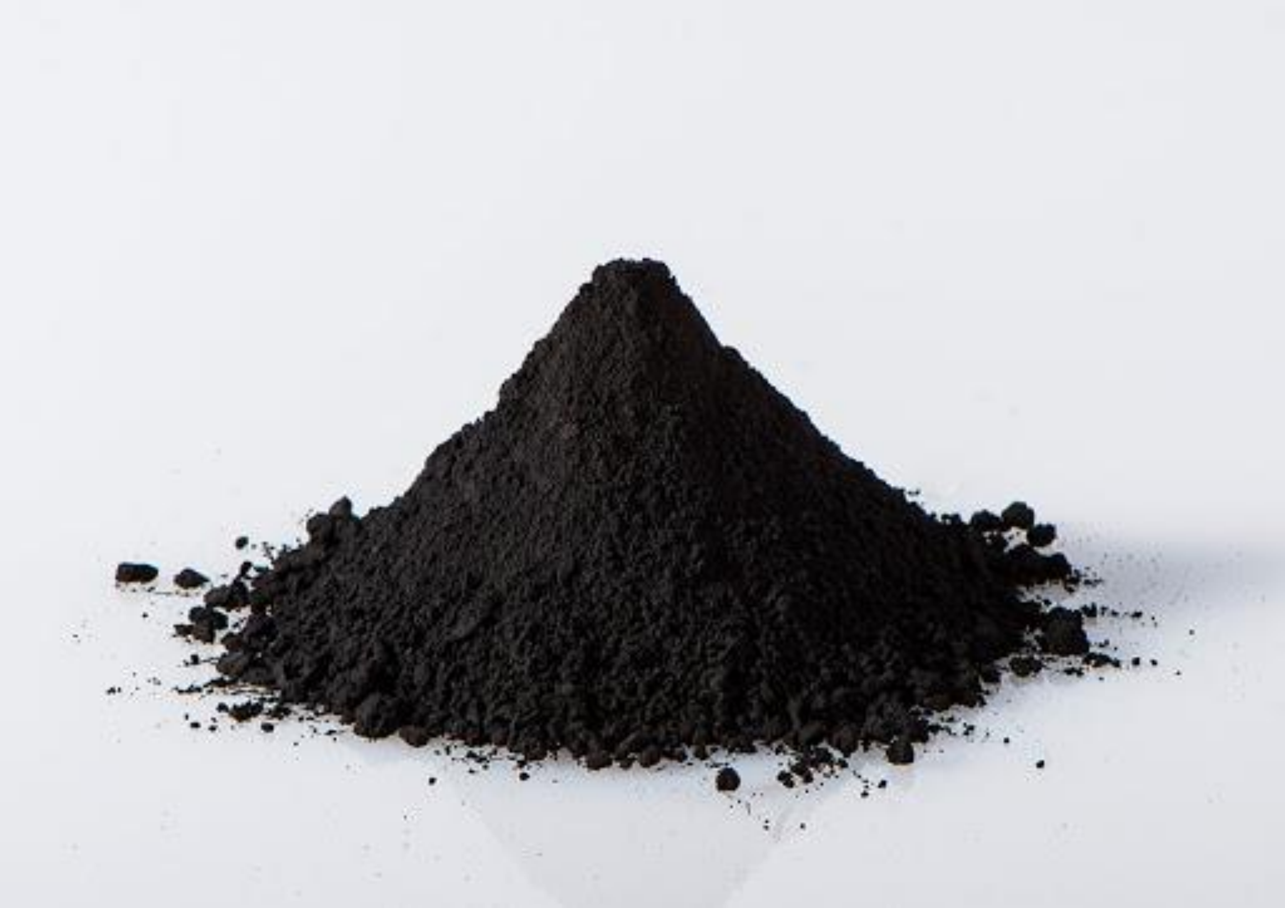
The investment from the private sector is evident in both countries, demonstrating a very different panorama from Cambodia and Laos resulting in far more widespread access to drinking water. For example, Nhat Tinh and Greenerso are examples of enterprises which offer consultation, design treatment facilities and supply biofilters in Vietnam.

While rural households, in general, have far greater access to drinking water than in the urban areas, the challenges are at the industry level where there is a high demand for wastewater treatment, for example from the textile industry which uses harmful chemicals and dyes at washing facilities. There is very limited knowledge of biochar as a potential alternative to activated carbon to treat contaminants from industrial effluents; therefore, further research and development are needed.

Within the industrial sector, as well as eliminating organic and non-organic contaminants from wastewater effluents, water filtration for fish farming is also a market to be explored for biochar. However, biochar in the fish farming industry is still in its infancy and in need of research to compete with the more established market of activated carbon for wastewater treatment.

Europe - biochar vs. activated carbon

Research undertaken to compare the viability of biochar versus active carbon in terms of heavy metal adsorption amongst other parameters is at its most mature in Europe with leading biochar producers investing in research and development in this field. As with agricultural applications exporting biochar in large volumes to Europe for water filtration on industrial purposes could be a significant barrier. While the leading players within the European Biochar community may be researching this field, there are currently very limited collaboration mechanisms between these actors and small-scale biochar producers in Vietnam.



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1.3 Activated Carbon

Application of activated carbon (from biochar) in water filtration

Water filters for domestic and industrial use in reverse osmosis in combination with clay filters and other adsorption filters.

Technological - Sophisticated laboratory processes combine precision heating with the addition of specific chemicals are required to increase the porosity to a minimum of 800 g/m2. While there is a general understanding that activated carbon has a high porosity, there are to date no international industry standards or certification bodies for this.

Environmental - Activated carbon is an established water filtration medium to remove organic and inorganic contaminants, heavy metals, and other pollutants from water.

Economic - The market value for activated carbon is between 10 and 25 USD/kg.

Social - There is a growing body of scientific research about activated carbon; however, no standardised approach yet established across industries.

Application of activated carbon (from biochar) in cosmetics, medicine, and nutraceuticals

Activated carbon is used as a value-added component of several products in the cosmetics industry, particularly toothpaste, face scrubs and creams as well as an emerging sector of health supplement products.

Technological - Sophisticated laboratory processes required to increase porosity to a minimum of 800 g/m2 with even higher porosity required for medicinal applications, and several quality requirements to meet standards for food and cosmetic products.

Environmental - No significant environmental benefit.

Economic - Significant investment required in laboratory equipment to produce activated carbon, market value between 10 and 25 USD/kg.

Social - Significant technical capacity required to develop activated carbon both for domestic and industrial wastewater treatment.

Application of activated carbon (from biochar) in home care and pet care

Activated carbon is used as a value-added component of several products in the homecare sector, including pillows, bedding, and home furnishings as well as pet litters and other accessories.

Technological - Sophisticated laboratory processes required to increase porosity to a minimum of 800 g/m2.

Environmental - No significant environmental benefit.

Economic - Significant investment required in laboratory equipment to produce activated carbon, market value between 10 and 25 USD/kg.

Social - Significant technical capacity required to develop activated carbon both for domestic and industrial wastewater treatment.

Market demand analysis

A series of indicators for the potential market for activated carbon in the target countries is provided in Annex 3. As with the agriculture and water treatment pathways the countries analysed are at different stages of evolution.

Vietnam and Thailand - growing markets

The following table shows details of some of the most common activated carbon products commercialised in Vietnam. Currently, there are only two local producers, and the remaining products are imported. In the case of the cosmetics sector, further analysis was undertaken and can be found in Annex 2. In the case of activated carbon in cosmetics, all of the major brands currently being commercialised in Vietnam are imported from Japan, Korea, Thailand, and Taiwan. In the case of Thailand, the total value of imports of activated carbon products in 2017 was 2,8 million USD.

Table 2 Commercialised activated carbon products in Vietnam

Sector	Product	Producers
Medicine	Surgical face mask with activated carbon filtration[14]	Buben Vn Co., Ltd
		Liworld Co
Cosmetics	The Face Shop Phyto Power in Cleansing Foam – Charcoal[15]	The Faceshop, Korea
	Dabo Charcoal Cleansing Foam (Beauty, 2019)	Dabo, Nexxen, Korea
	LUSH Dark Angels	Lush, United Kingdom
	Pond's Pure White Deep Cleansing Facial Foam	Pond's, America
Air purification	Hapaku Active Carbon Air Purifying Bag 100g[16]	Hapaku, Vietnam
Water filtration	Iodine activated carbon from coconut shell, 500 mg/g, 1200 mg/g[17]	Truc Vang Ltd., Vietnam

While there is a growing demand for activated biochar products in Vietnam, the capital investment costs, and highly trained staff required to set up a professional laboratory to produce activated carbon to the quality expected for the above applications would be prohibitive for an agricultural cooperative. In addition, activated carbon producers in Vietnam prefer to purchase larger pieces of biochar than those produced by the small-scale pyrolyser investigated here, which they later refine to smaller ones, as this allows for a broader product offering (Flammini et al., 2020). However, there may be some scope in linking the producers of biochar as potential suppliers of raw material to the existing activated carbon producers such as Hapaku and Truc Vang.

Cambodia - local charcoal favoured over imported activated carbon

An alternative market entry point for small scale producers of biochar is to offer a product that is similar to activated carbon but has not undergone the chemical processing. This approach for example has been adopted by Khmer Green Charcoal Co. Ltd.18 who sell powdered charcoal from their coconut husk based sustainable charcoal business to Bodia, one of Cambodia's leading natural cosmetic brands. Their product is likely to have similar qualities to powdered biochar from rice husk which has a significantly higher surface area compared to coffee husk biochar. Similarly, Coco Khmer, another

14 Vietnam Factory offer High Quality Washable face mask with Nano Silver Inside, 2019. https://www.alibaba.com/product-detail/Vietnam-Factory-offer-High-Quality-Washable_50033809384.html?spm=a2700.7724857.normalList.67.2b605c52B7psH9.
15 Disposable face mask -active carbon- beautiful life-2. https://www.alibaba.com/product-detail/DISPOSABLE-FACE-MASK-ACTIVE-CARBON-BEAUTIFUL_50023334365.html?spm=a2700.7724857.normalList.1.26101d82UMMW7a
16 Than hoạt tính khử khuẩn không khí Hapaku Active Carbon Air Purifying Bag 100g. https://www.adayroi.com/than-hoat-tinh-khu-khuan-khong-khi-hapaku-active-carbon-air-purifying-bag-100g-p-1316939
17 Truc Vang Ltd., 2019. Price of activated carbon products. https://thanhoattinhtrucvang.com/bang-gia-than-hoat-tinh-truc-vang.html
18 www.kgc-cambodia.com

Cambodian natural cosmetic brand has expressed interest in locally produced powdered biochar as their brand promotes the use of locally produced ingredients, and therefore would consider Cambodian biochar over imported activated carbon.

The market for activated carbon products is at its most mature in Europe and not considered relevant for small scale pyrolysis biochar producers, although it may be interesting to explore Vietnamese activated carbon produced by Vietnamese biochar.

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1.4 Carbon Finance

Carbon finance uses a suite of financial mechanisms such as carbon emission trading schemes and carbon offset programmes to avoid, reduce and sequester greenhouse gases (GHG). For the purpose of this study carbon emission trading is investigated as a potential source of revenue for biochar projects.

Biochar has a high carbon content and given its recalcitrant nature to degradation, can be employed as a method to sequester carbon and reduce GHG emissions in the following ways:

(Thermal) energy recovery: Process heat, gases and oil generated during the pyrolysis process can be used for energy generation purposes, which displaces fossil fuel consumption, thus avoiding emissions.

Carbon sequestration: Biochar can sequester carbon over the long-term and prevents the release of carbon back into the atmosphere in case of decomposition of biomass (Biochar International, 2019.). This includes both CO_2 and methane emissions, as biomass used for biochar production is not left to decompose. Methane emissions have a global warming potential which is much higher than that of CO^2 (21-28 times).

Reduction of soil emissions: Emissions of nitrous dioxide from soils may be reduced through the application of biochar to soils and methane uptake by soils can be enhanced.

Improving fertilizer uptake: Applying biochar to soils can reduce the consumption of conventional fertilizers, including N-based fertilizers produced from fossil fuels. This contributes to carbon dioxide and nitrous dioxide (N_2O) emission reductions.

Reduced methane emissions from livestock: Biochar based animal feed supplements improve the health of the digestive tract of livestock and can therefore reduce methane emissions produced by the animals.

The relative contribution to the overall GHG emissions mitigation of the individual pathways depends on the baseline scenario (the scenario prior to the biochar production), the type of fuels displaced, the biomass employed and the application scenario (soil type, type of chemical fertilizer or contaminant displaced etc.).

1.4.1 Carbon markets for biochar producers

Carbon emission trading occurs in compliance or regulated markets and voluntary markets. Compliance markets are where government regulations require emitters to either reduce their emissions or purchase offsets. Carbon trading enables entities that can reduce emissions at a lower cost to be paid to do so by higher-cost emitters, thus lowering the economic cost of reducing emissions.

For the voluntary market if a biochar project meets certain criteria, the relevant standard will issue carbon offsets equivalent to the emissions reduction's credits traded, known as VERs (Voluntary Emission Reductions), or more commonly known as carbon credits equivalent to 1 ton CO_2 abated or sequestered.

The main buyers for VERs are multinational, private, for profit companies buying these as part of their CSR (Corporate Social Responsibility) agenda (Forest Trends, 2018). VERs are also sold to individuals seeking to reduce their carbon footprint, i.e. from flying.

VERs are traded mainly through environmental consultancies or brokers that help MNCs to calculate, reduce and compensate their carbon footprint. New marketplaces and technology developers are entering in the markets enabling the matchmaking between buyers and sellers i.e. Puro, Patch, Removement, Carbon Future. Since 2018, more operators are positioning themselves in the portfolio creation of VERs from removal technologies which exclude afforestation but promote DACCS (Direct Carbon Capture and Sequestration), BECCS (Bioenergy with Carbon Capture and Storage), and biochar falls within this category.

In 2020, the demand for voluntary carbon removal credits has overcome the supply, thus increasing the competition between intermediaries to gain access to a long-term portfolio. There has also been considerable visibility for biochar-based carbon removal credits due to Microsoft's recent purchase of credits through three different biochar projects as part of their overall carbon removal strategy[19] as well as Shopify portfolio creation of biomass related carbon credits.

19 Microsoft buys 1.3 million carbon offsets in 2021 portfolio, (Source: SP Global)

Access to market

Biochar producers must meet **the requirements of each marketplace** to distribute VERs through their channel.

In 2020, most of the marketplaces trading VERs from biochar producers **recognized EBC- C-Sink standard** and only required this standard to showcase a particular carbon removal project. This is the case for example for Removement, Patch and MyCarbonZero. Other trading platforms require additional information or technical specifications to become eligible. Puro, the Finnish marketplace which pioneered in showcasing biochar projects only trades VERs from biochar producers that do not use fossil fuels for heating the reactor and 70% of waste heat produced by pyrolysis must be used for units producing more than 50 ton annually.

Standards- Compliance

Since in 2018, the IPCC recognized biochar as one of the top five carbon removal technologies with most capacity for scale the reduction and avoidance of GHG, the sector has seen a lot of development including a number of marketplaces and new standards being developed.

The **IPCC Guidelines** were developed for national GHG inventory reporting. Parties included in Annex I (industrialized countries) to the United Nations Framework Convention on Climate Change (UNFCCC) are required to report on their inventory every 4 years (so-called National Communications, NC), and a biennial report (BR) on progress in achieving emission reductions. Non-Annex I parties, or developing countries, are also required to submit an NC every 4 years and a BR on a biennial interval unless they are classified as LDC, in which case it can be submitted at their own discretion.

The 2019 refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories includes for the first time a method to estimate carbon sequestration from biochar application to the soil. Method for Estimating the Change in Mineral Soil Organic Carbon Stocks from Biochar Amendments: Basis for Future Methodological Development. This refinement to the 2006 IPCC guideline was accepted on 12 May 2019 at the 49th session of the IPCC. The biochar method may be subject to final copy-edit and layout changes but it with the acceptance of the refinement the technical approach of the method is also approved.

Although it is generally accepted that biochar has a long soil residence time, there will still be some carbon that will not remain fixed over the period typically considered for GHG emission reduction calculations: 100 years. The IPCC estimates that depending on the production process, between 65% to 89% of the C remains in the soil after 100 years (IPCC, 2019b). Biochar may therefore not be considered as Stabilized Biomass (SB)[20], that is biomass recalcitrant to further degradation by the carbon standard bodies. If that is the case, then emissions from biochar need to be considered, for which there is no approved methodological guidance. This may render the project ineligible for carbon finance mechanisms. Gaast and Spijker (2013) however argue that the methodologies have acknowledged the role of SB and that it is quite similar to biochar. This potential issue needs more research and direct discussions with the carbon standard bodies are necessary for that.

20 Stabilized biomass (SB) is defined as biomass adequately treated to prevent further degradation in the environment. Examples of SB are: pellets, briquettes and torrified wood chips (Source: CDM methodologies AMS-III.E and AMS-III.L

Although the current biochar standards for carbon removal are in their infancy, in 2020, EBC- C-Sink was already widely recognised by marketplaces.

The European Biochar Certificate (EBC) In 2019 the EBC developed the first methodology and standard to specifically certify biochar as a carbon sink. The EBC C-sink is currently the most rigorous standard available for carbon sinks based on the carbon-preserving applications of biochar. The EBC provides a platform for verifying and certifying that C-sink credits are real, measurable, unique, and independently verified according to the guidelines defined in the EBC C-sink standard.

A new accounting methodology is being developed for biochar by Verra under **their Verified Carbon Standard (VCS)** programme, which is the largest voluntary programme for the reduction or avoidance of greenhouse gases with over 1.500 projects certified in 80 countries. The new Verra biochar standard should be completed by the end of 2021 and will include a methodology available for biochar producers to use within the VCS programme. A consortium of organisations has been selected to develop the methodology including South Pole and Biocharworks and there is an ongoing consultation process to involve key stakeholders, including HUSK in the process.

Other key requirements

Almost all of the above standards require projects to develop a project design document (PDD) which is submitted to third party validation and verification to ensure that project has achieved their stated emission reductions. Verification typically occurs on an annual basis, and entails monitoring of the performance of the project/technology, development of a standardized monitoring report and third-party verification. Other key aspects are:

- Additionality: Projects have to demonstrate that they are additional to the business as usual (BAU) scenario such that the project would not have occurred in the absence of the revenue generated by selling a carbon removal credit.
- Third-party auditing: All carbon projects are subject to desk and field audits by qualified recognized independent third parties and staff of the standard to ensure that rules and procedures of the applied carbon standard are met, and methodologies are properly applied.
- Accounting methodologies: Projects are assessed using approved GHG emission reduction quantification methodology specific to that project type.

Carbon credit value of 1 Tn of biochar produced with PPV300

The PPV300 operated by HUSK in Cambodia removes 1.75 tonnes (Tn) of carbon from the atmosphere for every Tn of biochar produced and HUSK is the first biochar company outside the EU and US to be certified as a Carbon Sink by the European Biochar Certificate (EBC). The carbon sink capacity is calculated as below.

Burning 1 Tn of carbon produces 3.66 Tn of CO_2 and HUSK Biochar contains 48% carbon so for every Tn of biochar we remove 1.76 Tn of CO_2 equivalent from the atmosphere. However, the production of 1 Tn of biochar (dry matter) generates emissions of 10 kg CO_2 due to the small amount of electricity and starter fuel used in the operation of the pyrolysis plant. These emissions are deduced from the carbon sink value of the biochar. The CO_2 emissions of the combustion of the pyrolysis gases used for energy production are considered as carbon neutral as the feedstock for the pyrolysis originated from harvest residues. This means the net carbon removal capacity for every Tn of biochar is 1.75 tonnes of CO_2 equivalent.

Table 3 Carbon Sink Potential calculation

CO_2 mass to C mass ratio, i.e. amount of CO_2 produced from burning 1 tn of Carbon	3.66
Carbon content of HUSK Biochar	48%
CO_2eq-content per t of biochar (dry matter) [gross C-sink] (3.66 x 48%)	1.76 t CO_2eq
Total GHG emissions per t biochar (dry matter)	0.01 ton
C-sink potential in tCO_2eq per t of biochar (dry matter) [net C-sink]	1.75 t CO_2eq

Market Price

The potential income for biochar companies to market their capacity to sequester carbon by selling Carbon Removal Credits has seen a sharp increase since early 2019. When the first Puro platform auction was carried out in late 2019 and the average price was c. 25€. Puro in 2021 is now selling credits at 100€ to 150€ and other platforms are trading around 100€. The assumption is that the price will change over time depending on supply and demand for credits, however given the time needed to establish new biochar operations it is likely that there will be a period whereby demand continues to outstrip supply and the market price is either sustained or increases as biochar awareness increases.

Once the Verra standard is operational in 2021 there is likely to be a boost in the supply of certified projects as this platform has a global reach and many years of experience in the market, this could affect global prices. Another factor to consider around price is the value associated with the co-benefits that carbon removal from biochar generates. In the case of HUSK the additional value of soil regeneration and livelihood improvement increases the value of the carbon removal credits.

Biochar Policy Landscape in Vietnam

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Chapter 2

Biochar Policy Landscape in Vietnam

2.1 Biochar Projects and Research Activity

Several players from the research community, private sector, international and local NGOs have been experimenting with biochar projects in Vietnam over the last 20 years. To date, most activity has been undertaken in the agriculture sector. Activities in water filtration applications and activated carbon are emerging and these are currently very limited work on carbon sequestration.

In the agriculture sector the results of the projects and research to date has been focussed on the composition of different types of biochar (mainly coffee husks, rice husk and rice straw), with very limited rigorous trials on the effects of biochar on crop yields, with the exception of coffee and pepper, both showing positive results.

Key players in the research field are ADB (2016), FIBL, Soils and Fertilizer Research Institute and the Vietnam Academy of Agriculture Sciences, Thai Nguyen University of Sciences, Thai Nguyen University. Biochar use for sustainable soils research has been carried which has been focused on the barriers for uptake of biochar by smallholders. The research concluded that farmers are resistant to use biochar as the impact may not be observed in the short-term. The research further illustrated that there was a lack of technology to produce high quality biochar consistently and at a reasonable price. There are three active commercial biochar producers in Vietnam, Binh Dinh Fertilizer and Services, (BIFFA) and Mai Anh Ltd and Vinatap presented in the table below.

Table 4 Active commercial biochar producers in Vietnam

Company	Production capacity	Price of products
Binh Dinh Fertilizer and Services (BIFFA)	Uses 100 kg/hour batch system to produce biochar, using coffee husks and other inputs sourced from farmers cooperatives. Produces 6,000 T of biofertilizers p.a. (20-30% biochar).	Biochar: 260 USD/T Organic fertilizer: 130 USD/T *wholesale prices
Vinatap	Developed their own kiln technology with a conversion rate (26%) and the capacity to produce 1,000 per year. 90% of their biochar is used for their own organic fertilizers. Previously exported to Japan.	Biochar: 520 USD/Tn* Organic fertilizer: 110-330 USD/T *retail price
Mai Anh Company	Used to make pellets and briquettes from rice husk and now moving towards biochar for agricultural inputs. Now using Japanese biochar technology and received research support from the Ministry of Science and Technology to improve the production cess.	Biochar: 430 USD/Tn* *price sold for research purposes to Can Tho University. Wholesale prices not disclosed.

The capacity of biochar to filter water has been identified with experiments by Can Tho University in fish farming undertaken to reduce effects of fenobucarb on enzyme cholinesterase extracted from climbing perch. There is no evidence of these results translating into commercial operation.

The Physical Chemistry Department at Hanoi University of Education undertook research to show that activated carbon obtained from rice husk by NaOH activation at 800oC may be a suitable candidate for application as supercapacitor electrode material. The School of Materials Science and Engineering, Hanoi University of Science and Technology has undertaken a research study on silica separation in the production of activated carbon from rice husk in Vietnam, given that the presence of silica in the charcoal does not allow for the formation of activated carbon with a high purity. The conclusions showed that the efficiency of the process was greater with increasing temperatures up to 133°C, however, commercial viability was not studied.

Annex 1 shows details of eleven projects carried out to date from which these observations have been drawn.

2.2 Biochar Regulatory Framework Legacy

The public and donor-funded policies and programmes which support biochar in Vietnam to date are focussed mainly on the agriculture pathway, primarily to reduce greenhouse gas emissions and adopt biochar as part of a wider sustainable agriculture agenda. The Ministry of Agriculture and Rural Development (MARD) has adopted recent priorities targeted at scaling up agricultural waste management which refers to biochar. Policies implemented to date but are not exclusive of MARD and the Green Growth of Agriculture to 2020 which also mentions biochar involves a considerable number of other public bodies. Since 2017 the government has also had a policy to promote the development of organic fertilizers.

Vietnam's Nationally Determined Contribution (NDC) (2015)

Vietnam's Nationally Determined Contribution (NDC) report, which was submitted to the UNFCCC in September 2015 proposed various measures to reduce GHG emissions and promote climate change adaptation. One of the measures included is the development of sustainable agriculture. A sub-measure identified is "biochar application" highlighted as a means to turn waste into a valuable soil amendment which not only sequesters carbon and improves yields it also reduces the release of other climate-damaging pollutants such as methane and nitrous dioxide from the soil.[21]

Action plan to respond to climate change in agriculture and rural development (2016-2020)

To respond to climate change, the Decision **No. 819/QD-BNN-KHCN on 14/3/2016 from the Ministry of Agriculture and Rural Development** specifies missions to reduce greenhouse gases emissions through the demonstration and scaling up models of agricultural waste collection. This could be achieved with pyrolysis technology to convert biomass (rice straw, corn cob, bagasse, coffee husk, cassava cover, etc.) to produce organic fertilizer, biochar, husbandry food, etc. to reduce environmental pollution and greenhouse gas emissions. This decision includes a vision for 2050.

Green Growth of Agriculture to 2020, Ministry of Agriculture (2017)

The Decision No. 923/QD-BNN-KH dated on 24th March 2017 on approval of Green Growth of the agricultural sector to 2020 specifies that the following projects and programs will be supported: reuse and recycle agricultural waste to produce food for husbandry, mushroom, industrial material, biogas, **biochar**, organic fertilizer in order to develop an agriculture waste recycling industry, improve production value and reduce waste, treat, and reuse sludge in aquaculture. These supporting will be carried out in 2017-2020 period.

The leading agencies for this program include General Department of Forestry, General Department of Fisheries, Department of Crop Production, Department of Livestock Production. The Department of Crop production will be in charge of supporting biochar production. Results on biochar specific projects are not yet available.

In addition, a number of agencies with the role of collaboration will be relevant to biochar production, including Planning Department, Finance Department, Department of International Cooperation (of

21 https://www.jica.go.jp/project/vietnam/036/news/ku57pq00002j69mm-att/20160927_02_02.pdf

MARD), National Agricultural Extension Center, Vietnam Academy of Agricultural Sciences, Institute of Animal Husbandry, Institute of Strategic Policy, Department of Agriculture and Rural Development

The Decision also stipulates the Department of Crop Production and Department of Livestock Production will be responsible for compiling and issuing policies to promote the recycling of agricultural waste (including biochar production).[22]

Approval of the amendment of investment decision of biochar production project for a clean, organic, environmentally friendly agricultural sector (2017)

The decision No. 719/QD-UBND dated on 28/7/2017 on to support biochar production and its application in organic agricultural experiment site of Ky Quang, a private limited company was made by the Ministry of Agriculture and Rural Development. This project has been implemented in two periods. The first one is from 1st quarter of 2017 to 2nd quarter of 2020 providing 3000 tons of biochar per year; the second phase is from the 3rd quarter of 2020, providing 10,000 tons of biochar per year for experimentation on baby cucumber production. The biochar production site will be constructed in Kon Gung and experimental site at hamlet 2, Dak Mar commune, Dak Ha district, Kon Tum province.

Policy on organic fertilizer (2017)

In 2013, the Government issued the Decision No. 210/2013/ND-CP on fertilizer management, but the application of this Decision met difficulties, especially the separation of management rights between the Ministry of Industry and Trade and the Ministry of Agriculture and Rural Development. In order to innovate on fertilizer management, the Government replaced Decision No. 210 with Decision No. 108/2017/ND-CP issued on 20/9/2017. It stipulates that the organic fertilizers produced by individuals or organizations but not used for commercial purpose will not be considered under this Decision. The article No. 5 mentioned:

- The Government has a policy on credit, tax and land budget for research, technology transfer, production and use of organic fertilizer which includes the following:
- Promotion of advanced technologies for the production of new-generation fertilizer to improve the quality and efficiency of fertilizer.
- Investment to increase capacity in testing and appraising for research, inspection, and supervision of fertilizer quality.
- Encourage socialization of public service in the fertilizer sector.

Therefore, policy on production and use of organic fertilizer, including biochar has been defined as the top priority in the Government's policies on fertilizer, reflecting the strategy of the Government in promoting organic and clean agriculture development.

22https://thuvienphapluat.vn/van-ban/Linh-vuc-khac/Quyet-dinh-923-QD-BNN-KH-duyet-Ke-hoach-hanh-dong-tang-truong-xanh-den-2020-2017-346546.aspx

2.3 Policy Barriers and Opportunities

The following section summarises the barriers and opportunities for each of the pathways analysed in the context of public policy frameworks for each.

Agriculture pathway

Policy: To date, the Government of Vietnam have not created a legal framework specifically for biochar or biochar production. Biochar is included in policies and regulations related to organic fertilizer and organic agriculture.

Development of organic agriculture is a trend in restructuring the agricultural sector of Vietnam. This creates an opportunity for development of organic fertilizer, necessary material for production of organic. Particularly the Decree No. 109/2018/ND-CP dated on 29th August 2018, on Organic Agriculture issued by the Government specifies that projects/programs on organic fertilizer (biochar in particular) will be financially prioritized; small-scaled enterprises, cooperatives, farms, households who producing organic products will be cover the cost of determining organic production locations; cover the cost of granting certification of organic products; supporting for training and educating organic farming, scaling up organic models, etc.

For the first time, Vietnam issued a series of National Standards (TCVN) on organic agriculture. It took effect on 29/12/2017. This includes regulation of fertilizer management such as the organic agriculture only uses natural mineral fertilizer and uses biological measures to increase the fertility of soil such as manure or compost; Organic agriculture will not use inorganic fertilizer (NPK), or dissolved fertilizer (superphosphate).

Vietnam has not applied subsidies for chemical fertilizer as other countries (India, Indonesia), however, the policy on intensive farming has facilitated the use of chemical fertilizer leading to over-use of chemical fertilizer causing high levels of contamination to water and soils.

Barriers: Although Vietnam issued the series of National Standards (TCVN) on organic agriculture the country still lacks legal documents and policies to promote the development of organic agriculture while other countries have issued more binding regulation on organic agriculture.

There is an overlap in responsibilities and difficulty in coordination between ministries: Ministry of Agriculture and Rural Development, Ministry of Industry and Trade, Ministry of Natural Resources and Environment, local Authorities on fertilizer management.

Limited awareness of farmers, agricultural promoting staff and managers on the important role of organic fertilizer for sustainable agriculture and national food security

The price of biochar would be the most challenge for commercializing biochar in the agriculture sector in Vietnam. The price of other kinds of fertilizer (organic fertilizer imported or produced by Biffa) is relatively low, around 3 million VND per ton (130 USD) to compare with only biochar produced from Viet Hien, about 8 million VND per ton (348 USD). The reasons for the high cost of biochar production are low production capacity and high cost of input material (for example rice husk). Therefore, Biochar produced from small-scale pyrolysis can only have its own market if it clearly proves the effects on crop yields at an acceptable price.

Proving the effect on crop yields is also a significant barrier, especially at large scale. Although there have been several research projects undertaken on biochar application on different crops, these have not been conclusive, and the results have not been communicated effectively to promote uptake.

Opportunity: Currently, the demand for organic products for domestic consumers and for export is increasing. The production of organic fertilizer using biochar will open a market to meet this demand in the future. Biochar applications with high potential are being tested in organic agriculture include organic vegetable farms, cantaloupe farms, and grape growers. Applications for biochar for the orchid and bonsai sector are also being tested.

Waste management in animal husbandry, especially at medium and large-scale production is a problem. Currently, many farms are applying a biogas model to manage the waste and utilize biogas as fuel. However, this model is causing negative impacts such as: overload of biogas tanks leading to overflow of husbandry waste; burning or discharging abundant biogas to prevent overload, leading to greenhouse gas emissions; no policy on electricity tariff generated from biogas to encourage husbandry farms to use abundant biogas for electricity generation and trading. It creates an opportunity to utilize the waste of these farms and combine with biochar to produce organic fertilizer, at the same time improve the environment at husbandry farms, thanks to the smell absorption and water retention capacity of biochar.

Biochar application for water filtration

Policy: There is currently no policy framework for biochar application in water filtration.

Barrier: Biochar application in water filtration is currently only at the research or demonstration level.

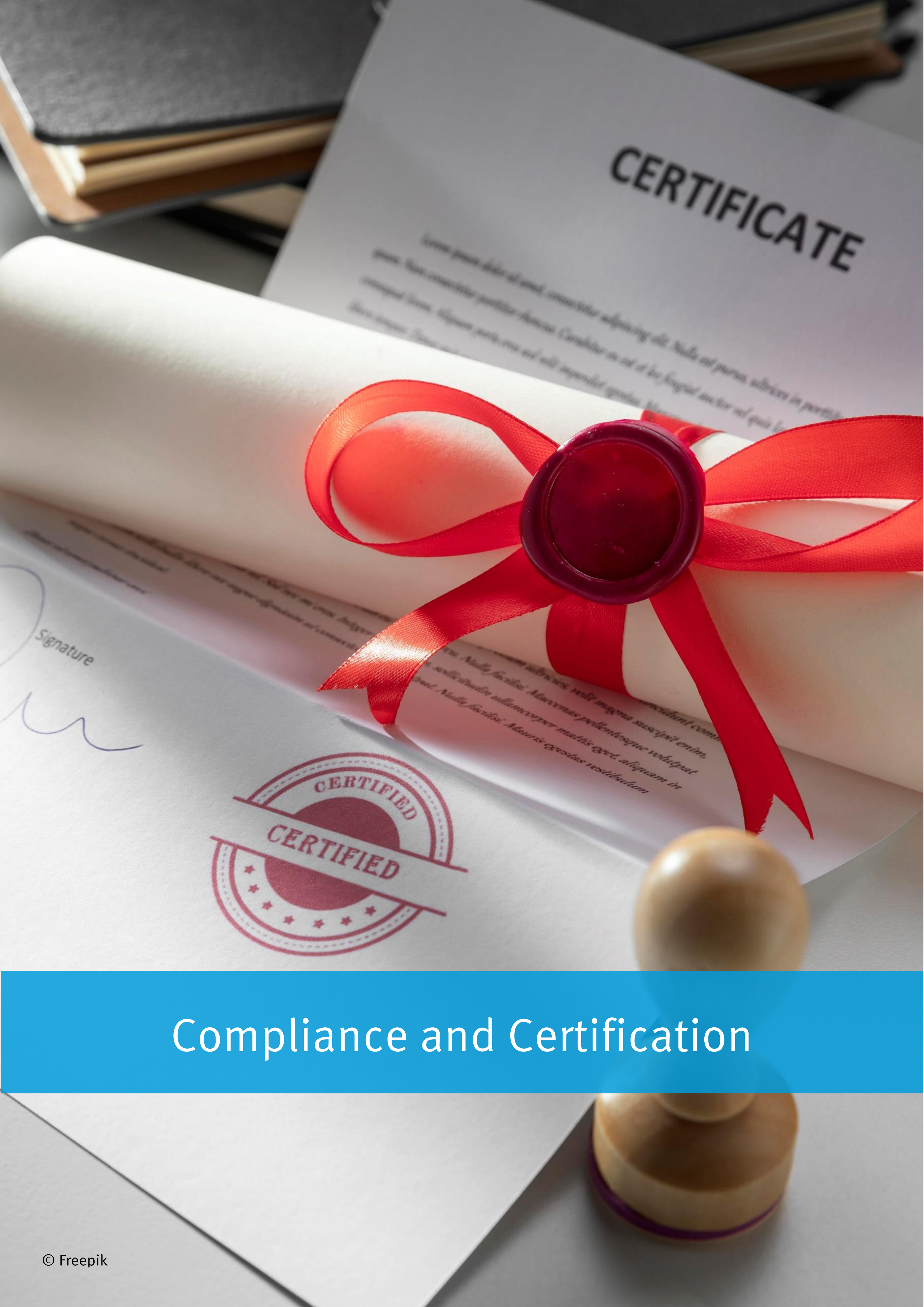
Opportunity: Biochar produced by the pyrolysis technology employed by Viet Hien company has been tested in a shrimp farm in Phan Rang, Ninh Thuan province. The initial results are positive with application of biochar in water filtration for a shrimp farm for a month. The farm had 100 tanks with 1-1.2 million shrimps per tank. Seawater pumped from the sea. However, some moments during the year the input seawater is not enough safety for shrimp farming. It contains toxic substances caused by “fire” jellyfish. By using biochar in water filtration system with sand, the survival rate of shrimp increased from 50% to 100%. Therefore, there is a potential market for development of biochar in this field.

Another application of biochar for water filtration such as methylene blue adsorption in colour treatment of textile industry; or the reduction of the effect of fenobucarb (toxic substances contained in pesticide) on brain cholinesterase (a kind of enzyme). However, these studies are at research level and have not applied outside the lab.

Policy: No policy for production of activated carbon from biochar.

Barrier: The activated carbon technology from biochar using the small-scale industrial pyrolysis technology investigated here leads to prohibitively high production costs, making simpler and cheaper technologies, such as carbonization of the biomass in a barrel, more attractive for activated carbon producers (Flammini et al. 2020).

Opportunity: With appropriate technology to produce activated carbon from biochar with low cost, it can create a potential market for biochar for this field since activated carbon has been currently applied for various fields: Medical (disinfection and detoxification); chemical (catalyst and loading substance for catalyst); technique (gas filtration, odour absorption); environmental treatment (domestic water filtration, treatment of gas and wastewater)



Compliance and Certification

Chapter 3

Compliance and Certification

3.1 Certification and Labelling

There are two main international certification systems for Biochar, the International Biochar Initiative (IBI) which operates from the US and the European Biochar Certificate (EBC). Both organisations have been collaborating with each other since they began certifying biochar in 2012 and largely use the same requirements for their standards. Common parameters that both certifications require fall into three categories with some minor variations.

Basic utility properties: Molecular H/C ratio, Ash content, Electrical conductivity, pH, Water content, particle size, bulk density, liming equivalence

Soil enhancing properties: Macronutrients (NPK), surface area, volatile matter

Toxic substances: Heavy Metals, PAH, PCBs and PCDDs

In July 2019 EBC changed their internal procedures to allow for non-EU produced biochar to be certified in the framework of their new certification for processed biochar products. IBI only enables US produced biochar to be certified.

Table 5 Key features of IBI and EBC Certification

IBI	Cost (USD)	Certification procedure	Carbon Content
IBI	500	Self-declaration with signed laboratory tests of samples of biochar with annual review	Class 1: ≥60% Class 2: ≥30% and <60% Class 3: ≥10% and <30%
EBC	1.580 audit* 836 lab test Does not include travel from Europe	On site audit of biochar production and laboratory tests of products Annual revision as above	Biochar ≥ 50% Pyrolytic carbon material ≲ 50%

The choice of certification will depend on the target market for biochar products. If the products are targeted at European clients EBC is the most obvious choice and the parameters are in line with recently adopted European regulations for organic fertilizers which since 2020 recognise biochar as organic soil amendment (EU Regulation (EC) No 889/2008 ANNEX I). Biochar for organic farming in the EU must meet the following requirements:

- Only from plant materials.
- Maximum value of 4 mg polycyclic aromatic hydrocarbons (PAHs) per kg dry matter. This value shall be reviewed every second year, considering the risk of accumulation due to multiple applications.

While IBI certification is not available for biochar producers outside the US and EBC is costly to achieve given the need to cover travel costs for an auditor from Europe, what is useful at this stage is to test biochar using the parameters set by these certifications to start building a common understanding of the key criteria for defining quality biochar. Two key parameters are the minimum threshold of PAH (polycyclic aromatic hydrocarbons at 12 mg/kg), and carbon content. This initial test is available in Eurofins Germany and cost less than 300 USD.

Samples of both rice husk biochar produced by the PPV300 have already undergone the successful test of full EBC parameters so this could provide a potential competitive edge against other Vietnamese biochar producers, who have not yet met these parameters.

3.2 Product Standardization

One of the challenges observed for broader uptake of biochar in the agriculture sector has been the lack of standardization of pure biochar and biochar-based products, such as biofertilizers. The lack of an established consensus on the impact of biochar on yields and other factors that influence the economics of using biochar, including water retention, nutrient uptake and pest resistance is also a limiting factor that has been considered a barrier for uptake. Finally, the challenge of meeting international standards was identified for one Vietnamese biochar producer that exports to Japan.

Opportunities for product standardization

Within Vietnam, the recognition of biochar as part of the Green Growth of the Agriculture Sector to 2020 from the Ministry of Agriculture is an opportunity to develop a process of standardization across the sector. Given the low levels of consumer awareness of the benefits of biochar and the lack of standardization and quality control there is a limited trust in biochar as a product. The development of basic standards and common parameters could help overcome this issue.

Carbon content and PAH testing

A potential area for development that would favour the development of the PPV300, and similar technologies is to support the development of a testing procedure for certified laboratories to measure the key parameters for biochar quality, including the levels of polyaromatic hydrocarbons (PAH). This would be a way of starting to develop some basic minimum industry standards.

PGS and GAP systems

A second area for development is connected to the growing movement of organisations certifying and promoting natural and sustainable agriculture practices, such as the GAP and PGS systems, both of which are prevalent in Vietnam. The inclusion of biochar as a recognised sustainable agricultural input for these systems would be a means of raising awareness of the product amongst early adopters of sustainable agriculture practice.

Organic certification

Organic certification is another potential mechanism to build trust in the effectiveness and quality of biochar products. However, the main European and US organic certification systems that are adopted in SE Asia, EcoCert and USDA Organic certification are largely focussed on products for export to these global regions, and there is very little consumer awareness of these standards in Vietnam.

At the regional level there is an organic standard that has been adopted by the ASEAN Ministers Meeting on Agriculture and Forestry (AMAF) that includes the post-harvest technologies and could be an opportunity for further exploration.

Annexes

Annex 1

Biochar Projects in Vietnam

Table 6 Application of biochar in Binh Minh Cooperative, Dak Lak Province

Title	Application of biochar produced by pyrolysis technology as a soil enhancer for pepper in Binh Minh cooperative.
Pathway	Agriculture
Summary	Binh Minh cooperative is a coffee cooperative with 27 official members and 118 linked members with an area of coffee plantation of 103 and 412 ha respectively. It is the first pilot in Vietnam using the pyrolysis system manufactured by Viet Hien Ltd. The system is used to dry the wet coffee husk and produce biochar on the coffee plantation.
Organization (s)	Binh Minh Agricultural service Cooperative: Village 3, Cusue commune, Cu M'gar District, Dak lak Province
Date	Installation in December 2016. Activity is ongoing
Key findings	Trials of 2-2.5kg biochar per tree were carried out on 1500m^2 of coffee in 2017 and 2018 and showed higher survival rate and stable productivity. The biochar application on vegetable also showed positive results: with better aspects, higher productivity and fewer insects and snails. Biochar shows its effectiveness as water and nutrition absorption. A challenge for developing biochar market to apply for agriculture in Vietnam is that: the result of this application is not obvious enough to convince farmers. Besides, the price of biochar produced by the pyrolysis is a bit high, around 6,000-10,000 VND (0.26-0.44 USD) per kg also a challenge for application of biochar into plants such as pepper or coffee, especially in the context of the low market price.
Contact details	Ms. Trieu Thi Chau – Director of Binh Minh Cooperative Mobile: 0395436493
Website	NA

Table 7 Biochar research by the Swiss Institute of Organic Agriculture (FiBL)

Title	Recommendations for application of coffee pulp biochar in Vietnamese coffee plantations.
Pathway	Agriculture
Summary	This project aimed to evaluate the best use of coffee pulp biochar for coffee farming systems. The pyrolysis-produced biochar was mixed into coffee plantation soil (in Buon Ma Thuot, Daklak province) at different rates and then incubated at 20°C for 10 days to test pH and water holding capacity (WHC). The experimental results indicate that biochar could work as a soil pH conditioner and improve soil WHC. This biochar can also be used as a substitute of potassium (K) fertilizer, transformed into a biochar NK fertilizer, or employed as a soil conditioner to new coffee plantations.

Organization (s)	FiBL Suisse (Research Institute of Organic Agriculture), Ackerstrasse, CH-5070 Frick, Switzerland
Date	2017
Key findings	Biochar is effective for coffee plantations in Buon Ma Thuot region. Continued application has the potential to improve soil pH, WHC and nutrient availability. This can reduce nutrient leaching and thus less nutrient demand during the rainy season and reducing drought stress in dry season. Risks of biochar applications are low with negative effects only anticipated with applications greater than 50 ton per hectare Biochar sorption capacity can reduce nutrient availability therefore it is strongly recommended to mix biochar with liquid N fertilizer such as human/livestock urine or slurry, or co-composting before adding to the field and good monitoring of nutrient balances is needed to avoid over fertilization of the coffee plantations.
Contact details	Michael Scheifele, Andreas Gattinger, +41 (0)62 865 72 72, info.suisse@fibl.org
Website	www.fibl.org

Table 8 Biochar project of Ecofarm using Pyrocal technology

Title	Production of bio-fertilizers, a mix of biochar with compost and enriched with microbes, for the cultivation of organic crops.
Pathway	Agriculture
Summary	Biochar was produced via BiGchar2200 technology (manufactured by Green Pty Ltd, Queensland, Australia) from rice husk and corn cobs and stalks. The output biochar is rich in carbon content, up to 30% and retains most of the nutrients. The heat after combustion was used for drying biomass. This project was funded by Vietnam Business Challenge Fund (VBCF).
Organization (s)	Ecofarm joint stock company, Phu Quoc, Kien Giang province or At Duc Hoa district in Long An province.
Date	2013 – 2015
Key findings	In 2014, the biochar capacity reached 1000 tons/year, and used to serve the internal demand of Ecofarm. Biochar was used to produce bio-fertilizers which was subsequently used for the cultivation of organic crops (peppers, vegetables, rice, and corn). At the end of 2015, Ecofarm stopped producing biochar due to the decreased price of domestic corn and because rice husk was too expensive. Furthermore, the price of imported corn become cheaper than locally produced corn. Another major challenge was the harsh competition from other types of organic fertilizers including coconut peat, black sludge and farmers that make their own compost.
Contact details	MSc. Nguyễn Hồng Quang, Project manager
Website	http://www.ecofarm.vn/ecofarm-facilitating-an-international-collaboration-to-install-biochar-technology-in-vietnam/

	https://biochar-international.org/profile_ecofarm/ & BiGchar (Pyrocal)1500, 2200

Table 9 BIFFA's biochar and new generation fertilizer from coffee husk biochar

Title	Biochar and new-generation fertilizer
Pathway	Agriculture
Summary	Binh Dinh fertilizer and general service joint stock company (Biffa) transferred Sino pyrolysis technology from Japan in 2017. This technology is pyrolysis process within 25-30 days to produce high quality wood-made charcoal with fixed carbon content more than 90% which has high calorific value without CO_2 and CO emission and can be commercialised used as charcoal for cooking. Biffa regulates specification of the Sino technology (for example, keeping temperature over 600°C within more than 48 hours) to produce Biochar using agricultural biomass such as coffee husk, rice husk, bagasse, etc. and this is then mixed with nutrients to produce bio-fertilizer.
Organization (s)	Binh Dinh fertilizer and general service joint stock company (BIFFA)
Date	Since 2007
Key findings	Biffa produces and commercialises the following products; Biffa pure biochar: the fixed carbon content is more than 50% with addition of Humic and Fulvic acids, increasing absorption and nutrition exchange capacity of soil, stabilizing pH; maintaining humidity; slowly releasing nutrition into soil then save fertilizer; reducing leaching and increasing nutrient efficiency. Retail price is 6 million VND per ton (260 USD) Biffa organic biochar: including 15% of fixed carbon content, 25% organic matter, multi-functional microorganisms of phosphorus and cellulose decomposition, nitrogen fixation, symbiotic fungi with root and antagonistic microorganisms (Trichoderma); mean and micronutrient substances. It can be used for soil improvement and stabilizing pH, serving organic farming. Retail price is about 3 million VND per ton (130 USD). The percentage of biochar is about 20-30% Applications: farmers and companies applied the technology; companies providing input material for Biffa. Currently, all kinds of products (Biffa pure biochar and Biffa organic biochar) are being commercialized The production capacity of the company is about 5000-7000 ton per year with the market is mainly Lam Dong, Dong Nai and Northern provinces.
Contact details	Dr. Nguyen Dang Nghia - Soils and Fertilizers Research Institute MSc. Nguyen Thu Ha - Soils and Fertilizers Research Institute Mr. Vo Tuan Tona - Director of Biffa
Website	Reference: https://nongnghiep.vn/than-sinh-hoc-va-phan-bon-the-he-moi-biffa-biochar-post140522.html

Table 10 Biochar Research from Soils and Fertilizer Research Institute

Title	Research on the reduction of biochar from rice husk, coconut fibre, coffee husk and the addition of nutrient so produce bio-fertilizer using for paddy, corn, vegetables, coffee, and pepper
Pathway	Agriculture
Summary	Research was carried out on biochar from rice husk, coconut fibre, coffee husk: to evaluate 12 formulas with 4 different burning temperatures (450, 550, 650 and 750°C) in 1 and 2 hours and compare values (before and after burning) of factors, including: Weight of material, moisture, density (weight/volume), maximum water absorption capacity (ml/100g), total content of C, N, P_2O_5, K_2O, CaO, MgO and SiO_2. This research also evaluated the addition of nutrients and mineral substances into grounded biochar to produce new generation mineral-organic fertilizer, using for paddy, corn, vegetables, coffee, and pepper.
Organization (s)	Soils and Fertilizer Research Institute and Vietnam Academy of Agriculture Sciences
Date	2012 - 2014
Key findings	The new generation mineral-organic fertilizer from biochar was able to meet the following parameters: organic content › 30%; humic acid › 5%; total NPK › 5%; addition of 4 mean nutrient substances HC (CaO, MgO, S, SiO_2) and micronutrient substance (TE) Composition of some bio-fertilizers as below: Basal fertilizing: organic content 24%; humic acid =5%; N=2%; P_2O_5 =3%; K_2O = 1.5%; CaO = 1.5%; MgO = 2.4%; S = 1.0%; SiO_2 =18% Bio-fertilizer for corn 1: organic content 37%; humic acid = 4%; NPK ›16%; HC + TE Bio-fertilizer for corn 2: organic content 25%; NPK ›20%; HC Bio-fertilizer for vegetable of harvesting leaf: NPK (8-5-5 + HC + TE); Bio-fertilizer for vegetable of harvesting root: NPK (8-5-10 + HC + TE); Bio-fertilizer for coffee 1: NPK (9-4-6 + HC + TE) Bio-fertilizer for coffee 2: NPK (8-4-10 + HC + TE) Bio-fertilizer for pepper 1: NPK (6-4-2 + HN + TE) Bio-fertilizer for pepper 2: NPK (12-4-14 + HN + TE)
Contact details	Dr. Nguyen Dang Nghia
Website	http://cesti.gov.vn/UPLOADS/XUHUONGCONGNGHE/OVERVIEW/201709141003201595Ky%208_Tongquan%20-%20Than%20sinh%20hoc_14.11.2014.pdf

Table 11 Biochar for Sustainable Soil (B4SS) project

Title	Biochar for Sustainable Soil (B4SS) project in Viet Nam
Pathway	Agriculture

Summary	The B4SS project was implemented in Quang Chu commune, Cho Moi district, Bac Kan province, the Northeast highlands of Vietnam. The project aimed to convert crop residues into biochar for application to soil and improve the awareness of farmers about the use of biochar for sustainable land management. A survey was conducted on 20 households to determine the most crops grown, soil types and management practices (such as cultivation methods, fertilisers used, residue management and available biomass resources), in order to select representative agricultural systems in which to trial biochar and identify the most suitable feedstocks for producing appropriate biochar formulations.
Organization (s)	This project is funded by Global Environment Facility (GEF) and implemented by the United Nations Environment Programme (UNEP) Main local partner: Thai Nguyen University of Sciences (TNUS) – Thai Nguyen University.
Date	2013 - 2015
Key findings	The conclusion of this project was that the use of biochar as a soil amendment is limited in Vietnam. Reasons for this may include: (1) the char may be more valuable for other purposes such as cooking and space heating during winter; (2) biochar production requires special equipment and sometimes complex control measures, which can be time-consuming and labour-intensive; (3) farmers do not recognise the effect of biochar on increasing crop yield as the effect may take a while to be apparent in some soils; and (4) the country does not have a long term strategy for improving soil conditions for sustainable land management.
Contact details	https://biochar.international/governance/ http://b4ss.tnus.edu.vn MSc. Mai Thi Lan Anh Tel: (0208).3703.338 Email: tnmt@tnus.edu.vn
Website	University of Science – Thai Nguyen University https://biochar.international/

Table 12 Research on rice straw and husk biochar to improve soil fertility, yields and reduce GHG

Title	Research project to produce biochar from rice straw and rice husk to improve soil fertility, crop yields and reduce greenhouse gas emissions.
Pathway	Agriculture
Summary	Testing different biochar-production methods from rice husks and rice straw to identify the most suitable biochar production employed for Vietnam's rural context. The results were published in Vietnam Journal of Agricultural Sciences (ISSN 1859-1558) No. 3(24).
Organization (s)	Institute for agricultural environment (IAE) and Vietnam Academy of Agriculture Sciences (VAAS)

	1-8/2010
Date	2011
Key findings	Total carbon content, organic carbon and potassium in straw are higher than that in rice husk. In contrast, nitrogen and P2O5 (phosphorus pentoxide) content in straw is lower than that of rice husk. Biochar made from rice husk by indirect burning method (PP3) has total carbon content, organic carbon, nitrogen and P2O5 higher than these by direct burning method (PP1 & PP2). Biochar made from rice straw by indirect burning method (PP7) also gives higher carbon, organic carbon, nitrogen and K2O than that by direct method (PP4, PP5 & PP6). Carbon recovery efficiency from rice straw is lower than that from rice husk. PP3 for rice husk and PP7 rice straw have the highest carbon recovery efficiency.
Contact details	Mr. Mai Van Trinh, VAAS
Website	http://iae.vn/Data/upload/files/VanBan/publication/13_MaiVanTrinh_Thansinhhoc_cuong(8-3-2013).pdf

Table 13 VNUA's research on biochar for methylene blue adsorption

Title	Research on manufacturing biochar of agricultural by-products and application in environmental treatment.
Pathway	Water filtration
Summary	The research focuses on producing biochar from 7 different agricultural by-products to test for methylene blue adsorption. Biochar samples were produced from rice husk, rice straw, bamboo leaves, cane leaves, corn leaves, sawdust, and corn cobs in the pyrolysis kiln in range of temperature from 200 to 350°C. The research was conducted in the laboratory of Department of Environmental Technology, Faculty of Environment, Vietnam National University of Agriculture (VNUA). The produced biochar was assessed its characteristics of shape and colour, weight, pH, electrical conductivity (EC), cation exchange capacity (CEC) and methylene blue adsorption capacity. The methylene blue adsorption capacity of biochar is a representative feature of its colour treatment ability. Use of biochar in colour treatment of industrial wastewater, specifically textile wastewater (from dyeing/ printing process), could be a potential application.
Organization (s)	Faculty of Environment, VNUA
Date	Jan – May, 2016
Key findings	Besides feedstock nature, pyrolysis temperature is the key factor that affected the biochar characteristics. The higher the pyrolysis temperature, the darker the colour of the biochar, the original structure remains basically the same, but the breakability gradually increases, whereas the weight of biochar tends to decrease. pH increased in proportion to the temperature in all 7 materials, the cation exchange capacity (CEC) varies, in which biochar

	obtained from cane leaves at a temperature of 300°C, for 3 hours has the highest CEC value (86meq/100g, milliequivalents per 100 grams biochar) versus others. The methylene blue adsorption efficiency of the samples of biochar produced range from 51.3 to 99.8%, with 64% of the biochar samples obtained from materials at different temperatures having an efficiency of over 90%. The research concludes that it is possible to use biochar made from agricultural by-products as the material for colour treatment of textile wastewater, especially biochar obtained when rice husk pyrolysis at 350°C conditions for 3 hours with the highest adsorption efficiency of 99.8%.
Contact details	Student: Ms. Tang Thi Kieu Loan (MTE Class, 57th Batch of VNUA) Advisor: Ms. Ho Thi Thuy Hang (Faculty of Environment, VNUA)
Website	https://kmt.vnua.edu.vn/Portals/1081/Ban%20CN%20Khoa/thu%20vien/%C4%90H%202016-70k.docx

Table 14 Can Tho University research to reduce pesticides in aquaculture

Title	Research on using bamboo, melaleuca, rice husk and activated coconut shell biochar to reduce effects of fenobucarb on enzyme cholinesterase extracted from climbing perch (Anabas Testudineus).
Pathway	Water filtration
Summary	Using biochar made from bamboo, melaleuca, rice husk and activated coconut shell for reducing effect of fenobucarb on brain cholinesterase activity of climbing perch was carried out in laboratory conditions. Fenobucarb solution was prepared from commercial Bassa 50EC (contained 50% fenobucarb in weight). Each kind of biochar was conducted with a control (no fenobucarb), fenobucarb (no biochar) and biochar (1, 2, 3, 5 and 7 g/L) for retention time 30, 60, 90 and 120 minutes. Afterward, fish were exposed to each treatment for 3 hours and then sampled for brain cholinesterase assay. The results showed that these biochar samples can reduce the effects of fenobucarb on cholinesterase. The research was published in HUAF Journal of Agricultural Science & Technology, Vol. 2(2), ISSN 2588-1256.
Organization (s)	College of Environment and Natural Resources, Can Tho University
Date	2018
Key findings	The activated coconut shell, melaleuca, bamboo, and rice husk biochar can reduce the effects of fenobucarb on cholinesterase. The efficiency of reduction was in order: activated coconut shell biochar › rice husk biochar › melaleuca biochar › bamboo biochar. These results indicated that above biochar can be used to treat fenobucarb pollution. Results of this research will be the basis for biochar application from local biomass sources in reducing pesticide pollution in general and Fenobucarb in particular.

Contact details	Nguyen Khoa Nam, Nguyen Huu Chiem, Nguyen Van Cong nvcong@ctu.edu.vn
Website	http://tapchi.huaf.edu.vn/index.php/id20194/article/view/159/99

Table 15 Research on silica separation in the production of activated carbon from rice husk

Title	Research study on silica separation in the production of activated carbon from rice husk in Vietnam.
Pathway	Activated carbon
Summary	This study considers the process of separating silica from charcoal, which is an important step in the production of activated carbon from rice husks in Vietnam. The efficiency of the process is greater with increasing temperature up to 133°C, the ratio of alkali/charcoal up to 0.6 and sodium hydroxide concentration up to 6 M as well. A regression equation has been obtained, which allows describing the influence of the parameters on the degree of silica separation from the carbon. Under optimal values of process parameters, the efficiency reaches up to 95.6%.
Organization (s)	Department of Chemical Engineering, National Research Tomsk Polytechnic University (Russia), School of Materials Science and Engineering, Hanoi University of Science and Technology (Vietnam)
Date	2015
Key findings	Environmental pollution due to mismanagement of the waste from rice production is a serious problem in Vietnam where rice cultivation occupies the largest proportion of the crops produced. In Vietnam, the average annual production of more than 40 million tons of rice, particularly in 2015 the country's rice output reached 44.7 million tons. Husk accounts for 20% of the rice content, so approximately 9 million tons of rice husk is released to the environment each year. This huge amount of waste if not treated properly will lead to environmental pollution as well as waste local resources. Production of activated carbon from Vietnam rice husk is an important task because this material can be widely used in wastewater treatment processes and adsorption of harmful impurities from waste gases of various plants, including rice processing. The presence of silica in the charcoal does not allow for the formation of activated carbon with a high purity. Silica separation in the production of activated carbon may be accomplished by a physical method, but the efficiency is very low. High efficiency and a significant degree of separation are accomplished in the chemical method. Under the optimum conditions (temperature 133°C; alkali concentration of 6M; ratio of alkali/ash of 0.6 g/g and separation time of 1 hour), the maximum degree of separation is up to 95.6%.

Contact details	N.M. Hieu (Department of Chemical Engineering, National Research Tomsk Polytechnic University, Lenin avenue, 30, Tomsk, 634050, Russia) N.V. Tu (School of Materials Science and Engineering, Hanoi University of Science and Technology, 1 Dai Co Viet, Hanoi, Vietnam)
Website	https://reader.elsevier.com/reader/sd/pii/S187661961500128X?token=D755E1E63A68B880B7F3A07469C54E382B60BB3311F5F26625BCB3D1E769CFB5332F77BF5B57B4516F863DDA404364BC

Table 16 Activated carbon derived from rice husk and its application in supercapacitor

Title	Research on activated carbon derived from rice husk by NaOH activation and its application in a supercapacitor.
Pathway	Activated carbon
Summary	Four activated carbon samples prepared from rice husk under different activation temperatures have been characterized by N_2 adsorption-desorption isotherms, thermogravimetric analysis (TGA–DTA), Fourier transform infrared spectroscopy (FTIR) and scanning electron microscopy (SEM). The specific surface area of AC sample reached 2,681 m^2/g under activation temperature of 800°C which is considered very high within the range of activated carbon approximated at 500 to 3000m2/g The AC samples were then tested as electrode material; the specific capacitance of the as-prepared activated carbon electrode was found to be 172.3 F/g using cyclic voltammetry at a scan rate of 5 mV/s and 198.4 F/g at current density 1000 mA/g in the charge/discharge mode.
Organization (s)	Journal: Progress in Natural Science: Materials International 24, page 191 - 198
Date	2014
Key findings	Activated carbon from rice husk was successfully synthesized by chemical activation with NaOH as the activating agent at different activation temperatures in the range of 650-800°C. The obtained materials were characterized and evaluated for potential application as a supercapacitor electrode material. The AC samples have porous structure, variety surface functional groups and high specific surface area (S_{BET} = 2,482-2,681 m^2/g), which contains micropore and mesopore distributed mainly from 0.9 to 3.0 nm. High activation temperature resulted in high specific surface area (S_{BET} = 2,681 m^2/g), high mesopore contribution (V_{me} = 0.3906 cm^3/g) and high total basic surface group (1.08 meq/g), which in turn improved gravimetric capacitance of AC when using as active material in supercapacitors. Specific capacitance of the as-prepared electrode reached 172.3 F/g at scan rate of 5 mV/s and 198.4 F/g at current density of 1000 mA/g. The latter was stable even after 1000 cycles of charge/discharge. So, AC obtained from rice husk by NaOH activation at 800°C may be a suitable candidate for application as supercapacitor electrode material.

Contact details	Khu Le Van and Thu Thuy Luong Thi (Physical Chemistry Department, Hanoi University of Education)
Website	https://reader.elsevier.com/reader/sd/pii/S1002007114000653?token=57EB2E5B2F992A607D75AA71DE294E6C0ECF9C11FC51A8D6A0BA612D4A03023A795672663BC752D7B6BB581DA99EED0D

Annex 2

Activated Carbon for Cosmetics

The main applications of activated carbon for cosmetics are to remove makeup and tighten pores, make skin masks, as an additive to toothpaste for teeth whitening, and a component of hair beauty to make hair soft and smooth. The following table shows examples of products currently commercialised in Vietnam.

Table 17 Activated carbon for cosmetics in Vietnam

Applications	Names of products	Names of producers
Cleansing and tightening of pores	3W Clinic Fresh Charcoal Mask Sheet	3w Clinic
	OHUI Extreme White 3D Black Mask	OHUI, Korea
	Oil Balancing + Charcoal Purifying Gel Cleanser	Sukin,
	Activated carbon lotion cream	Erina VIP, Thailand
	Tightening Mask Kracie	Hadabisei, Japan
	Daiso Natural Pack	Daiso, Japan
	Liftarna-PDC Concentrate Mask	PCD, Japan
	Miniso activated carbon mask	Miniso, Japan
Black head removal	Blackhead Removal Activated Carbon Mask Set	My Scheming, Taiwain
	Activated Carbon Face Wash Activated Carbon Peel Off Mask	Earthe Essentials
Skin and teeth whitening	Whitening Body Cream with Activated Carbon	Erina VIP, Thailand
	Activated Carbon Soap	Earthe Essentials
Hair care	Activated Carbon Shampoo	Earthe Essentials
	Activated carbon shampoo for Men	Men's Softymo, Japan

Sources: Styleguide Leflair, 2018. 5 most favourable activated carbon cosmetic products. https://styleguide.leflair.vn/my-pham-than-hoat-tinh/

Makeup Lung Linh, 2018. Top 5 best Japanese activated carbon masks 2018. http://www.makeuplunglinh.com/top-5-mat-na-than-hoat-tinh-nhat-ban-tot-nhat-2018/

Beauty, 2017. 4 products of activated carbon cleanser effectively clean skin. https://dep.com.vn/4-dong-sua-rua-mat-than-hoat-tinh-lam-sach-da-hieu-qua/

Annex 3

Market Demand Indicators

Market demand indicators – Biochar in the agricultural sector

The following table highlights a series of indicators for the potential market for biochar-based products in the agriculture sector for the target countries, including Viet Nam.

Table 18 Market demand indicators for agriculture

<table>
<tr><th>No.</th><th>Indicator</th><th>Vietnam</th><th>Thailand</th><th>Cambodia</th><th>Laos</th><th>EU</th></tr>
<tr><td>1.1</td><td>Organic Area Vegetable Production (Ha) (2017)[23]</td><td>58,017</td><td>91,266</td><td>11,042</td><td>7,668</td><td>11,140,000</td></tr>
<tr><td>1.2</td><td>Organic area in farmland (%) (2017)[24]</td><td>0.5</td><td>0.4</td><td>0.2</td><td>0.2</td><td>2.9</td></tr>
<tr><td colspan="7">An indicator of potential demand for the agricultural applications of biochar as a stand-alone organic input or as a component of value-added products such as biochar based organic fertilizers or animal feed. Organic farmers are more likely to take up biochar-based products.</td></tr>
<tr><td>1.3</td><td>Sustainable Nitrogen Management Index (SNMI)[25]</td><td>39</td><td>105</td><td>34</td><td>71</td><td>40.2</td></tr>
<tr><td colspan="7">SNMI uses nitrogen use efficiency (NUE) and crop yield to measure the environmental performance of agricultural production. It ranks countries from the most efficient (1) to (177). On one hand, countries with a higher SNMI score can benefit from biochar to increase nutrient uptake efficiency in the soil, at the same time countries with a lower SNMI score (higher efficiency) may have greater awareness of the benefits of biochar.</td></tr>
<tr><td>1.4</td><td>Fertilizer consumption kg/Ha[26]</td><td>429.8</td><td>161.7</td><td>17.4</td><td>n/a</td><td>158.4</td></tr>
<tr><td>1.5</td><td>Soil degradation (ha) / Average land degradation in GLASOD erosion degree[27]</td><td>3.38</td><td>3.15</td><td>2.45</td><td>2.19</td><td>2.09</td></tr>
<tr><td>1.6</td><td>No. of Participatory Guarantee System certified initiatives[28]</td><td>7</td><td>15</td><td>19</td><td>5</td><td>n/a</td></tr>
<tr><td>1.7</td><td>No. of certified Good Agricultural Practice Producers[29]</td><td>1.495</td><td>140.000</td><td>n/a</td><td>n/a</td><td>56.347</td></tr>
<tr><td colspan="7">Participatory Guarantee Systems (PGS) are locally focused quality assurance systems to certify producers based on active participation of stakeholders and are built on a foundation of trust, social networks, and</td></tr>
</table>

23 Willer and Lernoud, 2019.
24 Willer and Lernoud, 2019.
25 EPI. Sustainable Nitrogen Management Results, https://epi.envirocenter.yale.edu/epi-indicator-report/SNM
26 World Bank, 2017. Fertilizer consumption in 2016, https://data.worldbank.org/indicator/AG.CON.FERT.ZS?view=chart; Europe indicates EU.
27 FAOSTAT, 2017. Soil degradation in 1991, http://www.fao.org/faostat/en/#data/ES
28 IFOAM, 2019. https://pgs.ifoam.bio/pages/why-this-map
29 FAO, 2019 . www.fao.org/3/ag130e/ag130e12.htm

No.	Indicator	Vietnam	Thailand	Cambodia	Laos	EU
knowledge exchange. PGS producers are obliged to minimise the use of inorganic inputs and therefore an indicator of demand for sustainable inputs. PGS are a potential entry point for sales of biochar. Good Agricultural Practice (GAP) codes, standards and regulations are guidelines which have been developed by the food industry, producers' organizations, governments, and NGOs, aiming to codify agricultural practices at farm level for a range of commodities.						

Market demand indicators - Biochar for wastewater treatment

The following table highlights a series of indicators for the potential market for biochar for wastewater treatment in the target countries.

Table 19 Market demand indicators for water treatment

No.	Indicator	Vietnam	Thailand	Cambodia	Laos	EU
2.1	Mortality rate attributed to unsafe water, unsafe sanitation, and lack of hygiene (% of 100,000 population)[30]	1.6	3.5	11.3	6.5	0.3
2.2	% population relying on unimproved water sources[31]	5.30	0.58	11.97	14.19	<<1
2.3	% population relying on surface water[32]	0	0	12.66	4.33	0
2.4	Share of rural population with access to improved water sources, 2015[33]	96.90	98	69.10	69.40	>99
2.5	Investment in water and sanitation (private participation) million USD in 2017[34]	2,447	1,437.4	12.5	0	Data unavailabl e
2.6	Existence of expertise in biofilters[35]	Yes, some e.g. Nhat Tinh Greenerso	Yes, some e.g. Acqeuos Solutions	Yes some, e.g. Hydrologic	Yes some, e.g. Terraclear	Yes many

30 World Bank Group, 2015. "World Development Indicators: Improved Water Source (% of Population with Access)." http://data.worldbank.org/indicator/SH.H2O.SAFE.ZS. Accessed through Resource Watch, (date). www.resourcewatch.org.
31 World Bank Group, 2016. Mortality rate attributed to unsafe water, unsafe sanitation and lack of hygiene (per 100,000 population). https://data.worldbank.org/indicator/SH.STA.WASH.P5?view=chart
32 WHO/UNICEF JMP, 2018. % population relying on surface water. https://washdata.org/data/household#!/
33 Our World in Data, 2016. Share of rural population with access to improved water sources, 2015. https://ourworldindata.org/water-use-sanitation
34 World Bank Group, 2017. Investment in water and sanitation (private participation) million USD in 2017. https://data.worldbank.org/indicator/IE.PPI.WATR.CD?view=chart
35 Nhat Tinh Environment Technologies Solution Corp (Vietnam), 2019. http://wsc.com.vn/san-pham/thiet-bi-loc-sinh-hoc-biofilter-ecotec Greenerso (Vietnam), 2019. Consultation, design environmental technologies Greenerso Ltd. https://greenerso.com/cong-nghe/qua-trinh-sinh-truong-bam-dinh-74.html

No.	Indicator	Vietnam	Thailand	Cambodia	Laos	EU
2.7	Fish produced annually with land-based aquaculture (metric tons)[36]	3,450,200 metric tons	3,743,564 metric tons	143,000 metric tons	108,500 metric tons	1,301,483 metric tons

Market demand indicators – Activated carbon

The following table highlights a series of indicators for the potential market for activated carbon for the target countries.

Table 20 Market demand indicators for activated carbon

No.	Indicator	Vietnam	Thailand	Cambodia	Laos	Europe
3.1	GDP per capita in 2017 (USD)	2.342	6.595	1.384	2.457	36.984
3.2	% of population with tertiary education[37]	28	49	13	16	73
	Countries with higher levels of disposable income and higher levels of education are assumed to have greater purchasing capacity for consumer products that use activated carbon, such as homeware, pets ware, cosmetics, nutraceuticals etc.					
3.3	Total volume of imports of activated carbon USD (2017)[38]	n/a	20.814.104	24.413	138.747	281.208.957
	The volume of imports of activated carbon products is a clear indicator of the actual demand for the products. In the case of Cambodia and Laos the majority of the products imported were from Vietnam and a countries' capacity to export high technology goods is an indicator of the maturity of the sector to produce activated carbon products.					

36 FAO, 2017. http://www.fao.org/state-of-fisheries-aquaculture and Vietnam and Thailand data in https://www.indiasstuffs.com/largest-fish-producing-countries/ FAOSTAT, 2017. Cambodia. http://www.fao.org/fishery/countrysector/naso_cambodia/en Trading Economics, 2016. Laos - Aquaculture production (metric tons). https://tradingeconomics.com/laos/aquaculture-production-metric-tons-wb-data.html

37 World Bank Data

38 UN Comtrade , World Bank Data

Annex 4
Carbon Markets

Table 21 Carbon emission trading markets

<table>
<tr><td colspan="2">1. EU ETS - EU emission trading scheme</td></tr>
<tr><td colspan="2">The ETS is the largest and oldest compliance market and covers around 40% of the EU´s greenhouse gas emissions. It operates with a cap-and-trade system. A cap is set to the total amount of GHGs that can be emitted by installations covered by the scheme. Emissions above that cap have to be reduced or traded by buying emission allowances from other entities in the EU.
Credits from outside the EU can also be bought from emission savings projects that are certified under the Clean Development Mechanism (CDM). CDM credits are known as Certified Emission Reduction (CERs) which represent 1 t CO^2 equivalent abated or sequestered.</td></tr>
<tr><td colspan="2">2. Voluntary Carbon Markets (VCM)</td></tr>
<tr><td colspan="2">Buyers and sellers trade credits on their own volition, with the vast majority following rules and procedures set out by a voluntary carbon standard.
The main voluntary carbon standards are, in order of size (a-d).</td></tr>
<tr><td>a. Verified carbon standard (VCS): the largest VCM is developing a methodology to certify biochar producers' capacity for carbon sequestration.</td><td>b. Gold Standard (GS): most rigorous voluntary standard with a strong emphasis on contribution to the SDGs and local stakeholder consultation. GS-VERs are sought by end-buyers that look for ‘charismatic’ offsets and are often willing to pay higher prices.</td></tr>
<tr><td>c. America Carbon registry (ACR): standard for project seeking to sell credits on the US market. The registry is both voluntary and an Early Action Offset Program for the California Cap-and-Trade program.</td><td>d. Plan Vivo: Much smaller than the other standards and focuses exclusively on land-use change and forestry</td></tr>
<tr><td colspan="2">3. Japanese Joint Crediting Mechanism</td></tr>
<tr><td colspan="2">A project-based bilateral offset crediting mechanism initiated by the Government of Japan to facilitate the diffusion of low-carbon technologies. Bilateral agreements have been signed with Vietnam and neighbouring countries such as Cambodia. Rules and procedures are similar to the CDM.
The mechanism operates on the principle that clean technology transfer occurs from Japan to the host country in exchange for the credits which are then used to achieve Japan’s emission reduction targets. Thus, in the case of promoting a Vietnamese technology, this mechanism cannot be utilized.</td></tr>
<tr><td colspan="2">4. Vietnam Domestic Carbon market</td></tr>
</table>

Vietnam is developing its own domestic carbon market with assistance from the Partnership for Market Readiness (PMR) Program of the World Bank (PMR, n.d.). The objective of the PMR is to strengthen the capacity of the Vietnam Government to develop market-based instruments (MBI) to reduce GHG emissions. Phase 1 of the PMR (2013-2018) focused on establishing legal frameworks and piloting market-based instruments and Phase 2 will establish a domestic carbon market instrument and connection to an international market (PMR, n.d.). The market is in nascent stages but could, over time, create opportunities for domestic projects that reduce or sequester carbon.
5. Paris Climate Agreement
Annex 2 of the Paris agreement highlights the potential for increasing carbon storage in soils and the post COP-21 initiative '4 per mile' is an example of action that has already been taken up by several countries to boost their soil carbon. Several studies support the significant potential to climate mitigation through increasing soil carbon (Minasny et al., EASAC, 2017a) and the endorsement by the UNFCCC for increasing soil organic carbon could be a key enabling factor for the future development of biochar-based carbon trading initiatives.

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Vienna International Centre
Wagramerstr. 5, P.O. Box 300,
A-1400 Vienna, Austria

+43 (1) 26026-0

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