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Trading the Temperature- Voluntary Carbon Offsetting as Climate Change Mitigation Tool for Developing Countries: Lessons from Cookstove Projects in Nepal

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Affidavit

I, **ANSGAR FELLENDORF, BA**, hereby declare

1. that I am the sole author of the present Master’s Thesis, "TRADING THE TEMPERATURE- VOLUNTARY CARBON OFFSETTING AS CLIMATE CHANGE MITIGATION TOOL FOR DEVELOPING COUNTRIES: LESSONS FROM COOKSTOVE PROJECTS IN NEPAL", 71 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
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Abstract

Current societies face accelerated anthropogenic climate change and accordingly have searched for mitigation responses. Voluntary carbon offsetting (VCO) schemes have emerged as one pathway through CO_2 footprint compensation and accounting for climate injustices by channelling funds to developing countries. This research analyses to what extent VCO provides an effective mitigation tool for developing countries in the context of cookstove promotion. Globally, 2.8 billion people rely on traditional and polluting technologies for cooking which concurs with multiple development concerns. Clean cookstove promotion reduces CO_2 and black carbon emissions and is considered best practice of consolidating greenhouse gas reductions and sustainable development.

A novel case study of Nepal, a country heavily reliant on solid biomass, illustrates practical carbon credit potentials and challenges for VCO financing of cookstove programs. First, the carbon price is too low for profitable project design and coupled with an oversupply of offsets leads to risks and uncertainty. Moreover, the certification process is strenuous and deters additional mitigation projects. Nonetheless, the voluntary scheme is advantageous because it differentiates between cookstove projects and other market activities. Thereby clean cooking earns a premium price for its development co-benefits. Moreover, the scheme has led to capacity building and fostered environmental entrepreneurs in Nepal.

The thesis concludes that with 63.4 $MtCO_2e$ annual offsets, VCO represents no profound mitigation instrument in absolute emissions reductions. This might change, however, with the implementation of Article 6 of the Paris Agreement and a sectoral emissions cap for international aviation. On the other hand, VCO provides capacity building and the possibility to monetize co-benefits of cookstove programs. In Nepal, funding from the carbon market could help alleviating more than three million households from indoor air pollution, coinciding with climate benefits. Lastly, it is recommended to measure black carbon emissions reductions for offset issuance since the substance purportedly adds the second strongest forcing on the climate system.

Keywords: **Carbon offsetting; Climate change mitigation; Cookstoves; Sustainable development; Nepal**

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List of Abbreviations

AEPC -	Alternative Energy Promotion Centre (Nepal)
AMS -	Approved Methodology for Small-Scale Project Activities
BC -	Black Carbon
CDM -	Clean Development Mechanism
CER -	Certified Emissions Reduction
CH_4 -	Methane
CO -	Carbon monoxide
CO_2 -	Carbon dioxide
CO_2e -	CO_2 equivalent
CORSIA -	Carbon Offsetting and Reduction Scheme for International Aviation
CREF -	Central Renewable Energy Fund (Nepal)
CRT/N -	Centre for Rural Technology, Nepal
DNA -	Designated National Authority
ER -	Emissions Reduction
ESAP -	Energy Sector Assistance Programme (Nepal)
ETS -	Emissions Trading System
FRA -	Forest Resources Assesment
G -	Giga (10^9)
GACC -	Global Alliance for Clean Cookstoves
GHG –	Greenhouse gases
GS -	Gold Standard
GWP -	Global Warming Potential
IAP -	Indoor Air Pollution
ICS -	Improved Cookstove
IPCC -	Intergovernmental Panel on Climate Change
ISO -	International Standardization Organisation
LDC -	Least Developed Country
LPG -	Liquefied Petroleum Gas
M -	Million (10^6)
N_2O -	Nitrous Oxide
NDC -	Nationally Determined Contribution
NGO -	Non-governmental Organization
NIBC -	Nepal Interim Benchmark for Cookstoves
NRREP -	National Rural and Renewable Energy Program (Nepal)
PA -	Paris Agreement
PDD -	Project Design Document
$PM_{2.5}$ -	Fine Particulate Matter
Ppm -	parts per million
RETS -	Renewable Energy Testing Station (Nepal)
SDGs -	Sustainable Development Goals
SE4All -	Sustainable Energy for All
tCO_2e -	Tonne of carbon dioxide equivalent
TCS -	Traditional Cookstove
UNFCCC -	United Nations Framework Convention on Climate Change
USD -	United States Dollars
VCO –	Voluntary Carbon Offset(ting)
VCS -	Verified Carbon Standard
WBT -	Water Boiling Test
WHO -	World Health Organization

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1. Introduction

'Putting a price on carbon at a global scale could unleash innovation and provide the incentives that industries and consumers need to make sustainable choices.'

– United Nations Secretary General Antonio Guterres, 30 May 2017

The international community and current societies are confronted with accelerated anthropogenic climate change. There is scientific agreement that carbon dioxide (CO_2) emissions constitute a main driver for the unprecedented warming of the Earth's troposphere. Atmospheric concentrations of the major greenhouse gases (GHGs) CO_2, nitrous oxide (N_2O) and methane (CH_4) have all drastically increased since pre-industrial times. (IPCC 2015) Consequently, global policy makers agreed in the 2015 UNFCCC Paris Agreement (PA) to maintain the planet's warming between 1.5 and 2°C compared to pre-industrial levels. Indeed, 'limiting warming to 1.5°C is not yet a geophysical impossibility.' (Millar et al. 2017, 741) However, in light of a 12- 14 $GtCO_2e$ emissions gap between mitigation proposals by the PA Parties until 2030 and the 2°C objective, (UNEP 2016) strengthened climate action is needed.

The funding of required emissions reductions (ER) holds paramount and debates around climate finance have gained momentum. Article 9 of the PA states that 'developed country Parties shall provide financial resources to assist developing country Parties with respect to both mitigation and adaptation.' Moreover, Article 6 recognizes cooperative carbon pricing approaches and related market schemes as key mitigation tools. Similarly, the World Bank (2017) assigns carbon pricing initiatives an increasing role, with at least 81 Parties to the PA invoking carbon pricing and emissions trade as integral part of their Nationally Determined Contributions (NDCs). Certainly, the concept and benefits of carbon trade in the decarbonization of the global economy towards the 2°C goal garnered many supporters. (cf. Newell and Paterson 2010; World Bank 2017) Indeed, the market mechanism and carbon offsetting have become major mitigation schemes in international politics to limit GHG emissions. (Ehrenstein and Muniesa 2013, 161)

To date, the most prominent and voluminous carbon offsetting scheme has been the Clean Development Mechanism (CDM) established under the Kyoto Protocol. However, it also gained criticism *inter alia* for only marginally reducing overall emissions, corrupt practices and lenient procedures. (cf. Böhm et al. 2012; IPCC 2014) Parallelly and complementary to this compliance market, companies, sub-national leaders, non-governmental organizations (NGOs) and individuals have created a voluntary carbon market. Whereas in the compliance scheme governments and regulated facilities use offsets as substitutes for mandatory emissions obligations, voluntary markets issue credits to be used by business, governments, NGOs and individuals to compensate their carbon footprints for reasons such as individual and corporate-environmental responsibility. (Lee et al. 2013) Essentially, voluntary carbon offsets (VCO) allow consumers and companies to pay someone else to reduce GHG emissions by investing in i.e. renewable energy projects, energy efficiency, and forest protection. Carbon credits, or offsets, represent one tonne of CO_2 equivalent (tCO_2e) and form tradable units. The offsets differ from other low carbon activities because their impact is measured and usually verified by a third party. (Guigon 2010; Kotchen 2009) Many non-state climate action initiatives, indispensable in transitioning to a 2°C compatible pathway, rely on VCO. (Graichen et al. 2016)

Voluntary carbon offsetting facilitates a price tag on negative externalities of climate harming activities. Many enterprises, multinational corporations and citizens have jumped on the bandwagon and market themselves as ‘climate friendly’, ‘green’, and ‘sustainable’. Lately, also the concept of ‘carbon neutrality’ has emerged both as marketing tool and for ‘true believers’ to act for change. (Dhanda and Hartman 2011) Several industries offer VCO, with airfare and energy spearheading. It is even possible to offset the GHG from diapers and to bid farewell deceased in carbon-neutral funerals. (Kotchen 2009) In 2016, the aviation industry, responsible for an ever-increasing share of global GHG emissions, announced a novel sectoral carbon offsetting scheme. While the details of the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) remain to be negotiated, (World Bank 2017) it exemplifies that (voluntary) carbon offsetting embodies a favoured option to narrow the emissions gap.

VCO is particularly relevant for developing countries since it fosters capacity building in mitigation efforts. The market further assists in establishing stringent carbon standards, for instance on additionality and co-benefits. (Guigon 2010; GS 2017) Notwithstanding, some critics compared offsetting to the Medieval Catholic church’s practice of selling indulgences (Monbiot 2006) and questioned the real-life ERs. (Böhm et al. 2012) Another opposition has been the lack of standardized rules for carbon calculations and accounting. Despite dominant schemes such as the CDM and the Gold Standard (GS), there exist no uniform legal rules for the issuance of carbon certificates. (Dhanda and Hartman 2011) Certainly, the debate around the efficacy, implementation and applicability of carbon markets is ongoing. (cf. IPCC 2014, 1046; Hamrick and Gallant 2017b)

This short review illustrates a focus on the demand side of carbon credits, mostly in developed Annex I[1] countries, and regulations around it. The VCO market albeit relies equally on project developers and in this sense, science may connect global views with local circumstances. (Gramelsberger and Feichter 2011) An eminent item in offsetting portfolios are clean cookstove projects. Cooking represents the basic daily chore in developing countries (Interview C) and in fact, 'clean cooking is widely recognized as a global development and climate priority.' (GACC 2017, 3) In 2016, more than three $MtCO_2e$ VCOs originated in cookstove projects and were sold on the market. (Hamrick and Gallant 2017a) The actual ER from clean cookstoves lie substantially higher because compliance projects are excluded in the account and many activities remain unrecorded. Graichen et al. (2016) estimated that by 2020, 270 $MtCO_2e$ may be reduced by efficient cookstoves and others even computed an annual 1,000 $MtCO_2e$ ER potential from cookstove projects. (Lee et al. 2013)

A 'clean' or 'improved' cookstove replaces traditional three-stone fires and is characterized by reduced fuel consumption, increased combustion efficiencies and lower emission levels of fine particulate matter ($PM_{2.5}$) and climate forcing species. Because of this 'win-win' climate and development nexus, cookstove projects have gained global traction. Major public-private partnerships such as the Global Alliance for Clean Cookstoves (GACC) and the Sustainable Energy for All (SE4All) Initiative were launched. In fact, 'cookstove projects are viewed as being one of the few carbon credit project types that directly promote sustainable development.' (Freeman and Zerriffi 2014, 14112) Currently, 2.5 billion people rely on biomass for cooking, inducing 2.7 M premature deaths per year due to indoor air pollution (IAP). Undoubtedly, clean cooking concurs with key UN Sustainable Development Goals (SDGs), including clean energy (SDG 7), climate action (SDG 13), and reducing air pollution (SDG 3). (IEA 2017) These nexuses also appear in the PA, which is framed in the context of sustainable development and poverty eradication. However, clean cooking solutions are vastly underfunded and there remains a global gap of 4.4 billion USD[2] per year. (SE4All 2017b) Veritably, carbon offsets may potentially close this gap by monetizing the ER of improved cookstoves. (Lee et al. 2013)

These considerations around (voluntary) carbon offsetting as a focal mitigation instrument and the requirement for sustainable pathways in developing countries inform this thesis. Essentially, it asks *to what extent voluntary carbon offsetting projects and clean cookstove programs constitute an effective climate change mitigation tool for developing countries.*

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[1] Annex I Parties to the Kyoto Protocol include OECD industrialized countries and several former USSR economies in transition.
[2] All prices and costs are given in [USD] of the year the data was generated. They are not adjusted to a common USD value.

To gain valuable insight and test concepts of the literature, the thesis conducts an in-depth case study about cookstoves and carbon offsetting programs in the Least Developed Country (LDC) Nepal. Related questions delve into the contextualization of VCO in the climate change regime, applicable standards for carbon credits, cookstove technologies and ER calculations and, eventually, the VCO challenges for market participants. Developing countries are defined as non-Annex I countries, with the notable exception of India and China. As will be described, they act *sui generis* with large-scale governmental cookstove programs and extensive experience in the compliance carbon market. Mitigation is defined as the 'human intervention to reduce the sources or enhance the sinks of greenhouse gases.' (IPCC 2014, 4) The effectiveness of VCO will be assessed in two realms. First, absolute amounts of ER in [$MtCO_2e$) will be discussed and benchmarked against gaps in the carbon budget and second, effectiveness is qualitatively discussed in terms of capacity building and structural development. With regards to cookstove programs, efficacy is further considered in ER, financial flows and co-benefits.

The issue areas of VCO and clean cookstoves form a relevant and original research for several reasons. First, voluntary carbon markets have recently gained traction, i.e. within discussions around CORSIA, and further scrutiny merits the understanding of their obstacles and opportunities. Second, this thesis undertakes a novel contextualization of VCO within the PA and the SDGs. The research is original in its interdisciplinary connection of political, scientific, economic and technological aspects. Third, carbon credits act as potential funding channels to alleviate those lacking access to clean cooking from drudgery and promote sustainable development. Lastly, the thesis adds an extensive case study of Nepal with new data and observations to the existing literature. Insights on the experience and applicability of carbon finance and its potentials for cookstove programs carry both academic and practical implications. (cf. SNV 2014)

This thesis combines different qualitative research methodologies to conceive data and conclusions. First, it reviews the literature to define debates around voluntary carbon offsetting and clean cooking and appropriates them in the mitigation toolbox of developing countries. Furthermore, the thesis offers a case study about cookstove projects and carbon offsetting in Nepal to test concepts of the literature. Case studies are recognized as strategic qualitative research methodology and valuable in understanding complex social realities. As opposed to quantitative hypothesis testing, they help to gain insight and proper interpretation of the research topic. The researcher acquires a holistic view through the diversity of sources and certain generalizations are possible by well-founded conclusions. (cf. Mohd Noor 2008)

The case study builds upon eight *in situ* semi-structured expert interviews with the most relevant stakeholders in carbon offsetting and clean cookstoves in Nepal. While a structured interview contains a limited set of questions and is formalized, the social science research method of a semi-structured interview presents itself more flexible. The possibility of open responses allows for accessible, adaptable and intelligible data collection since the researcher enjoys the freedom to follow up on what was said. (cf. Kallio et al. 2016; Qu and Dumay 2011) The interviews were conducted in a consistent and systematic manner, with a flexibility to probe into issues to elicit elaborate answers. The responses were recorded in writing and are attached in Appendix A. The questionnaire was guided by three themes of i) general questions about the institution ii) the voluntary carbon market and iii) clean cookstove programs in Nepal. All interviewees declared their consent on publishing their answers. Epistemologically, the answers are viewed as true accounts of the social and environmental reality in Nepal.

In an interdisciplinary approach, this thesis reveals scientific positivist findings and contextualizes them in the socially constructed and negotiated paradigm of the climate regime and mitigation policies. In other words, the positivist view of natural science on i.e. climate change science is supported, yet, to make sense of them in the social world requires hermeneutics. Hence, this thesis does not aim to causally explain, but to understand and describe the issues surrounding VCO and clean cookstoves. Moreover, the focus on financial flows from the VCO market to developing countries implicitly supports notions of 'climate justice' and distributive concerns. Several (neo)realists and functionalists argue that in the international policy domain justice is a redundant term because states maximize their utility in an anarchic structure. However, subsequent chapters disburse constructivists arguments that norms and ethical considerations are intrinsic to climate negotiations and existing practices. (cf. Okereke 2011)

Following this introduction with the problem statement, associated methodology considerations and theoretical underpinnings, a structured approach with five chapters responds to the research question. Chapter 2 describes the Earth's climate system and challenges of climate change. Section 2.1 introduces and quantifies Earth's cumulative carbon budget to remain within the PA 2°C goal. The subsequent fragment discusses equity concerns and 'climate justice'. These concepts coupled with an economic rationale of cost-effectiveness materialized in the CDM and other carbon markets (Chapter 2.3). Chapter 3 builds upon the wisdom of climate justice and compliance markets and introduces the decentralized voluntary carbon scheme. First, it justifies their importance and reveals recent developments (Chapter 3.1). Second, the economic performance in VCO volume transacted and offset price development are construed (Chapter 3.2). The last two sub-chapters contextualize two common standards and criticism of VCO. Following, chapter 4 spans to clean cooking and discusses the global picture. 2.8 billion people have no access to modern cookstoves, where the funding gap can potentially be covered by carbon markets. The part further presents methodologies for assessing improved cookstoves' ER in [tCO_2e]. Subsequently, chapter 5 provides a case study of Nepal's context, its national cookstove programs and potentials of the voluntary carbon market. The country faces substantial challenges of IAP, deforestation and lack of financing, which may be engaged by voluntary carbon markets.

The discussion (Chapter 6) and conclusion answer the research question. Indeed, voluntary carbon schemes do not constitute an effective mitigation instrument for developing countries in quantitative terms because transaction volume is marginal and prices do not reflect the external costs of one tCO_2e. However, the VCO's foundation of equity principles and structural reform are promising and inform current carbon scheme negotiations. In addition, the carbon market is paramount in localized capacity building and improving livelihoods, a claim supported by Nepal's experience. Lastly, synergies between the PA objectives and the SDGs emerge as a strong rationale for sectoral action.

2. Climate Change Science and Mitigation

This part briefly discusses main findings of the Intergovernmental Panel on Climate Change (IPCC), the role of carbon accounting, and finally carbon offsetting markets as mitigation approach. Anthropogenic activity impacts the climate system in three major ways. First, humans increase atmospheric GHG levels which absorb and emit solar radiation. Second, the emission of aerosol particles influences short-wave radiation fluxes and leads to a warming or a cooling of the troposphere depending on the fraction of black carbon (BC). Third, land surface properties are transformed, thereby altering albedo and absorption patterns. (cf. Gramelsberger and Feichter 2011; IPCC 2015) Accordingly, carbon offsetting may respond with mitigation projects targeting those human activities.

The Earth's climate represents a complex system where interdependencies and feedbacks between the atmosphere, biosphere, hydrosphere and anthroposphere must be studied. Climate models and simulations now increasingly represent such earth system models that consider *inter alia* atmosphere-ocean models, biological processes, the carbon cycle, land use change and human behaviour. Essentially, the climate system depends on the energy the Earth receives from the sun, the amount it radiates back into outer space, and the distribution of energy fluxes throughout the climate system. The Stefan Boltzmann law approximates this energy radiated from the Earth, which is proportional to the fourth power of the absolute temperature of -18°C. The atmospheric temperature T_a may be approximated by the formula $T_a = \sqrt[4]{\frac{S(1-A)}{2\delta(2-\alpha)}}$. GHG such as water vapour, CO_2, CH_4 and N_2O, but also BC aerosols, absorb the energy of a broad wavelength spectrum and thereby heat up the atmosphere. They act as a 'natural' shield that maintains the average global temperature of +15°C. In principle, it is possible to calculate an estimate of temperature change due to an increase in CO_2 concentrations. (Gramelsberger and Feichter 2011, 13ff; IPCC 2015)

As measured and visible in the so-called Keeling curve (Fig. 1), the CO_2 concentration in the Earth's atmosphere has continuously increased over the last decades. In pre-industrial times it was around 280 ppm by volume, in 2005 379 ppm with an additional radiative forcing of +1.66 Wm^{-2} and in February 2018 the atmospheric CO_2 concentration lay at 404 ppm. Scholars have argued for different 'safe' threshold values. However, most scientists have concluded that 'the 2°C increase […] requires stabilization at 450 ppm CO_2-equivalent in the long term.' (Gramelsberger and Feichter 2011, 81; IPCC 2015)

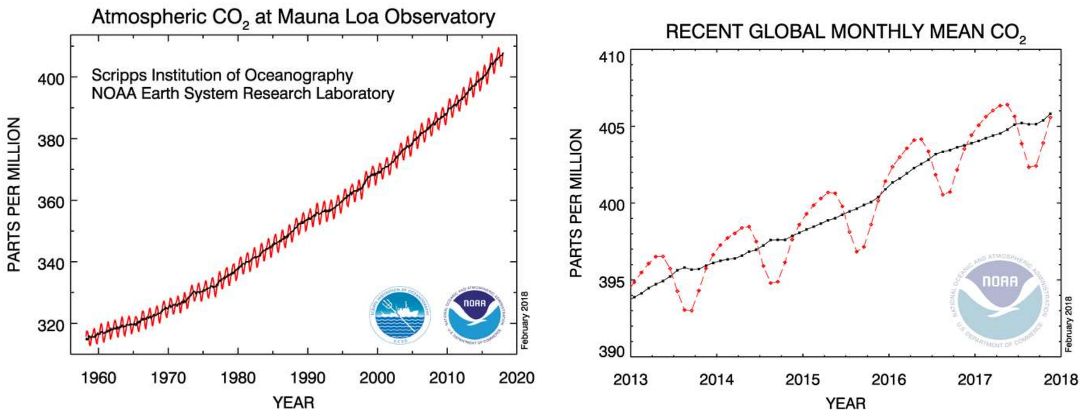

Figure 1. The 'Keeling curve' has measured atmospheric CO_2 levels since 1958. (Graphs from NOAA 2018)

However, there remains considerable uncertainty about the effects of increased GHG concentrations since only around 40 percent of warming is directly linked to the GHG effect and the rest depends on several feedback mechanisms. After this short description of the Earth's climate system, the next part summarizes main IPCC findings about climate change and discusses the role of carbon budgets.

1.1. The IPCC, Climate Forcing Species and Carbon Accounting

The IPCC represents a UN body established in 1988 to provide policy-relevant and scientifically sound knowledge and assessments about climate change. It has established itself as an honest broker between science and politics and all participating states approve the authoritative Summaries for Policymakers. (Ascui and Lovell 2011) In its most recent

Fifth Assessment Report, the IPCC (2015) finds that the climate system's warming – or climate change – is 'unequivocal'. The 30-year period 1983 to 2012 was likely the warmest in the past 1400 years. In fact, the Earth's atmosphere has warmed by 0.85°C since 1880. Currently, global mean temperature is increasing at almost 0.2°C per decade, and combined with El Niño effects total warming surpassed 1°C in 2015 and 2016. (Millar et al. 2017) Climate change associated risks and adverse effects are recognized by the international community *inter alia* in the UNFCCC, the 2030 Agenda for Sustainable Development and the PA.

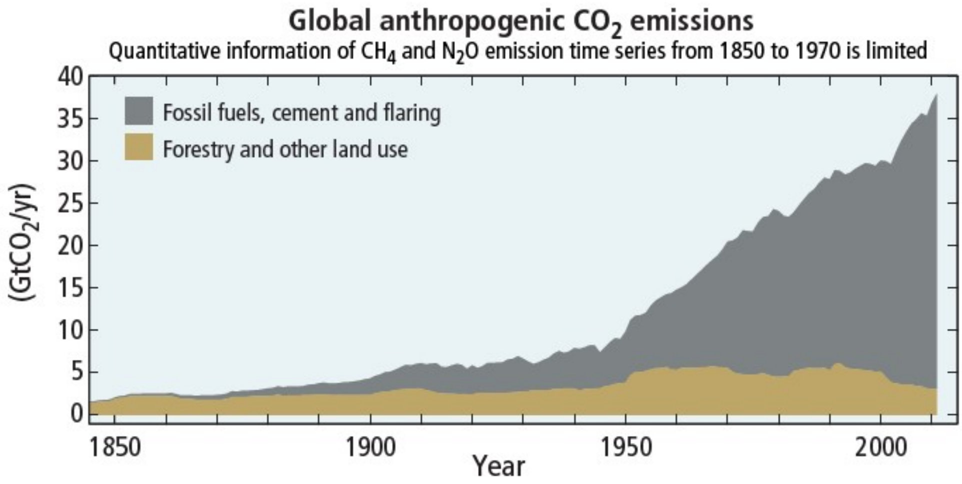

Figure 2. Cumulative anthropogenic CO_2 emissions. (Graph from IPCC 2015)

The IPCC report further leaves no doubt about a causal relationship between GHG concentrations and rising global mean temperatures. Current atmospheric concentrations of CO_2, CH_4, and N_2O are unprecedented in the last 800,000 years and their effects are '*extremely likely* to have been the dominant cause of the observed warming since the mid-20th century.' (italics in original; IPCC 2015, 4) There exists consensus that GHG emissions, coupled with other factors such as land use change and feedbacks, are a main factor for accelerated warming of the climate system. (Meyer and Steininger 2017) Between 1750 and 2011, the cumulative CO_2 emissions of humans were around 2040 $GtCO_2$, of which around 40 percent have remained in the atmosphere. As can be seen in Figure 2, anthropogenic GHG emissions experienced larger absolute increases between 2000 and 2010, despite mitigation policies. In 2010 total anthropogenic GHG emissions were 35 $GtCO_2$ and 49 $GtCO_2$-equivalents (IPCC 2015), by 2014 human GHG discharge already increased to 52.7 $GtCO_2$-equivalents. (UNEP 2016) Meanwhile, the oceans have absorbed 30 percent of emitted anthropogenic CO_2. Hence, next to global warming, raised CO_2 concentration has also resulted in ocean acidification. The pH value of surface water, measured in hydrogen ion concentrations, is now 0.1 lower than in pre-industrial times. (IPCC 2015)

Additional adverse effects of the observed and projected climatic changes include sea-level rise, changes in the hydrological cycle and increased frequency of weather extremes. Moreover, regions and people are disproportionately affected with i.e. the Arctic warming considerably faster than the rest of the globe. (cf. IPCC 2015) Another difficulty is the differing atmospheric residence time of the GHG. CO_2 remains for 5 to 200 years in the atmosphere, CH_4 for 12 and N_2O for 114 years.

Carbon dioxide constitutes the major but not only anthropogenic GHG, and therefore emissions have been coined in CO_2-equivalents (CO_2e) which corresponds to the impact of different GHG in terms of the amount of CO_2 that would create the same warming. Global Warming Potential (GWP) is a measure of how much energy the emissions of a mass unit of a gas will absorb over a given time relative to a mass unit of CO_2. By definition, the GWP of CO_2 equals one. For establishing market-based ER schemes with different climate forcing agents the GWP metric provides a useful tool. It allows policy-makers and project developers to compare multiple options of 'CO_2 equivalent' ER possibilities. This differentiation accounts for high radiative efficiencies of some short-lived radiatively active substances such as BC, CH_4, ozone and hydrofluorocarbons. (Allen et al. 2016) Generally, the GWP is integrated over a time horizon of 100 years and one unit of CH_4 then holds a GWP of 23 and N_2O 296. (cf. IPCC 2015) However, this methodology of GWP and CO_2e has gained criticism for *inter alia* arbitrary time frames and a lack of accounting justification. Still, it offers useful applications for carbon markets and provides a comprehensive view of non-CO_2 GHG.

More recently, a survey paper by Bond et al. (2013) foregrounded the significance of BC emissions and their forcing on the climate system. BC particles affect the global climate by solar radiation absorption, alterations of albedo properties as well as through influences on liquid water and ice cloud properties. The magnitude of the climate effects depends on the BC fraction in the respective aerosol mixture and on the mechanism of the climate impact. Notwithstanding, Bond et al. point out that BC emissions constitute the 'second most important human emission in terms of its climate-forcing in the present-day atmosphere.' (5381) It was estimated that BC emissions add a positive forcing of +1.1 Wm^{-2} and substantially warm the climate. The 100-year GWP of BC was placed on average at 900 within a range of 120 and 1800. However, due to the relative short atmospheric residence time of BC compared to GHGs, and the different physical interactions of aerosols and GHGs, the development of such metrics of BC and CO_2 comparison should be applied with caution. (Sarofim 2010) Of the total 7500 Gg yr^{-1} BC emissions in 2000, the burning of biomass for cooking emitted about 1300 Gg BC. After grass and woodland burning it constituted the second largest single source. (Bond et al.

2013) However, very large uncertainties >90 percent remain and conclusive evidence on climate effects of BC and the role of cookstove emissions must be further investigated.

These findings that 'cumulative emissions of CO_2 largely determine global mean surface warming' (IPCC 2015, 8) have led to the determination of a global 'carbon budget'. In this regard, 'carbon' does not only describe CO_2, but additionally relates to elemental carbon and stands shorthand for all GHG. (Ascui and Lovell 2011) Illustrating the cumulative nature of GHG emissions, the global carbon budget describes the anthropogenic GHG that may be added to the planet's atmosphere while keeping temperature increase to 1.5 – 2°C with a probability of 67 percent. Probabilities are applied because scientists cannot calculate precise amounts due to the complexity of the climate system. (Meyer and Steininger 2017) According to the IPCC, the total accumulated anthropogenic emissions must remain below 2900 $GtCO_2$ to achieve the 2-degree goal, making climate change principally a function of cumulative emissions. This translates to a maximum of 800 $GtCO_2$ cumulative anthropogenic emissions that may still be added to the atmosphere. Others found that limiting temperature rise to 1.5 degrees in a 'as likely as not' case, the remaining budget translates to only 370 Gt Carbon. (Millar et al. 2017)

Based on these considerations of the 2-degree goal, the global carbon budget and GWP, the annual 'Emissions Gap Report' is published. The gap is an authoritative estimate of the additional reductions necessary to ensure the goals. The 2016 report, accounting for the NDCs, found that for a 2°C scenario the emissions gap until 2030 equals 12 to 14 $GtCO_2e$, which may serve as a threshold for parties to the PA. (UNEP 2016) In a similar vein, the term 'carbon footprint' has been coined to inform an individual perspective. The carbon footprint in essence 'is a measure of the exclusive total amount of carbon dioxide emissions caused by an activity.' (Pandey et al. 2011, 137) Calculating the carbon footprint is relevant for several reasons. First, it allows to translate the global carbon budget to individual activities and enables comparability. For instance, some projects have tried to compute the maximum 'permissible' emissions per person to close the emissions gap. Second, the carbon footprint puts a price tag on consumer goods and activities and facilitates money transactions. It enables pricing CO_2 release and offsetting, thereby influencing consumer choices. Lastly, the quantitative expression aids in emissions management and evaluation of mitigation measures. There exist three ISO standards and IPCC guidelines for the calculation of a carbon footprint (Ibid.) and the World Bank runs an exhaustive database with country data on the median CO_2 footprint of a person.

1.2. Climate Justice and Restitution

Climate Change exacerbates several risks such as increases in climate-related hazards, threats to food security and changes in water supply. Sea-level rise even poses an existential threat to some small island states and low-lying coastal areas. Clearly, climate-related risks are unevenly distributed and are generally greater for disadvantaged people and developing countries. (IPCC 2015, 13) Nepal, for instance, is responsible for only 0.03 percent of total global GHG emissions. The average Nepalese emits 0.3 tCO_2 per year, as opposed to 6.7 tCO_2 per capita in Austria. (World Bank 2018) Nevertheless, the country is and will be disproportionately affected by the adverse effects of GHG emissions. Millions of Nepalese are at risk from climate change impacts, including by reduced agricultural output, glacier outbursts, strained water resources, and reduced tourism. (AEPC 2017a; WHO 2016)

The fact that mostly industrialized countries have contributed to anthropogenic climate change through their GHG emissions and that overwhelmingly developing countries suffer from the negative effects due to their exposure and reduced adaptive capacities has led to debate around 'climate justice'. Within the debate, disparate approaches from economics through political science to international law have been followed. (cf. Okereke 2010; IPCC 2014, Chapter 3) Following the IPCC conclusions and the PA, CO_2 emissions are required to be limited, which leads to distributional questions of the 'scarce resource' CO_2. (McKinnon 2015, 374) Such issues of emissions 'rights' partly ask moral and political philosophy to resolve global warming's ethical implications. Mainly, questions of distributive and corrective justice are raised, both between rich and poor regions and between generations[3]. Distributional justice concerns are intrinsic to the climate change regime in that it requires industrialized states to support developing countries in mitigation and adaptation efforts. (IPCC 2014, 211) Principally, climate change involves rich countries imposing risks and challenges on developing regions, and avoiding issues of justice would remove the purpose of a climate regime. It has been convincingly argued that *responsibility*, *capability*, and *need* constitute the core norms of the climate regime. (cf. Okereke 2010; McKinnon 2015)

There exists a wide range of classifications of applicable justice in the climate regime. Next to the general term *distributive justice* that describes the distribution of future and present responsibilities, there have been propositions for compensation of past harm (*compensatory justice*) and around fair procedures and inclusive decision-making processes (*procedural justice*). (McKinnon 2015) Admittedly, some principles and practical

[3] This text sidelines intergenerational justice debates. For an overview see Walsh et al. 2017.

implications derived from this intrinsic notion of justice feature prominently in climate change policies and the carbon market.

Many scholars have argued that those with exceeding emissions allocations are *prima facie* liable to provide compensation to those people and places suffering from the adverse effects. In the climate regime, this has been incorporated by the principle of ‘common but differentiated responsibilities’, which was introduced by the UNFCCC. Moreover, the polluter pays principle requires rich countries ‘to pick up the bill’ for their emissions. (Okereke 2010) However, culpability for development challenges is not linear and the extent of the applicability of the polluter pays principle in mitigation policy is still debated. The principle and compensatory justice, however, go hand in hand and justify financial flows from the global North to South within the carbon market. Those who emitted more GHG in the past and benefited thereof ought to bear a higher proportion of climate change mitigation and adaptation costs. (McKinnon 2015) Some scholars and civil society actors have used this advocated injustice to estimate North-to-South transfers ranging from an annual 100 billion USD to a natural debt of 529 billion USD. (Okereke 2010, 468) Moreover, the equity principle acknowledges that in the medium-term per capita GHG emissions should approach each other worldwide, meaning inhabitants of developing countries may emit more and those in industrialized countries less. (Meyer and Steininger 2017) Lastly, the climate regime incorporates additional principles of precaution, cooperation, and cost-effectiveness. (cf. IPCC 2014, 1008)

Next to deliberations on justice, the climate regime has largely relied on neoliberal economic thinking. In fact, ‘[e]conomic analysis will undoubtedly be at the heart of government assessments of how best to deal with these [climate change] problems.’ (Walsh et al. 2017, 2) This is also due to the global commons character of climate change. Mitigation costs are borne by individual actors and benefits spread around the world. This free-rider problem has arguably led to limited mitigation ambition and ‘overuse of the atmosphere as a receptor of GHG.’ (IPCC 2014, 1007) A seminal work was advanced by John Broome’s *Climate Matters: Ethics in a Warming World,* where he noted that economic mainstream is deeply embedded in climate policies and the regime it created. The case for incorporating economic thinking is strengthened by the realpolitik that governments are conditioned by market principles. Economic theory provides essential tools and thought models of i.e. efficiencies, cost-effectiveness and benefit maximization. Due to the longevity of capitalism, new markets for trading carbon allowances and balancing competing societal goals have formed a major mitigation repsonse. (cf. Ibid.; Newell and Paterson 2010) Capitalist economic approaches provide the thought pillar for carbon markets as appropriate and effective climate change mitigation tool.

This thesis explores only briefly individual liability, assuming that both governments and societies are affected by distributive justice and compensation for past and present GHG emissions. It suffices to note that there exist compelling arguments for individuals with high carbon footprints owing restitution to those suffering from climate change. Arguably, once you are individually responsible for excessive GHG emissions and benefit from them while harming others you undertake an unjust act. The ensuing duty of a balanced personal GHG budget may be enacted through VCO, since 'restitution can be accomplished by completely offsetting emissions.' (Nordhaus 2014, 1135)

The intrinsic distributive justice (climate justice) concerns, notions of equity and the prevalent economic thought have informed the creation of international carbon markets. Hence, carbon finance does not constitute another form of development aid, but a market mechanism for the global common 'climate'. The subsequent part briefly describes such mechanisms under the Kyoto Protocol.

1.3. Mitigation and Carbon Offsetting Markets

Climate mitigation describes the human intervention to reduce the sources or enhance the sinks of GHG emissions to achieve Art. 2 of the UNFCCC, namely the 'stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.' Prevalent mitigation strategies have included fostering behaviour change, fuel switch, carbon capture and storage, national policies and emission permit trade. They may be divided into 'command and control' and 'market based' mitigation approaches. (Dhanda and Hartmann 2011) As observed, economic thinking has dominated mitigation policy and climate change been framed a collective action problem. The Stern Review in 2006 even famously pronounced climate change the world's greatest externality. Hence, international cooperation is required to address climate change and indeed, burden sharing through a market approach has become a favoured policy option. (cf. IPCC 2014) In this sense, '[p]robably the most ambitious attempt at a global response to climate change is the introduction of market mechanisms for reducing greenhouse gas emissions.' (Gramelsberger and Feichter 2011, 6) This chapter briefly discusses the Clean Development Mechanism (CDM) and relevant debates around it.

Classic economic theory prescribes that the abatement of one ton of CO_2e carries the same effect on the global climate irrespective of location. Hence, economists and policymakers agreed in the 1997 Kyoto Protocol to introduce four flexible market mechanisms to reduce compliance costs for Annex I countries and increase ER opportunities by global trading. They included i) Target reallocation [Art. 4] ii) Joint

Implementation [Art. 6] iii) the CDM [Art. 12] and iv) International Emissions Trading [Art. 17]. The latter two allow countries to sell unused shares of their allocated carbon budgets to other countries. The CDM regulates mitigation projects that reduce GHG emissions and generate credits in non-Annex I countries without an emissions budget. The credits are coined Certified Emissions Reductions (CER) and were first generated in 2001. (Vasa and Michaelowa 2011, 128f) Accompanying, a detailed set of rules, controlled by external auditors, was installed. The principle of additionality represents a cornerstone in this regard, i.e. 'that a CDM project would not have happened without the CER incentive.' (Ibid., 128) In short, the CDM assists developing countries without emission targets in promoting mitigation action and simultaneously helps developed Annex I parties to comply with their ER commitments in a cost-effective way.

A broad range of GHG reducing projects and activities are eligible under the CDM, such as hydropower, wind energy, fuel switching, forestry, industrial efficiency and cookstove improvements. Additionality is calculated by applying an approved methodology to subtract estimated emissions of a CDM project from a hypothetical business-as-usual scenario (see Chapter 4.2 for cookstoves). This calculation is presented in the Project Design Document (PDD) that the project developer submits to the Designated National Authority (DNA) of a country for the letter of approval. Next, the PDD is validated by an accredited external certifier. Following, the registration of the activity makes the project an official CDM activity and is a prerequisite for verification, certification and issuance of CERs (the offset cycle is further described in Chapters 3 and 5.4).

The issued CERs represent one tCO_2e and may be bought and retired by developed countries, but also companies and individuals to meet own ER targets through voluntary schemes. (UNFCCC 2018a; Newell and Paterson 2010) Linkage is a generic term that describes the mutual recognition of international carbon credits. Increasingly, the mechanism 'as a robust standard to ensure quality emission reductions has also put the CDM in a good position to be used outside the UNFCCC context.' (World Bank 2017, 39) The linkage of CDM CERs external to the Kyoto Protocol compliance scheme makes the credits available on voluntary markets, as will be discussed in subsequent chapters.

Since its establishment, the CER market has grown substantially. By 2012, 215.4 billion USD in investments were channelled through the scheme, presumably avoiding 3.6 billion USD in compliance costs for Annex I countries. By the end of 2017, more than 7,800 CDM projects were registered and 1.9 billion CERs issued[4]. (cf. UNFCCC 2018a) The CDM has

[4] For a detailed description of projects, crediting periods and CERs issued refer to the CDM Registry at https://cdm.unfccc.int/Projects/ .

developed from an originally designed flexibility mechanism to an integral part of a fully-fledged global carbon market. (Newell and Paterson 2010, 85)

This has occurred partly due to the interlinkage with the EU Emissions Trading Scheme (EU ETS), facilitated by the EU Linking Directive 2004/101/EC. (Vasa and Michaelowa 2011, 133) The EU ETS represents the world's largest compliance carbon market[5], covering three-quarters of international carbon trade through a cap-and-trade scheme. Approximately two billion tonnes of CO_2e are included, accounting for around 45 percent of total EU GHG emissions. The possibility to purchase CERs from projects in developing countries proved controversial. Prices of the CER lay substantially below EU allowance costs, leading to an excess supply. Consequently, CERs were banked for future use as financial speculation and hedging item. Consequently, the European Commission unilaterally imposed a 1.3 billion limit of 'outside' allowances (cf. Ellerman et al. 2016) and decided that all imported CERs should stem from LDCs. (Lee et al. 2013)

The CERs have experienced substantial price fluctuations due to varying policies, high supply and the economic and financial crisis of 2007/08. First, it is important to note that there exists not one CER price because project activities result in different prices for one tCO_2e. Cookstove program credits, for instance, are considerably more expensive than CERs from large-scale wind power proliferation. Nevertheless, a genuine decline in CER average prices has been observed. Before 2008, the CER value was consistently above 20 USD per tCO_2e, whereas it fell to an average of five USD in 2008. Currently, some CERs are available for below 0.50 USD and the highest prices lie at around 10 USD. (cf. UNFCCC 2018b) Figure 3 displays the drastic fall of secondary CER prices vis-à-vis credit issuance. This price volatility increases the uncertainty of project developers about the generated revenue and will be discussed in Chapter 5.

[5] An overview of the world's carbon markets is provided by the World Bank's annual report *State and Trends of Carbon Pricing*.

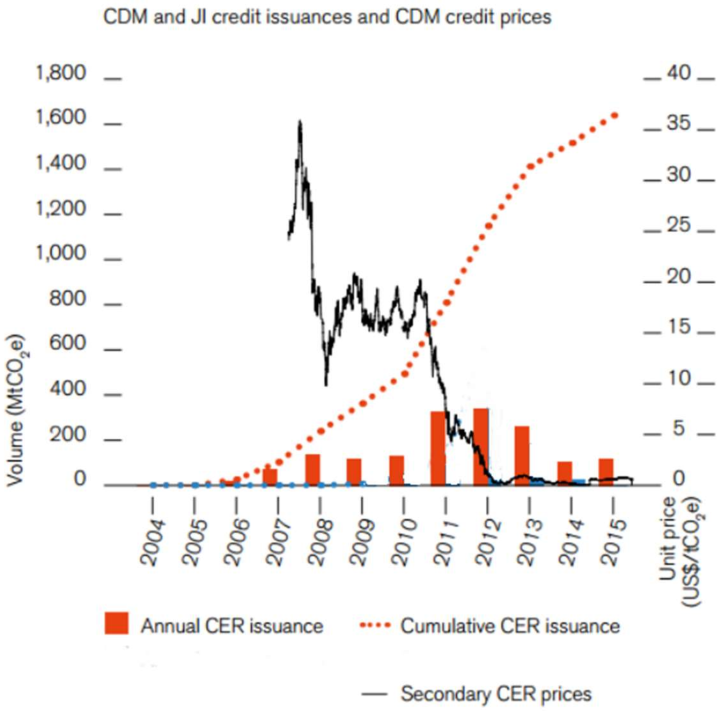

Figure 3. CER issuance and price development since 2004. (adapted from World Bank 2017)

Nonetheless, the CDM and carbon markets concur not only with ‘low-hanging fruit’ for investments, but carry important benefits for developing countries. First, a substantial amount of rents remains in the country. Second, they enable carbon entrepreneurs in the global South to connect investment opportunities with climate action and sustainable development. Institutions such as sector-based business associations and chambers of commerce have been strengthened in their capacities and training events led to (human) capital accumulation. In this vein, the CDM has enabled climate entrepreneurs to facilitate *inter alia* factory upgrades, clean technology proliferation and awareness raising for co-benefits of social and economic development. It has been immensely successful in establishing structures with a focus on climate action and decarbonised development. Moreover, the CDM embodies a channel of redistributing resources based on climate justice concerns. (Newell and Paterson 2010, 82ff; IPCC 2014) In fact, the very existence and continued application of the CDM constitutes an equity policy compensating for excessive GHG emissions from industrialized Annex I countries. (Okereke 2010)

Proponents of the carbon offsetting market and the CDM point to the economic efficiency gains which lead to more GHG reductions at a lower cost. In this sense, the CDM has become the ‘jewel in the crown of the three Kyoto Protocol mechanisms’ (Newell and Paterson 2010, 83) because it has reduced three times more carbon emissions than anticipated. Next, the CDM has advanced multilevel and multi-stakeholder engagement by creating novel responsibilities for sub-national communities and the private sector.

Certainly, the scheme enhanced local capabilities and improved the livelihoods of people in developing countries. It has fostered the sustainable development of the global South, sidestepping carbon intensive industrialization steps.

Meanwhile, practical challenges have been a volatile and decreasing price for carbon credits and high transaction costs. These deter potential market participants since there is no guarantee of receiving the CERs and associated revenue at the point of designing and investing into a CDM project. Indeed, the risks and costs are paid in advance and run into the tens of thousands of dollars. (Newell and Paterson 2010; Appendix A) There has also been plenty of criticism voiced about the CDM modalities. First, opponents argue that it provides a cheap way out for developed countries to avoid cutting own emissions. Second, foremost environmentalists argue that the CDM represents a perverted scheme of managing the global common climate by allocating private property rights to it. Thereby, humans become deprived of nature through economization and financial profit maximization. Moreover, around 80 percent of CERs have been generated by only two countries, China and India. Thereby, the sustainable development and financial benefits of most developing and LDCs have been marginal. (Okereke 2010, 470f; Böhm et al. 2012)

Critics further tabled a more fundamental flaw in the CDM, in that it is inconceivable to prove the 'additionality' of a project in comparison to a hypothetical baseline. The generation of CERs may be viewed an artificial product in a capitalist market scheme. This argument is partly supported by the empirical evidence that GHG emissions have increased even more sharply since the introduction of the CDM (cf. Chapter 2.1), thereby questioning the real-world effect of carbon markets. (cf. Böhm et al. 2012) Another criticism about the CDM originates in the climate justice debate. Whereas it is equitable to assign emissions amounts per capita and therefore foster reductions in the global North, carbon markets lead to the exact opposite. Critics argue that the purchase of CERs leads to renewed large GHG emissions in the industrialized countries while developing regions carry the burden of reducing CO_2e concentrations. (cf. Whitington 2012) Undoubtedly, debates around practical and ethical implications of carbon markets are not yet resolved.

Some considerations make it relevant to investigate the voluntary carbon offsetting (VCO) market. First, as compliance demand for CDM offsets has decreased, some project developers have turned to voluntary markets to sell the credits. (Hamrick and Gallant 2017a) Second, although carbon markets have emerged as a primary tool of international climate policy, they ‘can be created and destroyed with a stroke of a pen.’ (Vasa and Michaelowa 2011, 142) The markets suffer from inherent uncertainty created by political decisions and a lack of long-term legal commitments. Political actors such as the EU and more recently the US have sent both adverse and supporting signals to the carbon market. As can be observed in the following chapter, VCO schemes are less vulnerable to political decisions. Moreover, they create the structures and possibilities for sub-national actors and individuals to reduce their carbon footprints.

2. Voluntary Carbon Offsetting Markets

As discussed in the previous chapter, the private sector, individuals and NGOs have become subjects and agents of carbon markets. Since they are mostly under no legal obligations to measure and rectify their GHG emissions, they act within the voluntary carbon offsetting (VCO) scheme. One major strength is the focus on individual and per capita emissions, which is intrinsically fair because it recognizes equal entitlements to the global commons. (cf. Newell and Paterson 2010; Dhanda and Hartman 2011) It is important to note that there is not one single voluntary carbon market, but that it combines the transactions between climate mitigation project developers, traders, and purchasing entities. There exists no formal governance structure and the market is by nature decentralized. It relies on companies, organizations and individuals who voluntarily measure and reduce their emissions footprints. (Guigon 2010) The underlying mantra states 'reduce what you can, offset the rest.' (Dhanda and Hartman 2011, 125) VCO occupies a small share of the carbon market, however it gained importance over past years.

Conversely, by 2018 several countries and regions introduced domestic compliance offsetting programs or policies to encourage national financing for sustainable technologies. Currently, there exist 42 national jurisdictions and 25 sub-national regions with carbon pricing initiatives. Not all apply carbon trading, however these initiatives provide a threshold of eight $GtCO_2e$ coverage, which equals 15 percent of global GHG emissions. (World Bank 2017) Prominent examples include $MexiCO_2$, Australia's carbon offsetting scheme and Japan's J-Credit. Essentially, they function along the same logic as transboundary mitigation and offset trading efforts.

Table 1 summarizes the compliance and voluntary carbon markets in terms of their governance, principal actors, volume and selected standards. As can be seen, the legal structure varies to a large extent whereas some of the actors are the same. This chapter only describes the VCO scheme, which forms an integral part of the research focus.

Table 1. Characteristics of the compliance and voluntary carbon markets. (Table by author)

	Governance Structure	**Principal Actors**	**Volume**	**Selected applicable Standards**
Carbon Compliance Market	Cap-and-trade	Supply: (Developing) countries, Designated National Authorities, project developers	Large: ~8,000 $MtCO_2e$ (2016)	CER; European Union Allowances; Emission Reduction Units; Assigned Amount Units
	Emissions Trading	Demand: Developed countries, sub-national governments, large companies		
Voluntary Carbon Market	Non-governmental Private Standards	Supply: Developing countries, project developers, firms, NGOs	Small: 63.4 $MtCO_2e$ (2016)	CER; Gold Standard; Verified Carbon Standard; Climate Action Reserve; American Carbon Registry; ISO-14064; Plan Vivo
	Market Exchanges	Demand: Companies, organizations, individuals		

Similar to the CDM, there exists a unique voluntary carbon offset lifecycle that regulates the process from project idea over offset issuance to retirement. It assures additionality, external auditing and quality standards. First, the process is initiated with a project idea note that assesses the feasibility of the mitigation activity. Next, a project design document (PDD) lays out the details of ER calculation against a baseline scenario. Third, an independent third-party auditor validates the PDD and after project implementation another auditor verifies the delivery of GHG mitigation. Together with the offset registry the offsets are issued in [tCO_2e] with a unique serial number that can be transacted multiple times before an end buyer retires it. (cf. Hamrick and Gallant 2017a; Figure 4) This way, the reduced CO_2e emissions represented by these offsets are 'removed' from the atmosphere. Nevertheless, finding a buyer may pose a challenge since there exists no single marketplace for voluntary offsets.

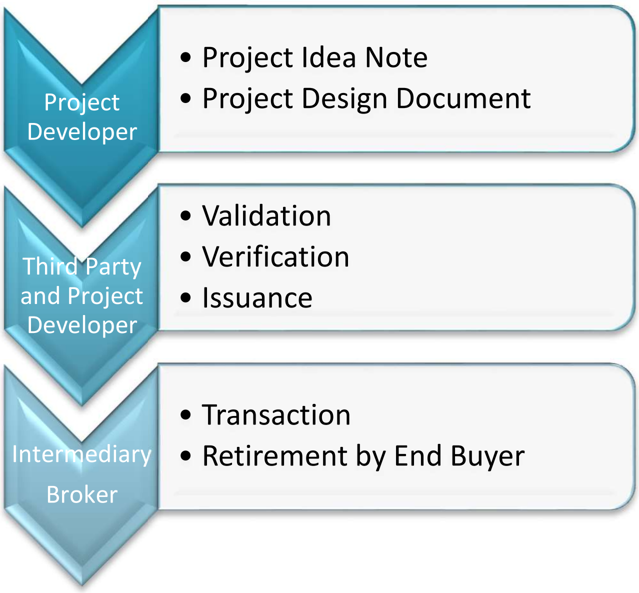

Figure 4. The Offset Cycle from Project Development to Retirement. (Adapted from Hamrick and Gallant 2017a)

The numbers in this chapter mostly stem from Ecosystem Marketplace and their reports, which are also used by i.e. the World Bank (2017). The amounts should be viewed as conservative since they rely on comprehensive, yet not complete, surveys. Chapter 3.2 scrutinizes the numbers in more detail. The report further contains relevant information on the structure of the market and the participation of developing countries.

3.1. Socio-Political and Legal Developments

The current regime for climate mitigation is decentralized and fragmented, however with a certain degree of flexibility regarding implementation measures. Only a few countries have priced GHG emissions and hence the global climate commons. Currently, 15 percent of global anthropogenic GHG output is covered by an ETS or carbon tax. (World Bank 2017) However, the 2015 Paris Agreement (PA) gave renewed political momentum to debates and initiatives around voluntary and compliance carbon markets. It is the first agreement to require both developing and developed countries to reduce GHG emissions and thereby increases opportunities for cooperation. However, it also foregrounds practical issues. Certainly, the accounting, standardization and verification of mitigation outcomes under a clear framework will be crucial. (World Bank 2017, 35) Arguably, the VCO scheme plays an important role in advancing such structures and innovative standards, i.e. the Gold Standard (Chapter 3.3).

A key provision within the PA is Article 6 that recognizes that Parties may voluntarily cooperate in the implementation of their mitigation commitments. Article 6.2 declares that states may meet their contributions by using 'internationally transferred mitigation outcomes', which is shorthand for generated and verified carbon credits. Then, Article 6.4 continues to establish a mechanism for GHG emissions mitigation and fostering sustainable development. It explicitly mentions public and private entities to participate in such a scheme. To manage the uncertainty on the role of the voluntary market under a future PA regime, the role of projects' host authorities is likely to increase. (World Bank 2017, 32ff)

Another important development has been the International Civil Aviation Organization's (ICAO) adoption of the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) in 2016. Essentially, international aviation will cap its GHG emissions at 2020 levels. Researchers and analysts estimate that CORSIA potentially generates demand for carbon credits worth 2,500 $MtCO_2e$ between 2021 and 2035. (World Bank 2017, 43) Similarly, proposals have been tabled and a roadmap agreed to develop a GHG emission reduction strategy for international shipping. Evidently, the VCO market potentially serves this immense demand for carbon offsets and should therefore be carefully studied.

Additional benefits of the voluntary carbon market to the aforementioned advantages of the CDM (Chapter 2.3) have been identified. First, voluntary schemes build capacities outside of official structures, notably through knowledge transfer, creation of standards, pilot projects and data generation. There exists some evidence that voluntary initiatives have been key in local low-carbon infrastructure development in the global South. (Guigon 2010) Moreover, the VCO markets are important to collect experience as 'pre-compliance' mechanism, as was the case with the Californian carbon scheme. VCOs often act as preceding step to compliance markets. Next, the voluntary market provides an arena for developing new methodologies and standards. It possesses more freedom to incorporate novel technologies and activities that reduce or sequester GHG emissions. (cf. Hamrick and Gallant 2017a) For instance, the World Bank's Biocarbon Fund financed the development of Verified Carbon Standard (VCS) methodologies assessing Agriculture, Forestry and other Land Use. Thus, VCO represents not only a complementary step to collective actions (cf. Nordhaus 2014), but may shape their emergence.

As mentioned in Chapter 2.2 the voluntary carbon market aims to internalize the externalities of GHG emissions, founded on underlying climate justice principles. The price for one tCO_2e claims to reflect the social cost of an emitting activity or product and compensate for it. Ethically, offsetting may hence alleviate concerns about one's carbon footprint and 'offset green guilt'. (Kotchen 2009) Arguably, '[o]nce carbon is appropriately priced, it can be placed in the ethical neutral zone.' (Nordhaus 2014, 1139) There exists a growing literature aiming to understand the social and economic factors why individuals choose to voluntarily pay for offsetting their carbon footprint. Answers are manifold and include the belief in procedural justice, social preferences, a 'warm glow', (Schleich et al. 2014) and the possibility of direct donations to substitute the consumption of an impure public good. (Lange et al. 2016)

For the present thesis it is not necessary to further delve into the issue why and who decides to purchase voluntary carbon credits. It suffices to describe the mechanism, note that VCO schemes are anchored in justice concerns and that VCO activities in the private sector have grown. VCO and 'carbon neutrality' represent popular marketing tools and influence consumer choices in developed countries. (cf. Schleich et al. 2014) Over 1,300 companies reported in 2017 to use an internal carbon price. That represents an 11 percent annual increase. Offsetting and low-carbon development present the opportunity to reduce risk and meet growing expectations on climate action. These companies, to varying degrees, integrate the negative externality of CO_2e emissions into their activities. (cf. World Bank 2017, 53ff; GS 2017) An essential advantage of the VCO market is that buyers can choose the type of mitigation activity to support. Because of the detailed PDD, it is practical to differentiate between the plethora of offsetting activities. It is i.e. possible to only purchase credits from cookstove programs.

Essentially, the importance of carbon markets is now largely recognized by international governmental and private actors. They measure their national GHG emission accounts and individual carbon footprints, thus enabling the trade of mitigation outcomes though linked markets. Together with domestic carbon prices, low-carbon development policies and climate finance, the voluntary carbon market constitutes an important pillar in achieving the 2°C goal of the PA. (cf. World Bank 2017, 60ff) Recent developments in societal proliferation of offsetting private activities' carbon footprint and 'carbon neutral' companies have aided the VCO market and are vital for future development.

3.2. Economic Aspects

After assessing some of the legal and socio-political developments around the VCO market, this part summarizes its main economic aspects. Despite a significant growth recently, the voluntary markets remain a niche. The most comprehensive data has been collected by Ecosystems Marketplace, who concluded that between 2005 and 2016 the annual volumes transacted in VCO schemes fluctuated between 12 and 135 $MtCO_2$e. From 2005 to 2008 the market grew rapidly from just 12.5 $MtCO_2$e to a 134.5 $MtCO_2$e peak. Subsequently, the volume transacted stayed above 100 $MtCO_2$e a year until 2013. Since then, the market volume contracted to between 60 and 85 $MtCO_2$e. In 2016, the analysts recorded certificate transactions representing 63.4 $MtCO_2$e. Parallelly, the cumulative volume of retired offsets reached more than one billion certificates. Figure 5 illustrates annual VCOs transacted over the last years. (Hamrick and Gallant 2017a) The decline in traded volume may be partially attributed to the conversion of voluntary credits into compliance mechanisms such as the California cap-and-trade program. Moreover, in 2016 at least 56 $MtCO_2e$ remained unsold, representing voluntary credits and ERs that have been verified but not monetarized. (cf. World Bank 2017, 42f) Hence, the voluntary carbon market represents a buyer's market with an oversupply of certificates in the registries.

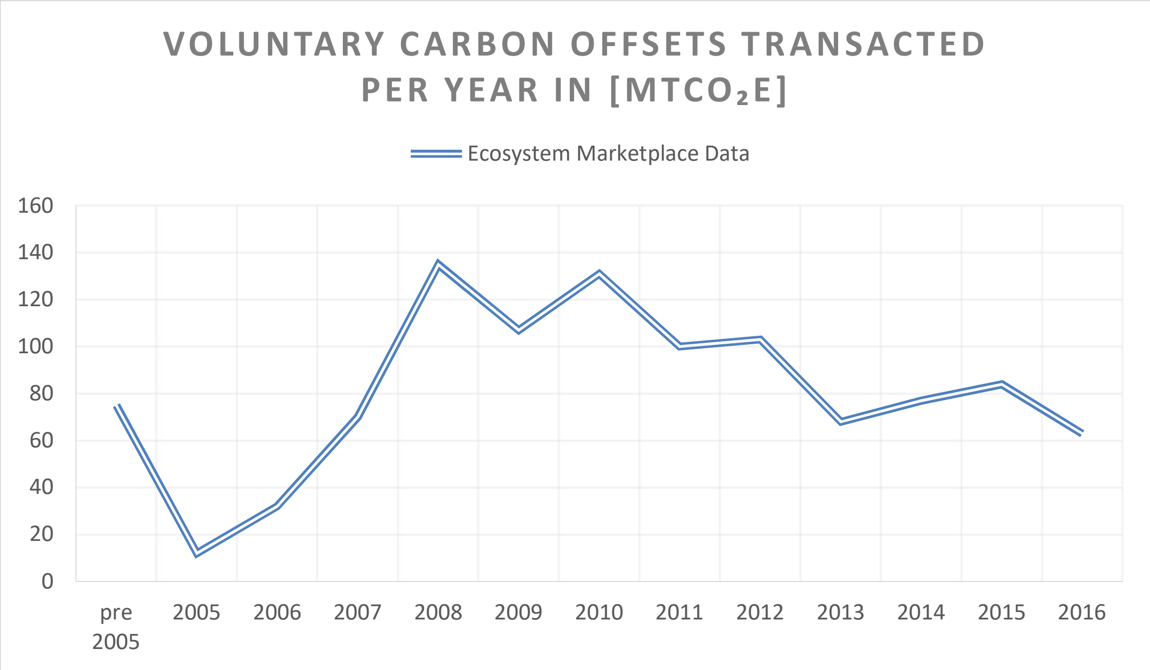

Figure 5. Voluntary carbon offset transactions per year. (Data from Hamrick and Gallant 2017a)

The 63.4 $MtCO_2e$ that were transacted in 2016 originated in 65 countries, mostly from Asia (21.5 $MtCO_2e$), followed by North America (10.1 $MtCO_2e$), Africa and Latin America (5.8 $MtCO_2e$ each), Europe (2.8 $MtCO_2e$) and lastly Oceania (0.6 $MtCO_2e$). This data relies on a total of 769 transactions representing 46.5 $MtCO_2e$ and is therefore only indicative for VCO origin. (Hamrick and Gallant 2017a) Nevertheless, it is relevant since it shows that a substantial majority of voluntary offsets were issued in developing countries. Assuming all countries in Asia belong to the Global South, more than 71 percent of project finances proceeded to developing countries (see Figure 6).

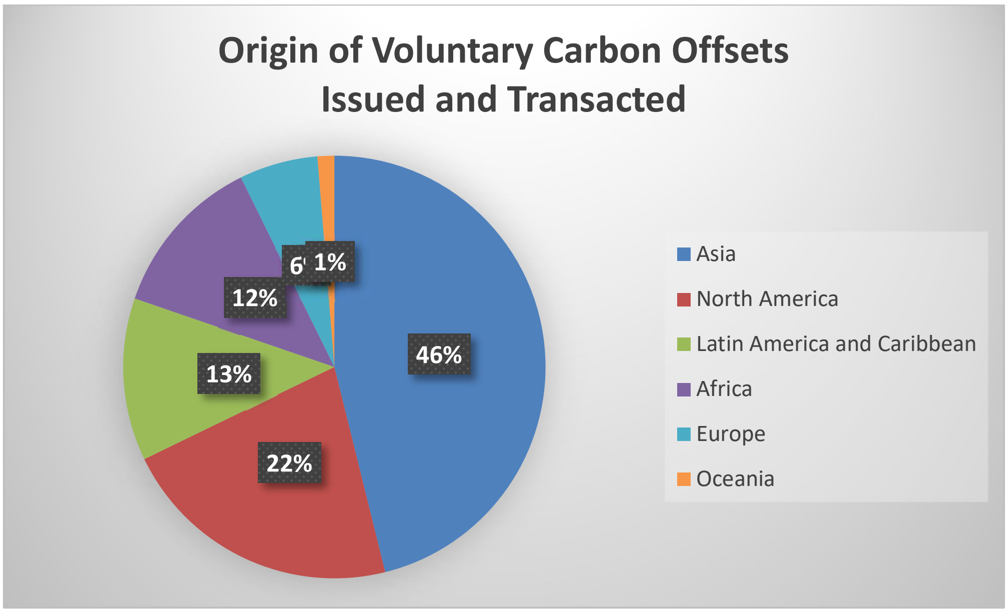

Figure 6. Transacted voluntary carbon offsets by origin. (Data from Hamrick and Gallant 2017a)

The buyers of voluntary offsets largely come from developed Annex I parties with the highest per capita GHG emissions. In 2016, 48 percent of the registered offsets were sold to European buyers and 38 percent to North American customers. The major customer categories for VCOs were for-profit companies, pursued by NGOs and individuals. (Hamrick and Gallant 2017b)

In theory, the reduction of one tCO_2e is the same around the world. In reality, buyers pay varying prices for voluntary offsets. Ecosystem Marketplace tracked prices between 0.5 USD to 50 USD for one tonne of CO_2e. In 2016, end buyers paid on average more for offsets (USD 4.7/tCO_2e) than retailers and brokers (USD 1.5/tCO_2e). The total value transacted, which does not include the unsold offsets, amounted to 191 M USD, which represented a record low since 2007. (Hamrick and Gallant 2017a) Figure 7 graphs recent market-wide VCO transaction values. Similarly, the World Bank observed in 2016 carbon prices between below one USD and up to 140 USD per tCO_2e. More than three quarters of carbon credits were priced below ten USD. It is estimated that price levels should reach 40- 80 USD per tCO_2e by 2020 to achieve the 2°C goal. (World Bank 2017)

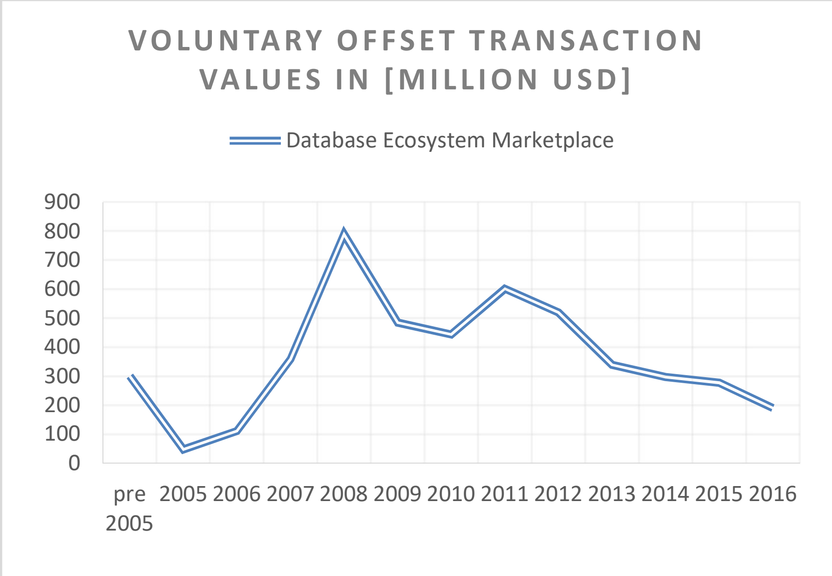

Figure 7. Total value of VCO transactions. (Data from Hamrick and Gallant 2017a)

Whereas compliance markets are commodities markets, the transactions of the VCOs take place in a decentralized market environment. Currently, there exist several small-scale carbon exchanges that comprise the secondary market. Next to these institutionalized transactions, an abundance of brokers and offset retailers has arisen in the primary market. Either they have partnered up with other companies, i.e. in airfare or event management, or offer own carbon footprint calculators and the possibility to offset. Lastly, bilateral retirements of VCOs are possible, such as the purchase of CERs directly from the UNFCCC website. As noted, this market environment leads to project activities being differently valued. For instance, cookstove offsets transacted at an average of USD 5.1/ tCO_2e in 2016, whereas landfill methane projects reached an average price of 2.1 USD. Buyers are influenced by a combination of attributes and may focus on so-called co-benefits when paying a VCO price. (cf. Hamrick and Gallant 2017a)

Low-carbon development may be coupled with economic growth and thereby lead to sustainable development. However, an ambitious carbon pricing, international market approaches and climate finance are necessary. The World Bank (2017) calculated an incremental investment need of annually 700 billion USD by 2030 to transition to a low-carbon economy. To add its resources and experience, the VCO scheme would need to be reformed and included in a PA Art. 6 arrangement. A crucial aspect are common standards and definitions to make climate markets efficient and environmentally robust. Therefore, the next part describes the two most prominent standards outside the CER.

3.3. The Gold Standard and Verified Carbon Standard

Using the CDM as a benchmark, several certification schemes have emerged in response to critique over a lack of quality control, corruption and absence of regulations. These carbon offset standards establish a set of procedures, requirements for project developers and ER verification. Most standards have also developed registries that guarantee transparency and integrity on carbon credit retirement. (cf. Guigon 2010)

In 2016, 99 percent of projects adhered to one of various standards. These require projects to submit to external third-party verification to ensure that they achieve the stated ER. These standards vary with project types and some also address non-carbon impacts, the so-called co-benefits. The most popular standards in 2016 were the Verified Carbon Standard (VCS) with 33.1 MtCO_2e transacted and the Gold Standard (GS) with 9.9 MtCO_2e retired. (Hamrick and Gallant 2017a) Both standards adhere to a common accounting methodology and use consistent recording of co-benefits. Moreover, permanence and additionality are ensured. The former indicates that GHG emissions are not simply delayed and the latter indicates that the ER would not have taken place without the carbon payment. Lastly, the standards prevent double-counting and leakage, meaning that retirement takes place only once.

The Gold Standard (GS) emerged in 2003 as a response to the criticism of the CDM's poor record in fostering sustainable development. First it represented a 'luxury label' of the CDM pipeline (cf. Drupp 2011), yet developed into an independent organization promoting and certifying long-term ER compatible with sustainable development. It was established by the Worldwide Fund for Nature and other INGOs to ensure additionality through clear criteria. Next to the focus on GHG ER, the GS equally incorporates a human-centred approach. Its certified projects must include local stakeholders and contribute to at least three SDGs. The PDD and verification requirements therefore include explicit sustainable development parameters. (GS 2017) The GS adds sustainable development as key commodity to the tCO_2e abated. Hence it is claimed that the GS 'acts as a best-practice benchmark and […] establish[es] a premium price for higher SD [sustainable development] benefits.' (Drupp 2011, 1214) Previously, the GS price premium was found to be around 5- 20 percent compared to CERs. (Ibid. 1215) Its offset cycle follows the procedure described in the introduction to this chapter. However, the GS excludes all project types that do not improve local populations' lives and applies conservative calculations of baseline scenarios and mitigation measures. (Interview C) In an empirical comparison, Drupp (2011) concluded that GS labelled credits indeed can be associated with distinctly higher SDG-related benefits. The administrative burden of the GS depends on the project type and volume. In 2018 the annual registry account fee lies at 1,000 USD and the review fee for a project equals, depending on the activity, 0.05 – 0.015 USD per credit. Lastly, the validation of a GS project costs 5,000 USD and verification 2,500 USD per year. Hence, the costs of a small volume project of 10,000 credits would be around 9,500 USD the first and at least 2,500 USD the subsequent years. (cf. GS 2018) As can be seen, the audit process consumes three quarters of initial investment. The case study will further assess the relationship between prices and a project's economic feasibility.

In line with the above discussion of data (in)availability, the GS communicated different numbers for 2016 than Hamrick and Gallant. According to its annual report, 13.1 M certificates were issued in 2016 and certificates worth 7.2 $MtCO_2e$ retired. Out of these, almost two $MtCO_2e$ were generated by cookstove programs, the second largest project activity after wind power offsets. 98 percent of the project sites were in developing countries, hence channelling finances towards the global South. (GS 2017)

The VCS, on the other hand, was founded in 2005 by a consortium of organizations including the World Economic Forum and the Climate Group. It has evolved into the most widely used voluntary standard with more than 1300 certified mitigation projects. Unlike the GS, the organization includes forestry and avoidance of deforestation in its portfolio. In fact, it established an own framework to accredit the forest sector. Contrary to the GS, the VCS pipeline places no specific emphasis on co-benefits and sustainable development. Its core business is providing private entities with offsets from their own registry. (cf. Verra 2018) The emphasis on forestry is important since 10- 15 percent of the 52 $GtCO_2e$ anthropogenic emissions stem from forest degradation and deforestation. The VCS acts as a 'legitimizing institution as it transforms the invisible commodity of carbon into a credible market good.' (Foster et al. 2017, 122)

The VCS registry includes hardly any ER generated by cookstove projects. Overall, 258 M certificates have been issued and 165 $MtCO_2e$ retired. (Verra 2018) In 2016, 33.1 $MtCO_2e$ were retired from VCS projects and the certificates earned an average price of USD 2.3 per tCO_2e. (Hamrick and Gallant 2017a) This lower price to the GS exemplifies that sustainable development earns a premium price. Lastly, it is worth noting that these voluntary standards are cheaper than the CDM for project developers, with the VCS capping the administrative burden at 10,000 USD. (cf. Verra 2018) Still, the audit process may consume up to one-third of offset revenue in VCS projects. (Foster et al. 2017)

To conclude, the voluntary carbon market hosts different standards and certificates that increase trust in the VCOs. The two most popular labels are the VCS and the GS. The former primarily certifies forestry, land-use and renewable energy projects whereas the latter carries a strong emphasis on sustainable development and tangible benefits for local populations. Interestingly, the VCS is not active in Nepal and the GS only to a marginal extent, which will be discussed in chapter 5.

3.4. Criticism and Myths of Voluntary Carbon Offsetting

Naturally, the VCO scheme has not remained without critics who contend the voluntary carbon market on different levels. First, one main point states that the market has failed to deliver any substantial mitigation impact and achieve real GHG emissions reductions. Confronted with a total of 52,700 $MtCO_2e$ in 2014 anthropogenic GHG emissions (UNEP 2016), the 63.4 $MtCO_2e$ retired in 2016 indeed appear a drop in the ocean. Other opponents criticize that the VCO scheme 'greenwashes' corporate activities and renders companies and individuals' climate proponents even if they engage in polluting and climate harming activities. One concern is that offsetting may encourage extended emissions behaviour, although there only exists ambiguous evidence. (cf. Kotchen 2009; Böhm et al. 2012) Another disapproval stems from social psychology and criticizes that voluntary offsetting allows to 'buy complacency, political apathy and self-satisfaction.' (Monbiot 2006) It follows that consumers and companies with large carbon footprints may emit ever larger amounts of CO_2e without taking responsibility for the adverse effects. Instead of representing a just mitigation tool, voluntary offsetting puts the burden of GHG emissions reductions on poor countries.

Further critique has focused on the neoliberal approach of VCO to 'fixing the climate crisis' in that it does not tackle the cause of the problem, capitalist markets themselves. Capitalism's growth imperative and limited factors of production purportedly lead to ever increasing demands for resources and thereby continued ecological degradation and accumulating GHG emissions. Carbon offsets devolve solving climate change to the market and individuals, instead of finding governance solutions to the global commons problem. Some argue VCO markets wager the future of the planet on speculation and financial capitalist practices. (Whitington 2012)

Moreover, the role of validators and verifiers has been criticized. In theory they are independent third-party auditors. In practical terms, the additionality and real-world GHG emissions savings at times could not be convincingly proven. Especially additionality may oftentimes be a 'fraught concept' because carbon finance may be spent on projects already financially viable and/or on activities with dubious climate mitigation credentials. Some reports highlight N_2O and HFC-23 projects, where the powerful GHGs were produced deliberately to earn money with their destruction. (cf. Böhm et al. 2012) On the other hand, there exists a conflict of interest that auditors per se verify emissions reductions to justify their work description. (cf. Whitington 2012) A similar concern was raised with forestry projects, where it is difficult to prove that the carbon sequestered in trees will not be burnt eventually and hence added to the atmosphere. The time horizon necessary to assess the CO_2 sink in forests extends all market mechanisms. (cf. Foster et al. 2017)

Additionally, the prices of offsets have been very low with an average three USD per tCO_2e in 2016. These costs arguably do not reflect the real externalities of climate harming activities and neither substantially help developing countries to pursue a low-carbon development. The World Bank (2017) calculated that only much higher prices of 40- 80 USD per tCO_2e would really put the globe on a trajectory towards the 2-degree goal. In fact, the very low prices question the credibility of the VCO scheme because certain credits sell at less than 0.20 USD. Thus, the differentiation between originating type is not only a strength, but also a weakness of voluntary carbon markets.

Another risk of the voluntary carbon market is that states may decide to incorporate mitigation activities, that are currently administered by VCO project developers, into their PA obligations. Since projects largely take place in developing countries that previously had no mitigation commitments, they may account the activities to their national activities instead of selling the ER abroad. (cf. Hamrick and Gallant 2017a, 19f)

Whereas some criticism is well-founded, much may be debunked. The VCO market represents a process, as exemplified by some voluntary offsets gradually entering a compliance scheme and new methodologies being applied. (Dhanda and Hartmann 2011) Hence, it is part of the journey that certain projects such as HFC-23 destruction were originally included. However, the market is capable of learning and by now these projects are banned. In a similar vein, 99 percent of projects were externally certified and audited in 2016 to restrain some of the ‘cowboy mentality’ (cf. Böhm et al. 2012) of early days. Carbon standards require developers to demonstrate that emissions are real, measurable, verifiable and additional. In fact, in almost all projects the ex post certificates issued after verification are less than ex ante promulgated in the PDD due to conservative estimations to calculate real CO_2e ER. (cf. Foster et al. 2017)

Concerning criticism of greenwashing, empirical evidence shows that companies charge themselves an internal carbon price to purchase offsets, thereby reducing net profits. Indeed, of those companies reporting carbon pricing, 88 percent formally adopted internal ER targets. (World Bank 2017; Hamrick and Gallant 2017b, 18f) Lastly, it is true that VCO barely makes a dent in the global carbon budget. However, the voluntary carbon scheme provides important structures for compliance markets and sector-based approaches such as the aviation offsetting scheme CORSIA. As proposed by actors such as the World

Bank (2017) carbon markets might be integrated under Art. 6 of the PA and scale-up their efforts. Moreover, offsetting activities, especially under the GS, carry not only climate benefits, but also promote sustainable development.

3. Sectoral Mitigation: Clean Cookstoves and Sustainable Development

3.1. Traditional Cooking as Development Challenge

As mentioned, climate change mitigation efforts require different implementation approaches such as fostering renewable energies, improving efficiencies, and increasing carbon sinks. In other words, '[n]umerous regional responses to climate change […] in terms of mitigation and adaptation are supplementing international and intergovernmental activities.' (Gramelsberger and Feichter 2011, 2) In this sense, clean cooking is 'widely recognized as a global development and climate priority.' (GACC 2017, 3)

Currently, 2.8 billion people around the world lack access to clean cooking facilities. Out of these, the overwhelming majority (2.5 billion) rely on solid biomass and traditional stoves for cooking daily meals. (IEA 2017; SE4All 2017a) Recently, progress on access to clean cooking has mainly been achieved in Asia. In China, for instance, the share of people using solid fuels for cooking fell from 52 percent in 2000 to 33 percent in 2017. Similarly, in Indonesia the share of people relying on kerosene for cooking decreased from 88 percent in 2000 to 32 percent in 2015. However, the situation in some Sub-Saharan African and South Asian countries has been deteriorating since population growth outstripped progress. (IEA 2017; Bonjour et al. 2013) Indeed, the share of the global population using clean cooking technologies rose from 56.5 to 57.4 percent between 2012- 14. However, in the same period the absolute population with no access to clean cooking also grew by 10 M.[6] Another interesting observation is that 85 percent of people applying polluting traditional cooking technologies live in only twenty high impact countries. (SE4All 2017a) The following map (Fig. 8) illustrates the distribution of people without access to clean cooking technologies.

[6] For a detailed discussion of solid fuel use in households in 150 countries see Bonjour et al. 2013.

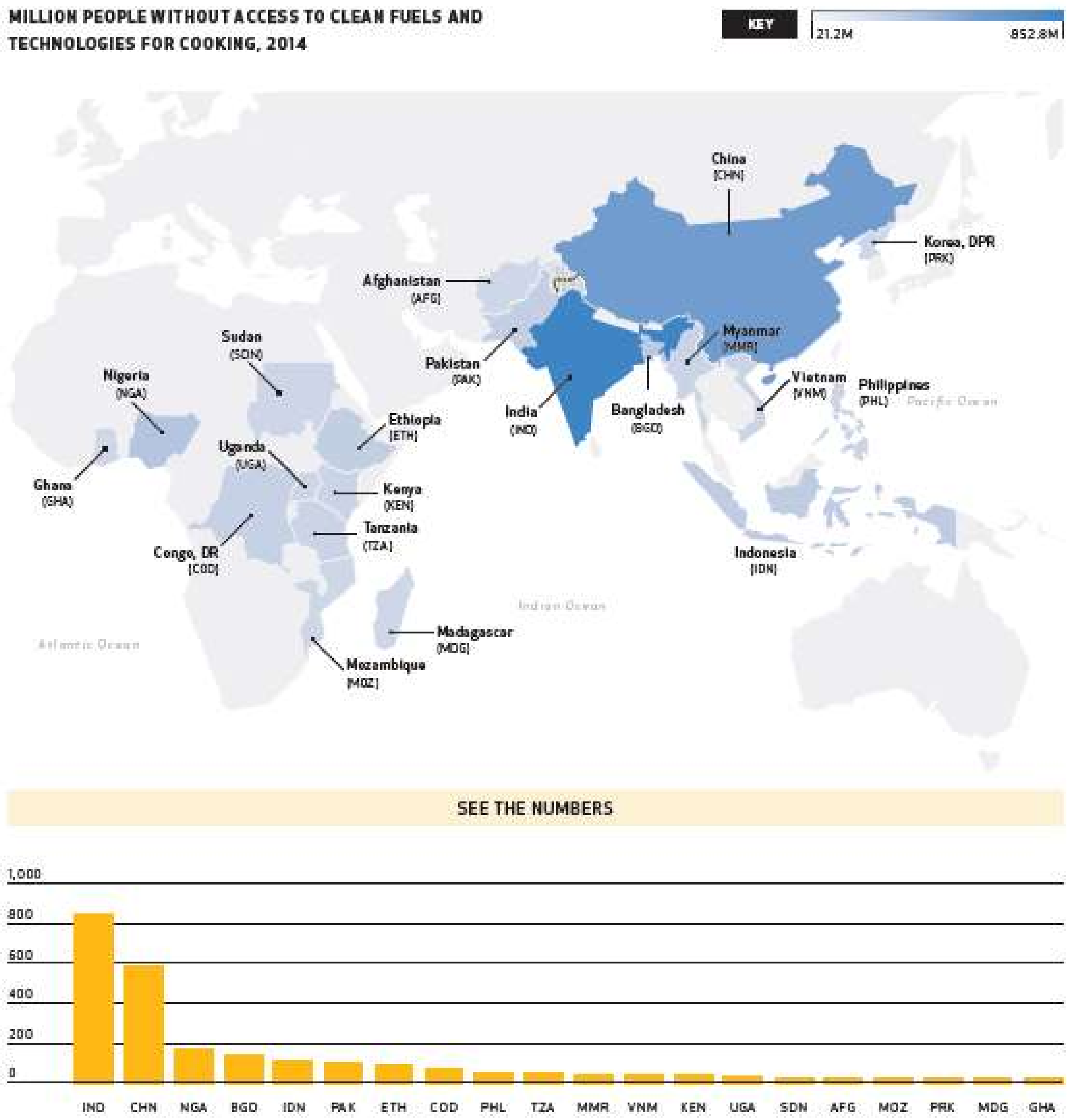

Figure 8. Number of people in [M] without access to clean cooking. (Graphic based on UN Maps and borrowed from SE4All 2017a)

As can be observed, polluting cooking practices occur in large parts of Africa and Asia, where India and China continue to host the largest populations without access to clean and safe cooking. Nepal, which is located between the countries, has not been considered, although more than 3 M households- about 14.7 M people – in 2017 still had no access to clean cooking technologies. (Interview E) This highlights the importance of the case study on clean cooking and carbon offsetting funding in Nepal in the subsequent chapter. Results may also be valuable for countries such as Cambodia, Myanmar, and Bangladesh, where access rates to clean cooking remain below 20 percent. (IEA 2017; Bonjour et al. 2013)

First, it is important to define access to clean cooking, which is mostly described in general terms as 'access to modern fuels and technologies, including natural gas, LPG, electricity and biogas, or improved biomass cookstoves, as opposed to the basic biomass cookstoves and three-stone fires used in developing countries.' (IEA 2017, 21) For better definition and categorization of the actual stoves, the GACC together with the International Organization for Standardization (ISO) developed Tiers of Performance. These also apply in Nepal (Interviews G and H) and rely on four parameters i) efficiency ii) indoor emissions iii) total emissions and iv) safety. Each parameter is then ranked along 5 Tiers. Commonly, traditional cookstoves (TCS) rank with Tier-0 in all categories. Conversely, Tier-4 for indoor emissions are determined by the World Health Organization (WHO) Guidelines for Indoor Air Quality and Pollutant concentrations. Table 2 illustrates the parameters.

Table 2. Emission thresholds for Tier categorization of cookstoves. High power values relate to heating water to boiling state and low power to remain water at simmering. (Data from GACC 2018)

EMISSION SUB-TIERS

	High-power $PM_{2.5}$ [mg/MJ_d]	Low power $PM_{2.5}$ [mg/min/L]	High power CO [g/MJ_d]	Low power CO [g/min/L]
TIER-0	>979	>8	>16	>0.20
TIER-1	≤979	≤8	≤16	≤0.20
TIER-2	≤386	≤4	≤11	≤0.13
TIER-3	≤168	≤2	≤9	≤0.10
TIER-4	≤41	≤1	≤8	≤0.09

EFFICIENCY/ FUEL USE SUB-TIERS

	High power thermal efficiency [%]	Low power specific consumption [MJ/min/L]
TIER-0	>15	>0.050
TIER-1	≤15	≤0.050
TIER-2	≤25	≤0.039
TIER-3	≤35	≤0.028
TIER-4	≤45	≤0.017

For each stove and indicator, the Tier boundaries are defined by the Water Boiling Test (WBT) 4.2.3 in a laboratory setting (described in Chapter 4.2 and 5.3). An important differentiation is between *clean* and *improved* cookstoves. The former generally meet Tier-3 requirements for $PM_{2.5}$ and CO emissions. Improved cookstoves (ICS), on the other hand, generally rely on solid biomass as fuel and reach a higher efficiency and lower pollution load through improvements such as a chimney or closed combustion chamber. However, virtually no biomass cookstove meets WHO standards for indoor air pollution (IAP) exposure and there persists ambiguity whether ICS are considered 'clean'. (GACC 2017; IEA 2017) In this paper, they are described together since all cookstoves lead to reduced GHG emissions.

As mentioned, clean cooking promotion has gained interest in the VCO market not only for its emissions reduction, but also for achieving multiple development priorities. The goal of universal access to clean and safe cooking fuels and technologies was explicitly included in SDG 7, emphasizing the nexus between energy access, climate protection, and socio-economic development. Indeed, the issue is linked to further challenges, such as poverty eradication (SDG 1), air pollution and increasing life expectancy (SDG 3), adaptation and mitigation of climate change (SDG 11) and gender equality (SDG 5).

First, household air pollution causes more than 2.8 M premature deaths per year, predominantly due to stroke, ischaemic heart disease, chronic respiratory disease and childhood pneumonia. A transition from inefficient use of solid biomass fuels towards less harmful energy sources such as biogas, LPG and electricity considerably improves health and extends life expectancy. Reduced indoor levels of BC and $PM_{2.5}$ lead to direct respiratory and heart health benefits. As can be observed in Table 2 an improved Tier performance reduces exposure to CO and $PM_{2.5,}$ and the risk of disease. There exist 'significant synergies between policies to address energy access, local air pollution, health and climate change.' (IEA 2017, 29; Bonjour et al. 2013)

Furthermore, mostly women are occupied with collecting the fuel and preparing meals, hence clean cooking access considerably advances gender equality (SDG 5). Because of gender-defined roles, women and children are disproportionately distressed by toxic IAP. Reduced pollutant concentrations therefore predominantly improve living conditions of women. Moreover, in rural households in South Asia women spend an average of 1.4 hours per day collecting firewood and up to four hours cooking when using TCS. To summarise, the health improvements, time savings and empowerment of clean cookstove programs constitute important aspects of gender equality. (IEA 2017) Table 3 lists primary SDGs and related targets that are influenced by cookstoves.[7]

Table 3. Main SDGs interlinked with clean cooking. (Table by author)

SDG #	DESCRIPTION	TARGET(S)	COOKSTOVE IMPLICATION
3	Good Health and Well-Being	3.9.1 Substantially reduce mortality rate from household air pollution	ICS improve household air by reducing $PM_{2.5}$ and CO concentrations
5	Gender Equality	5.B Enhance the use of enabling technology to promote women empowerment	Women save time collecting firewood and improve their health with ICS
7	Affordable and Clean Energy	7.1.2 Universal access to affordable, reliable and modern energy 7.A International cooperation to facilitate access to clean energy research and technology	ICS help tackle energy poverty and oftentimes aid fuel switch to modern and safe energy sources. Cookstoves are often promoted through international programs
10	Reduced Inequalities	10.3 Ensure equal opportunity and reduce inequalities of outcome 10.B Total resource flows for development	Cookstove programs may be financed through development aid and/ or carbon finance. Improved health and time savings translate to more equality
13	Action to Combat Climate Change and its Impacts	13.2 Integrate Climate Change into national policies, strategies and planning 13.B promote capacity raising for climate change management in LDCs	Improved and clean cookstoves lead to considerable fuel savings and GHG emissions reductions

Concerning the types of cookstoves, technologies vary widely due to local practices and possibilities. Generally, in urban areas LPG and electricity comprise the preferred technology, whereas in rural areas almost half of the projects involve improved biomass

[7] For a comprehensive discussion of SDG synergies and interactions, view the ICSU (2017) report *A Guide to SDG Interactions: from Science to Implementation*.

cookstoves. (IEA 2017) The international community, too, has recognized the importance of delivering clean cooking solutions to developing countries. Over the last decades, more than 800 M people have gained access to clean cooking and the GACC (2017) estimates that 116 M stoves[8] and fuels have been distributed since 2010 in developing regions of the world. They included all tiers of performance with at least 70 M efficient (>Tier-1) and 44 M clean (>Tier-3) cookstoves. These achievements are largely due to efforts and strong government commitments in China, Brazil and India. The Chinese authorities, for instance, established local energy offices that cater training and installation support. Moreover, the China National Improved Stove Programme promoted around 130 M ICS between 1982 and 1992. (Pachauri et al. 2012) Similarly, the Indian government has made a concerted effort in promoting access to modern cooking fuels. India hosts the world's largest population, approximately 800 M people (Fig. 8), relying on solid biomass for cooking. The Pradhan Mantra Uijwala Yojana is the present welfare scheme to provide at least 50 M LPG, of which 20 M have been distributed already, connections and stoves to marginalized women by 2020. Concerning the Indian efforts, Singh et al. (2017) found that the transition to LPG cooking in India improved the state of forests and led to modest climate benefits. Considering all GHG emissions, the fuel switch achieved a net emissions reduction of 6.7 MtCO_2e between 2001 and 2011.

3.2. Cookstove GHG Emissions and Offset Calculations

Greenhouse gas ER calculations are crucial in determining the tCO_2e reduced or sequestered by a cookstove project. All previous mentioned programs such as the CER, GS and VCS enabled crediting of ER from ICS projects. Each administers an approved methodology specifying eligible technologies and project types. Under the CDM, the Approved Methodology for Small-Scale Project Activities (AMS) AMS-II applies to cookstoves with improved efficiencies and reduced demand for non-renewable firewood. The AMS-I.E, on the other hand, is used for fuel switch, i.e. for biogas and solar cookers. The GS permits project developers to apply these CDM methodologies as long as they include stakeholder consultation and co-benefit requirements. (Lee et al. 2013; GS 2017) Undoubtedly, the 'Gold Standard plays a pivotal role in the market for cookstove offsets' because GS-certified cookstove offsets account for over 75 percent of ICS generated credits. (Lee et al. 2013, 7)

In cookstove projects the emission reductions ER_y are calculated as the product of the woody biomass saved B_y, the fraction of non-renewable biomass $f_{NRB,y}$, the net calorific

[8] N.B. there is no data on household size and how many people benefit from one cookstove distributed.

value $NCV_{biomass}$ and an emission factor for the fuel used. Hence, the AMS-I and AMS-II provide the following equation:

$$ER_y = B_y \times f_{NRB,y} \times NCV_{biomass} \times EF_{projected\ fossil\ fuel}$$

The case study in the next chapter provides a practical application example of this methodology and issued tCO_2e in offsets. The reduced biomass consumption serves as first key parameter and may be quantified in the Water Boiling Test (WBT), which constitutes the primary method, i.e. used by the GACC and the testing facilities in Nepal (Chapter 5.3). It is a laboratory-based test and therefore replicable and standardized. On the other hand, the emission factors do not always reflect real household cooking emissions. The value of the fraction of non-renewable biomass is more difficult to calculate. The UNFCCC uses indicators such as the time spent gathering firewood, survey results, remote-sensing data of carbon stocks, fuel wood prices and the type of firewood collected. Consequently, a fraction value is determined, generally around 80 percent in LDCs. (Freeman and Zerriffi 2014) Hence, ER calculations consider the GHG concentrations reductions due to the higher efficiency or fuel switch on the one hand, and the increase in sinks by reduced deforestation on the other. Depending on the parameters, one cookstove conserves one to four tCO_2e per year (cf. IEA 2017; GACC 2018; Interview G) The AMS-II additionally requires checking efficiency and usage of the stoves every two years to justify the crediting period of up to ten years. (UNFCCC 2018a)

Under the CDM methodologies, stove projects only receive offsets for reducing CO_2 emissions, whereas the GS also incorporates CH_4 and N_2O emissions. The latter is hardly emitted, however, and may be omitted. Neither standard, measures and accredits black carbon (BC), arguably the most important non-Kyoto climate forcing species. (Freeman and Zerriffi 2014, 14114) BC, commonly known as soot, results from incomplete combustion of solid biomass and, as discussed in chapter 2.1, adds major radiative forcing on the Earth's climate system. It has been estimated that solid biomass cooking fuel represents the second largest single source for BC emissions after grass and woodland burning and contributes about one quarter of BC to global emissions. (Lee et al. 2013) Cooking fuels add around 1300 Gg of BC per year and more than 75 percent stem from Asia. In South Asia biofuel cooking emits more BC than all other sources combined. (Bond et al. 2013) Whereas there is no direct measurement of how much TCS add in [CO_2e] to the global carbon budget, BC emissions render 'cookstoves as having the most promising cost-benefit characteristics, whether to achieve climate benefits alone or both climate and health benefits.' (Ibid., 5523) This is particularly true considering that other BC sources such as transport and industry are expected to decrease their emissions. Hence, there is a strong argument to include BC reductions in cookstove crediting methodologies.

(cf. Lee et al. 2013, 21f) In fact, the inclusion of BC would have a significant impact on the amount of carbon credits calculated, even when including the cooling effect of co-emitted organic carbon and sulphur dioxide. (cf. Freeman and Zerriffi 2014)

Even though cookstove programs have gained traction and their CO_2e savings can be calculated, there exists no conclusive data on how many cookstove programs received funding from the carbon market. The GACC hosts a database with cookstove projects that acquire carbon funding.[9] The database lists 101 projects across the globe, including the responsible project developer, the scale and verification standards such as GS, VCS and CER. However, after scrutiny of some projects, for instance in Nepal, some are not about clean cookstoves and there is a lack of reliable ER quantification.

Certainly, participants of the VCO market appreciate cookstove programs because of their identified co-benefits. Especially cookstove projects in LDCs are frequently and publicly traded by brokers. (Interview F) This geographic shift may be due to the EU ETS only accepting CERs from LDCs. (cf. Lee et al. 2013) One estimate is that in 2016 cookstove credits worth at least 3.4 MtCO_2e with a total value of 18 M USD were sold and retired on the voluntary carbon market. (Hamrick and Gallant 2017a) A short survey of VCO brokers such as the German 'Atmosfair', the Austrian 'Climate Austria' and the British 'ClimateCare' reveals that all VCO portfolios contained cookstove projects and to a limited extent refer to their advancing several SDGs.

Notwithstanding, there exists a large funding gap for clean cooking access. The global annual clean cooking investments needs equal 4.4 billion USD per year. Estimated current levels reach only 30 M USD, of which the majority (26 M) stems from international public funding. In fact, '[c]lean cooking solutions are vastly underfunded across all Tiers of access.' (SE4All 2017b, 37) Similarly, the IEA (2017) calculated that cumulative investments of 42 billion USD are required to ensure universal access to clean cooking by 2030, as described in SDG 7. Hence, 'carbon offset markets can provide a valuable means to support the further dissemination of improved cookstoves in developing countries.' (Lee et al. 2013, 20)

Under the Sustainable Development Scenario of the IEA (2017), which involves a strong carbon market, around 1.9 billion people gain access to clean cooking by 2030. Clearly, funding from the (voluntary) carbon market plays an essential role in providing access to clean and safe cooking technologies. Under the assumption that one household hosts five people, 380 M cookstoves generating between 380 M and 1,520 M tCO_2e in ER may be distributed and earn carbon funding. This result resembles the estimation of Lee et al.

[9] Accessible at http://carbonfinanceforcookstoves.org/tools/projects/?issuing=true.

(2013) that the global technical potential for GHG ER from ICS projects lies at one $GtCO_2e$ per year. The additional resources from offsets would help to finance developers that provide market-scale solutions and provide clean cooking infrastructure. In fact, the VCO market can generate significant revenue for stove businesses and '[p]rovide finance products that enable clean cooking companies to grow and expand inventory and distribution networks, while crowding-in private capital.' (SE4All 2017b, 39) Carbon finance would alter the funding dynamic and thereby help reduce donor dependency. (cf. SNV 2014) The following case study of Nepal describes in more detail some of the opportunities, experiences and challenges of cookstove programs and carbon market funding in a developing country.

4. Case Study: Biomass Cooking in Nepal

Many ICS studies have focussed on China and India, who account together for nearly half the global population lacking access to clean cooking. (IEA 2017, 116; Figure 8) Their smaller neighbour Nepal has been largely neglected, though it faces partly comparable development challenges and lies geographically and culturally between these two countries. The present case study is worthwhile because of Nepal's extensive reliance on fuelwood for cooking, excessive IAP due to biomass burning and lastly a significant need for foreign financial flows. The next sub-chapters rely on semi-structured expert interviews (methodology description in chapter 1) and country data for presenting an in-depth case study about clean cookstove programs, potentials and carbon funding. First, Nepal's context with regards to development indicators, energy and cooking fuel supply, and IAP is introduced. Next, previous official and small-scale private cookstove programs are comprehensively listed. Following, part 5.3 describes applicable cookstove technologies and emissions factor calculations. Finally, the carbon certification process and improvements for the voluntary carbon market are discussed.

4.1. Country Context

Nepal has an area of 147.000 km² and in 2016 hosted a population of 28.9 M. It is bordered by the world's most populous countries India to the South, East, and West and China to the North. The topography varies significantly and stretches from an altitude of 60m asl in the tropical Terai region to the summit of Mount Everest at 8,848m. There exist 126 reported caste/ ethnic groups and 123 languages are spoken as mother tongue. (CBS 2012) According to the UNDP, Nepal ranks as a LDC with a human development index of 0.588 (rank 144). The GNI per capita lies at 730 USD and in 2014 each Nepalese emitted on average 0.284 tonnes of CO_2 to the atmosphere. The life expectancy at birth has drastically increased over past decades from an average of 35 years in 1960 to 70.3 years in 2016. Men currently have a life expectancy of 68.7 and women 71.8 years. (World Bank 2018) For better contextualization, Table 4 compares Nepal's country data to Austria. (cf. Ibid)

Table 4. Nepal country indicators compared to Austria. (Data from World Bank 2018)

Indicator	***Nepal***	***Austria***
Human Development Index	0.588 (2015)	0.893 (2015)
GNI per capita [USD]	730 (2016)	45,880 (2016)
CO_2 emissions per capita [$t.yr^{-1}$]	0.284 (2014)	6.784 (2014)
Life expectancy at birth [years]	70.3 (2016)	80.9 (2016)
Urban Population [% of total]	19 (2016)	66 (2016)

According to the 2011 Nepal National Population and Housing Census, there were 5,427,302 households in the country that year. Of these, approximately two thirds (64 percent) utilized firewood as primary fuel for cooking. Especially in remote areas, such as Manang, almost 100 percent of households relied on firewood for cooking. Biomass continues to be the largest energy resource of Nepal providing 77 percent of the total energy demand measured in [GJ]. In one year, households use 308,604,000 GJ of firewood (WECS 2010), which equals around 18 M tonnes of solid biomass. Applying the above population data, each household in Nepal thus requires approximately 3.3 tonnes of fuelwood per year. Firewood is followed by LPG (21 percent) and cow dung (10 percent) as the most frequently used cooking fuels. Next, bio-gas is adopted by 2 percent and kerosene by 1 percent. (see Fig. 9) Interestingly, there exists a substantial urban-rural divide, since in urban areas 68 percent use LPG as primary fuel. (CBS 2012)

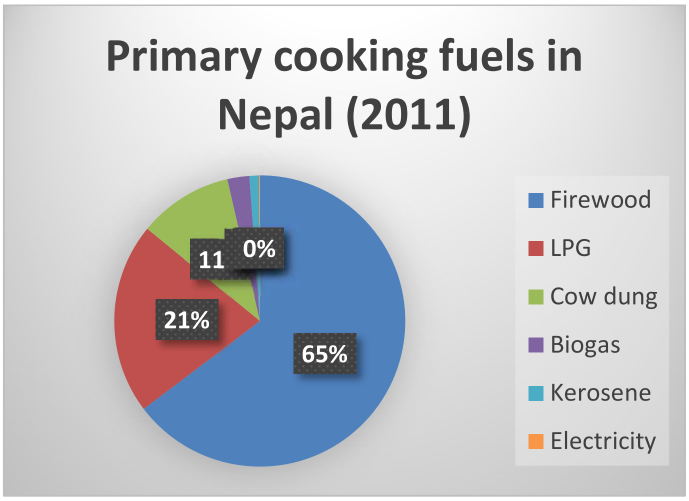

Figure 9. Primary Cooking Fuels in Nepal (Data from Central Bureau of CBS 2012)

In Nepal 19 percent of the population live in cities, ranking it among the ten least urbanized countries. (World Bank 2018) Especially in rural areas, firewood is considered free of charge and therefore the most attractive cooking fuel. (Interview F) Generally, LPG may be considered a clean cooking fuel. (Singh et al. 2017; SE4All 2017b) However, in Nepal 100 percent of LPG is imported from India, which renders it dependent on political and economic factors. For instance, during a 2015/16 blockage of the border, no LPG reached Nepal. This led to a cooking fuel shortage and increased deforestation. (Interview A) Moreover, many households cannot afford to pay for LPG and due to the inaccessibility of the Himalayan regions, transport of LPG bottles poses a challenge.

The government of Nepal has conducted several Forest Resources Assessments (FRA) over the past forty years. The latest FRA revealed that forest occupies 5.96 M ha in the country. Over past decades, substantial deforestation (or 'disturbance' in government terms) has been observed due to grazing, forest fire and cutting for fuel use and construction. (DFRS 2015) It is agreed that 'deforestation is one of the major environmental issues in Nepal.' (Chaudhary et al. 2016, 335) The harvest of trees for fuelwood is recognized as a main driver of deforestation. Six out of eight interviewees mentioned combatting deforestation as a main environmental benefit of ICS. In the absence of alternative energy sources, the rural population, which constitutes 81 percent of Nepalese, depend on fuelwood for cooking and heating energy. Some studies found that the annual deforestation rate was 1.7 percent during the 1980s to the mid-1990s. (Ibid.) Similarly, a UNEP (2001) study found the annual rate of deforestation in Nepal to be 1.8 percent between 1980 and 2000. This equals a mean forest loss of 100,800 ha per year. Trends reveal a recent slowing down of forest loss, yet degradation and illegal wood harvesting continue to pose serious challenges. (Chaudhary et al. 2016, 340)

It is also necessary to briefly address political circumstances in the context of carbon offsetting and ICS programmes. Over the last decades, Nepal witnessed profound political turmoil stretching from a massacre of the king's family (2001), to a treacherous civil war that ended in 2006, the abolition of monarchy (2008) and frequently changing governments. A new constitution was promulgated in September 2015, which sent a signal of stability. In November and December 2017, the first regional elections in 20 years were held and novel seven states formally established. The country is currently transitioning to a federal state. (EU EOM 2018) The importance of political stability has also been emphasized with regards to forestry since degradation was higher in years of instability. (Chaudhary et al. 2016) One interviewee (D) of a donor country responded that political stability and liability of government constitute crucial components in development cooperation. In fact, due to financial irregularities and volatility, the contribution to the large scale NRREP program ended in 2017. Another expert (Interview C) emphasized the current political changes and their effect on ICS and carbon projects. Since the principal actor in the field, the Alternative Energy Promotion Centre (AEPC) moved from the auspices of the Ministry for the Environment to the Ministry for Energy, stakeholders are uncertain about practical implications.

After having shortly discussed the reliance on fuelwood and political factors in Nepal, a discussion of IAP is necessary. In Nepal, the mean life expectancy at birth lies at 70.3 years, with high levels of IAP deterring a larger number. Unfortunately, there is no specific data available as to the precise difference of life expectancy between women and men due to IAP. Household solid fuel use and TCS generate smoke including BC, $PM_{2.5}$ and other particles as well as gaseous compounds like CO. They cause pulmonary diseases, asthma and other negative health effects. 42 percent of total deaths from ischaemic heart disease, stroke, lung cancer, chronic obstructive pulmonary disease and acute lower respiratory infections are attributable to IAP. This equals 23,058 premature deaths per year in Nepal. Additionally, more than 2,000 children die per year of respiratory infections because of IAP. (WHO 2016) Indoor smoke constitutes the second largest environmental risk factor in Nepal after lacking hygiene and sanitation. (Singh et al. 2012) In the Environmental Performance Index for air quality, jointly published by Yale and Columbia University, Nepal ranks last worldwide considering the indicators household solid fuel use, $PM_{2.5}$ exposure and $PM_{2.5}$ exceedance. (EPI 2018)

Large scale measurements found that in Bhaktapur, Nepal the fuel type correlates with ambient $PM_{2,5}$ concentrations. The mean household $PM_{2.5}$ concentration from biomass was 656 µg/m^3, from kerosene 169 µg/m^3, from LPG 101 µg/m^{3,} and from electricity 80 µg/m^3. All observed levels exceed the WHO Air Quality Interim-Target I of an annual level of 35 µg/m^3, even once ambient concentrations are deducted. (Pokhrel et al. 2015) In this vein, ICS act as appropriate intervention to substantially reduce $PM_{2.5}$ and CO levels in kitchens. Singh et al. (2012) found that replacing traditional TCS with two pot hole mud ICS in Nepal leads to a mean reduction of $PM_{2.5}$ concentrations by 63 percent and CO concentrations by 60 percent. After three months ICS use, $PM_{2.5}$ concentrations decreased from 2.07 mg/m^3 during TCS use to 0.76 mg/m^3 with the ICS. CO concentrations declined from 21.5 ppm before the ICS installation to 8.6 ppm afterwards. Moreover, a health survey revealed a change in cough, phlegm and eye irritation occurrence. The government of Nepal has recognized the gravity of IAP and declared to make the country indoor air pollution free by 2022 through clean cookstove promotion. Moreover, by 2030 all households should have access to modern energy sources such as sustainable biomass and biogas. (AEPC 2017b)

4.2. Cookstove Programs in Nepal

This combination of severe health risks from TCS, environmental degradation due to firewood logging and drudgery of women have informed ICS programs. In 1999 the AEPC, together with international donors, introduced the Energy Sector Assistance Program (ESAP) with the aim of creating a sustainable rural energy sector in Nepal. The first phase of the program (ESAP I) ran from 1999- 2007 and the immediate follow-up (ESAP II) from 2007 until 2012. Both contained an explicit focus on improved cookstoves. Most recently, the National Rural and Renewable Energy Programme (NRREP) operated from 2012 until 2017. (Interview A; AEPC 2017b)

The main actors in improved cookstoves and carbon offsetting in Nepal are the AEPC, the Centre for Rural Technology Nepal (CRT/N), international donors such as Norway, Denmark, and the UK development organization DFID, international NGOs, and finally the GACC. This comprehensive list is evidenced by the cross-referencing in the interviews conducted. Each respondent named AEPC as focal agency, six mentioned the CRT/N and five commented on the role of donor countries and INGOs. (cf. Appendix A) The AEPC was established in 1996 to develop and promote renewable energy technologies in Nepal. Currently, the centre fulfils several roles including i) assisting in formulating climate and renewable technology policies ii) setting standards and quality assurance iii) technical support and iv) managing subsidies. (Interview F)

The first ESAP led to the institutional strengthening of the AEPC and other stakeholders on the one hand, and the distribution of more than 275,000 ICS to rural households on the other. Around 200 local NGOs worked with ESAP to promote ICS technology. The ESAP II phase from 2007- 2012 scaled up efforts, both in scope and financial terms. 671,000 ICS were promoted to enhance biomass combustion efficiency, save fuel consumption, reduce indoor smoke and improve health. Arguably, firewood consumption could be reduced from 2500- 3500 kg to 1200- 1500 kg per year per household. Moreover, the share of kerosene in the cook fuel mix decreased from 13 percent in 2001 to only one percent in 2011, thereby reducing the reliance on fossil fuel. (AEPC 2013; Interview F)

Based on the ESAP experience, the National Rural and Renewable Energy Programme (NRREP) was designed in a context of strengthening resilience by diversifying the energy mix, promoting gender equality and sustainable development. By 2015 more than 316,000 cookstoves were distributed. (Danida 2018) Commonly, the implementation has been coordinated with local stakeholders such as village development committees. The programme covered costs for training, awareness raising and assisting with logistics. The customers then paid a contribution (5-15 USD) for the cookstove itself. (Interviews C and

G) In conjunction, several strategies were designed to provide resources to the rural and renewable energy sector. A main component has been the Central Renewable Energy Fund (CREF), that caters subsidies and facilitates credit access. The CREF is partly financed through carbon credits, which will be discussed in part 5.4. Eighty percent of the carbon earnings are channelled into the development and disbursement of the same technology to scale up efforts. (Interview F)

Next to the official ESAP and NRREP umbrellas, a few ICS projects have been completed privately by NGOs. The first such activity was the Terai Carbon offsetting project, which was registered under the UNFCCC and the GS and promoted 14,820 stoves. (Interview E) Next, the NGO Winrock International promoted the installation of 11,579 ICS in four different districts. (Winrock 2013) Other small initiatives included i.e. the Matribhumi ICS project in Chaimale district with 849 cookstoves. Currently, SNV is also implementing a five-year ICS Programme with the aim of generating carbon finance in seven hill districts in Far West Nepal. The aspiration is to provide access to improved cooking technologies for 150,000 households. (Interviews A and E) Lastly, in August 2017 the CRT/N completed a project on promoting women-led enterprises for energy access (WEE). In its course, 77 jobs were created and 28,176 ICS disseminated. (Interview G) Table 5 summarizes the public large-scale and small-scale private programs.

Table 5. Summary of Nepalese cookstove programs considering available data. (Table by author)

TYPE	PROJECT/ PROGRAMME	# ICS PROMOTED	VERIFIED?
OFFICIAL LARGE-SCALE	ESAP I 1999- 2007	275,000	Partly
	ESAP II 2007- 2012	671,000	No
	NRREP 2012- 2017	316,000	Partly
PRIVATE (NGO) SMALL-SCALE	Terai ICS Carbon Project 2011- 14	14,820	Yes
	Winrock ICS Promotion 2012- 13	11,579	Partly
	SGP Matribhuma ICS Project 2012- 13	849	Yes
	CRT/N WEE-Nepal 2014- 17	28,176	Yes
	SNV ICS with Carbon Finance in Far-Western Nepal 2017- 2022	150,000	No
	Total	**1,467,424**	No

In the interview responses, figures varied slightly. However, adding together ESAP and NRREP, around 1,262,000 ICS were promoted in virtually all development regions of Nepal stretching from the tropical plains to altitudes above 4,000m asl. Additional programs such as post-earthquake distribution and private activities added another

205,424 stoves. Therefore, this study estimates that since 1999 around 1.47 M cookstoves have been promoted in Nepal. This correlates with expert answers given in Interviews A and F.

However, there is no quantitative evaluation on the user behaviour and acceptance. All interviewees mentioned certain obstacles to sustained clean cooking in Nepal. The verifier of the Terai project found i.e. that three percent of ICS beneficiaries did not use the stove after one month. Another interviewee (H) claimed that in some areas more than half of ICS households did not apply the new technology because of a lack of awareness and traditional values. The CRT/N identified several barriers to stove switching. Unlike project developers, users are not primarily concerned about reduced fuel consumption, less IAP and faster cooking. In fact, other parameters feature more prominently, for instance durability, simultaneous cooking and multiple purpose. Versatile functions such as animal feed cooking, room heating and space for festivities are important. Next to these social barriers, there exist policy barriers to ICS acceptance, where the lack of coordination between governmental agencies and international actors constitutes the main problem. Economically, more appropriate financing mechanisms are necessary. In fact, many potential users do not own suitable financial means to purchase clean cookstoves. Lastly, interventions are also needed in research and development and in scaling up cookstove and biomass fuel production. (Interview G)

4.3. Technologies and Emissions Calculations

Chapter 4 already introduced the GACC Tier system and CO and $PM_{2.5}$ concentration thresholds, which are applicable in Nepal. They provide the basis for the ISO-endorsed WBT 4.2.3 (Chapters 4.1 and 4.2). The procedure meticulously describes the standard testing of emissions factors and consequently ER, which in Nepal is conducted exclusively by the CRT/N and the Renewable Energy Testing Station (RETS) (Figure 10). Essentially, the WBT measures emissions loads and how efficiently a stove uses fuel to heat water in a cooking pot. It consists of three phases that follow each other. First, the cold-start high power phase describes the initiation of the fuel combustion until the water in the pot starts boiling. Second, the hot-start high power phase identifies performance differences between a cold and a hot stove. Lastly, the simmer low power phase provides the fuel amount required to simmer water at just below boiling point for 45 minutes. The low power operation indicates a minimum and the high power operation a maximum rate of energy use. (Interview G)

Figure 10. Testing Facility for the WBT in Nepal (Photos by author)

For the issuance of carbon credits, the thermal efficiency and CO_2e calculations feature most importantly. The thermal efficiency h_c is a unitless decimal fraction expressed in percentage. It describes the ratio of work done by heating and evaporating water to the energy consumed by burning fuel. The formula reads as follows:

$$hc = \frac{\Delta E_{H2O,heat} + \Delta E_{H20,evap}}{E_{released,c}}$$

The energy to heat the water equals the water mass times the specific heat capacity times temperature change: $\Delta E_{H2\ \ ,heat} = m_{H20} \times c_p \times \Delta T$, where $c_p \approx 4.186[\frac{kJ}{kgK}]$

The energy to evaporate the water in the pot is the mass of water evaporated multiplied by the specific enthalpy of vaporization of water: $\Delta E_{H20,evao} = m_{H20,evap} \times \Delta h_{H20,evap}$, where $\Delta h_{H2\ \ ,evap} = 2.260\ [\frac{kJ}{kgK}]$.

Lastly, the energy consumed is the equivalent mass of dry fuel combusted multiplied by the heating value: $E_{released,c} = f_c \times LHV$. (cf. GACC 2014)

What follows from these equations used for cookstove efficiencies is that the result highly depends on the fuel type, moisture and biomass consumed. The efficiency forms the basis for many ER calculations since a higher efficiency directly correlates with reduced fuel use. The thermal efficiency of most TCS is below 10 percent. (Interview H)

Similarly, the carbon balance plays an important role in calculating GHG emissions reductions. In principle, all the carbon in the fuel is transformed to combustion products such as CO, CO_2, unburned hydrocarbons and PM. By measuring the carbon content of the fuel or the carbon concentration in the exhaust air, one can infer the other value and correlate fuel use and carbon emissions. The Emission Factor EF can be calculated by dividing the average pollutant concentration [g/m3] with the product of the average carbon concentration in the exhaust gas and the mass fraction of carbon in the fuel. (cf. GACC

2014) Anew, carbon content and fuel use carry implications for GHG emissions and carbon certificate issuance.

The Terai ICS Carbon project i.e. provides a practical example of GHG ER calculations. In line with the AMS-II methodology (Chapter 4.2) the computations were based on the biomass saved by the project, the fraction of non-renewable biomass, the net calorific value of the biomass and the emission factor of the fossil fuel that would replace biomass in absence of the project. (Interview C) The formula read:

$$ER_m = B_m savings_{,I} \times f_{NRB} \times NCV_{biomass} \times EF_{projected\ fossil\ fuel}$$

ER_m equals the emission reduction on a monthly basis, and $B_m savings_{,I} = B_y * (1 - \eta_{old} / \eta_{new})$ describes the quantity of firewood biomass saved in tonnes by the improved efficiency. The baseline scenario in Nepal may be considered with 2.7 tonnes/ year of woody biomass per cookstove. The fraction of non-renewable biomass f_{NRB} saved by the project was fixed at 0.8. The net calorific value of firewood equals 15 MJ/kg wood, which mirrors the IPCC default value. Lastly, the emission factor for the substitution value was 71.5 TCO_2/TJ. Based on the distribution of 14,872 ICS with a conservative η=27.94% and abstraction of leakage, the calculation resulted in the issuance of 41,760 tCO_2e. (cf. TÜV Süd 2015)

These international documents and parameters influenced the current Nepal Interim Benchmark for Solid Biomass Cookstoves NIBC2016. It is administered by the AEPC and RETS and defines thresholds for marketing permits of ICS. The NIBC2016 certifies stoves in terms of efficiency, total emissions, indoor emissions, user safety and durability; thereby mirroring the GACC parameters. NIBC2016 certified ICS may 'qualify for participation in government subsidies, Clean Development Mechanism or other carbon market schemes.' (AEPC 2016, 3) The Nepalese thresholds are described in Table 6.

Table 6. Cookstove parameters under NIBC2016 standard. (based on data by AEPC 2016)

Test Parameter	Chimney Stove	Chimneyless Stove
Thermal efficiency [%]	≥20 (Tier-1+)	≥25 (Tier-2+)
High Power $PM_{2.5}$ [mg/MJd]	≤979 (Tier-1+)	≤513 (Tier-1+)
Low Power $PM_{2.5}$ [g/min/L]	≤8 (Tier-1+)	≤4 (Tier-2+)
High Power CO [g/MJd]	≤16 (Tier-1+)	≤10 (Tier-2+)
Low Power CO [g/min/L]	≤0.20 (Tier-1+)	≤0.09 (Tier-4)

As displayed, chimney stoves may perform poorer than rocket stoves. Most thresholds are based on the Tier-1 of the GACC categorization, which means concentration values are only slightly improved to TCS. Chimneyless rocket stoves are required to perform at least on Tier-2 in all categories except with high power $PM_{2.5}$ emissions. The fuel savings from ICS to TCS are at least 30 percent and up to 67 percent. (Interview G and H) This correlates to one to two tonnes of CO_2e per year per stove. By 2030, the Nepalese government aims to provide at least Tier-3 cookstoves to every household. (AEPC 2017b)

Based on the NIBC2016, the RETS has certified 37 ICS for the Nepalese market. The thermal efficiencies range from a low 18 percent (the only ICS not meeting the threshold) of a biomass two-pothole mud stove with chimney to around 30 percent of most portable metallic rocket stoves without chimney to a high 49 percent of a Dutch produced gasifier stove. Since low power values are not mandatory under the NIBC2016, only high power emission concentrations are provided. The high power CO emissions for chimney stoves range from below 0.30 [g/MJ_d] to 1.30 in fugitive emissions, excluding chimney exhaust. For portable designs the values are between 2.05 and 9.35 [g/MJ_d]. Similarly, $PM_{2.5}$ concentrations range between 214.81 to 512.40 [mg/MJ_d] for rocket stoves.

Around 90 percent of promoted ICS since 1999 have been locally built mud stoves with a chimney (see Fig. 12). Typically, local artisans built the structures after receiving training, thereby generating de-centralized income. (Interview F) The two-pothole mud ICS has an improved efficiency in fuel wood consumption and a chimney vents smoke outside of the kitchen. The enclosed design of the ICS allows for improved combustion and higher efficiency. (Singh et al. 2012) They all use firewood as cooking fuel and thermal efficiencies range between 18 and 26 percent. (Interviews A and H) Three mud-stove designs were developed by the AEPC, two by UNDP and only one by a private company. This mirrors the interview responses that private companies have had difficulties entering the Nepalese cookstove market. (Interviews B and C)

<table>
<tr><th>Traditional 3 stone fireplace</th><th>Improved 2 pothole mud stove</th></tr>
<tr><td>
Figure 11. A girl in Dolakha, Nepal cooks tea on a TCS. (Photo by author)</td><td>
Figure 12. A beneficiary of ICS distribution with a 2-pothole chimney mud stove. (photo provided by Karuna Bajracharya)</td></tr>
</table>

During the NRREP program, biogas powered stoves were increasingly fostered because of higher efficiencies and availability of stock in certain regions. Especially the southern Terai plains carry potential for producing biogas as cooking fuel. (Interviews A, D and F) Recently, pre-fabricated portable rocket stoves have gained popularity. As discussed, they reach higher efficiencies, are more durable and therefore closer to WHO values for indoor air quality. (Interview E) However, portable stoves are also more expensive and oftentimes Nepalese prefer to spend their disposable income on other consumer goods such as mobile phones. (Interview F)

LPG continuously increased its share in cook fuels and has become a social status. (Interview C). However, the technology is not promoted by developers since all LPG is imported from India. The gas is bottled and distributed by private companies around the country and not affordable to many. (WECS 2010, 67) The government and related actors further plan to gradually promote electric stoves as future clean cooking solutions. Lastly, solar powered cookstoves are not an option in Nepal because there exists no culture of cooking outdoors. (Interview A) Only 600 solar cookers have been promoted in the country (AEPC 2017b) with no study on user acceptance.

What has become apparent is that in Nepal there exist clearly identified and internationally recognized ER calculation infrastructure and methodologies in terms of CO_2. However, other GHG emissions such as CH_4, N_2O and BC are not measured or included in offset issuance. Neither the testing facilities nor the NIBC2016 consider other climate forcing species than CO_2. Undoubtedly, it would be beneficial to assess BC emission change with ICS, especially since Bond et al. (2013) found that mud cooking stoves have the highest BC emissions of all cooking technologies. Additionally, South Asia is the region with the highest fraction of biofuel cooking in BC emissions and therefore has substantial reduction potential with beneficial climate mitigation outcomes. Only one interviewee (G) mentioned BC as relevant parameter with cookstoves.

4.4. Carbon Certificates

Recently, the Nepalese government and relevant actors have recognized carbon markets as a viable option for generating income for renewable energy technologies. In 2010, a dedicated Climate and Carbon Unit (CCU) was established within the AEPC to foster carbon credit development in Nepal. The CCU is a clear outcome of capacity building efforts by SNV and DFID. Carbon income has become an additional source of finance, even if compared to grants by development partners the amounts are marginal. (cf. AEPC 2017a) In fact, several respondents (Interviews C, D and F) mentioned the prominent role of donours in cookstove promotion. Previous programs such as the ESAP I and II and

NRREP were all coordinated by government institutions and international donour countries, hence creating path dependencies. Indeed, these constitute a problem and 'paralyze' the stove promotion. (cf. Interview C) The VCO market and public-private partnerships provide a mechanism for establishing a competitive market mechanism for cookstoves. (Interview D)

To date, Nepal has registered seven CDM projects that generated 1.6 M carbon credits and a total of 7.77 M USD revenue. Five projects promoted biogas development, one supported de-centralized micro hydro plants and one CDM project was the 'Efficient Fuel Wood Cooking Stoves Project in Foothills and Plains of Central Region of Nepal'. (UNFCCC 2018b) Here, a total of 22,920 cookstoves was distributed in six districts of the Central Development Region of Nepal under the ESAP program. The validation report confirmed real, measurable and sustainable GHG emissions reductions and issued annual 19,899 tCO_2e over a crediting period of ten years. (DNV 2011) In fact, this project included activities of the Terai ICS Carbon project registered under the GS, but used another methodology which explains the different amount of CERs. Double counting was arguably avoided because CERs may be granted the additional GS label.

Furthermore, the Nepalese NGO Chulo, together with a private German cooperation partner, built a total of 9,400 ICS. The project was certified under the GS to reduce 6,860 tCO_2e per year. The SNV ICS project with carbon finance in the Far-West has also been registered with the GS. However, no carbon certificates have been verified at the time of writing (May 2018). (cf. Markit 2018) The Winrock project on ICS promotion in Nepal also calculated reductions of 6,000 tCO_2e. However, there is no information whether certificates were issued or sold. Based on this short summary and the conducted interviews, it is reasonable to estimate that out of 1.47 M promoted ICS in Nepal around 35,800 received carbon credits so far and a potential 150,000 may be registered in the upcoming years. This shows that only a small fraction of ICS activities in Nepal has received funding from the carbon market.

There exist several advantages of the voluntary carbon market, and the GS in particular, over the compliance market procedure as discussed in chapter 3. Especially for LDCs such as Nepal, flexibility is an important aspect for project developers. The formalities, i.e. with stove standards, are less rigid in the voluntary market. (Interview C) Moreover, there is less administrative burden and i.e. the Letter of Approval of the UNFCCC Designated National Authority (Ministry of Environment) is not required for a GS project. Moreover, the GS assigns an independent validator who ensures project quality and durability. (Interview E) Lastly, carbon finance presents another revenue source for stakeholders in renewable energies promotion. Carbon finance projects may last from ten to 21 years and this comparably long crediting period permits sustainable financing and thus longer-term initiatives. (cf. SNV 2014) Oftentimes, the voluntary market pays a premium price for LDC ICS projects because of co-benefits and development needs. Hence, GS certification is preferable, also because of lower transaction costs. (Interview C)

The Nepalese experience with registering an ICS carbon project largely mirrors the procedure described in chapter 3. First a project idea note is drafted and a baseline scenario calculated. Next, the most important form, the PDD, is distributed. It contains the project description, the methodology (Chapters 4.2 and 5.3), environmental impacts and crediting period. It further describes co-benefits of the carbon activity, such as reducing CO and $PM_{2.5}$ concentrations and empowering women. The importance of the PDD's quality for the carbon credit issuance was confirmed by several interviews (B, C, E). Following, an external consultant registered with the UNFCCC validates the project. For the GS, co-benefits such as gender equality and sustainable development are key. (Interview E) Afterwards, the project developer may choose the verification interval. Since Nepal hosts only small-volume projects, verification usually occurs annually to reduce costs (Chapter 3.3). External auditors conduct an in-depth country and project visit and verify the ER. After verification, the credits are issued and enter a registry. They may be sold either directly to the buyer or a broker, who retire the credits. The benefit of a broker is he knows the buyer better. However, direct project developer-buyer relationships provide financial security. (cf. Interviews C and E)

This process guarantees additionality and transparency. In fact, the former is automatically granted to Nepal as a South-Asian LDC. (Interview C) Still, it involves many risks for project developers. This paragraph summarizes some of the criticism. First, the GS does not finance projects in advance, which constitutes a substantial problem. (Ibid.) Pre-financing and advance payment before the PDD would aid in developing more projects since loans in Nepal are difficult to receive and carry interest rates of 15- 20 percent. (Interviews E and F) Moreover, a purchase guarantee for the issued certificates would be beneficial because not all Nepalese ER have been sold, mirroring the buyers' market character of the VCO market. It would be important for the market to ensure developer-buyer relationships since 'it is crucial to know the buyer before verification of credits.' (Interview F). This direct link would create financial security for project developers and increase incentives. Lastly, there exists a knowledge gap with many stakeholders with understanding the necessary processes of carbon finance. (SNV 2014)

Additionally, the price per tCO_2e is currently too low for profitable projects. According to respondents, an offset must cost more than 11 USD to render the validation process feasible. A minimum price guarantee would reduce risks and uncertainties for developers and lead to more climate change mitigation projects. (Interviews B and G) In fact, at least two carbon-funded cookstove projects are in the AEPC pipeline, but have not proceeded due to the low price. (Interview F) The large price differences for credits constitute another problem, especially since Chinese and Indian offsets are much cheaper due to their large volume. (Interview E) In Nepal, on the other hand, only small-scale ICS projects with a maximum of 70,000 CERs are possible. (Interview C)

Lastly, the administrative burden and fees (more than 30,000 USD for CDM) only pay off for larger scale projects. The voluntary carbon schemes are cheaper with the VCS capping at 10,000 USD and the GS being only slightly more expensive (Chapter 3.3). As observed in 5.1, however, Nepal has limited financial means and validators and verifiers are too expensive for most private NGOs and companies. Therefore, bundling of several projects under one carbon project and procedure should be possible. Cheaper administrative costs would make it more attractive for project developers to apply for carbon certification. (Interview C and G)

4.5. Conclusions and Potentials

Nepal is a LDC with a large rural population and limited financial possibilities because of a GNI per capita of 730 USD. More than 77 percent of the country's total energy demand is met by solid biomass and 64 percent of households utilize firewood as primary cooking fuel. Consequently, the non-renewable harvest of trees for firewood, estimated at 80 percent, and loss of carbon sequestration, coupled with CO, CO_2 and BC emissions, have adverse effects for the climate. Moreover, the soil is degraded for future reforestation. Additionally, TCS lead to CO and $PM_{2.5}$ concentrations that are up to 100 times higher than the recommended WHO values and have serious adverse health effects. In Nepal, IAP leads to more than 23,000 premature deaths per year. In fact, the country ranks last worldwide in the EPI air quality index.

Out of all 5.4 M households in Nepal, more than 3.5 M continued to rely on firewood as cooking fuel in 2011. Interviewees confirmed that more than 3 M households require ICS technology. One Tier-1 improved cookstove, as applied in previous national programs, may lead to an annual firewood fuel demand reduction of 1,000 to 2,300 kg and to an average $PM_{2.5}$ and CO concentration decline by 63 percent and 60 percent. Increased promotion of ICS is also important to meet the government goals of eliminating IAP by 2020 and providing at least Tier-3 stoves to every household by 2030.

Ensuing this goal, a large amount of finance and investments in research and development as well as production and distribution are required. In the past, Nepalese stakeholders have largely depended on international donors to fund ICS programs. Also, access to loans at the local level has not been institutionalized and many banks have been hesitant to provide money to rural households. (SNV 2014) Recently, however, carbon offsetting and related earnings joined the financial portfolio and to date 7.7 M USD revenue were generated. For ICS, however, only 35,800 stoves out of the 1.47 M distributed received funding from the carbon market. Undoubtedly, there exists a large development potential for VCO market funding of ICS projects in Nepal.

Based on lessons learnt from the ESAP and NRREP programs it would be beneficial to develop carbon credit activities for ICS in Nepal. They would not only generate required income, but also allow for greater project transparency and accountability because of the detailed verification process. Since one ICS saves on average 43 percent firewood and up to two tCO_2e per year, an additional six M CERs per year may be generated by ICS projects in Nepal alone. One study found that at prices of three USD per offset a total of 40 USD may be earned per metallic cookstove over the entire crediting period. (cf. SNV 2014) The potential income from the sale of carbon credits creates incentives to promote efficient, durable and socially accepted projects that improve health, the environment and emissions factors.

However, increased carbon finance for cookstoves in Nepal would require some institutional reform. First, and foremost pre-financing mechanisms are necessary to stimulate additional project development, especially by private NGOs and companies. In the current system, all administrative costs and fees are borne by the developer without the security of a minimum price or that the reduction units will be bought. A price guarantee of at least 11 USD per CO_2e credit would make the PDD, and the validation and verification process profitable for developers. Since the GS pays a premium, the voluntary carbon market in Nepal has the potential to carry more impact than compliance offsets. Another suggested improvement of the VCO market is the possibility of bundling ICS projects to decrease the administrative burden and costs for project developers. In the past, some ICS activities promoted less than 1,000 stoves, for which carbon credits are too expensive to generate. Finally, the governmental actors in the market need to galvanize private developers to enter the ICS carbon market and use the CRE Fund to promote such activities. For now, private companies hardly enter because there is no profitable outlook and a few stakeholders dominate the market. (Interview B)

The design of future ICS would not only require higher efficiencies than current two-pothole mud stoves, but must also consider user needs such as multipurpose requirements of a stove. Moreover, more awareness raising activities for social acceptance of ICS are necessary. To conclude, clean cooking in Nepal implies complex and interdependent factors such as political stability, technology, culture, and financing.

For the latter, the VCO market has the potential to play a key role in reducing Nepal's GHG emissions and promoting public health, thereby advancing synergies between the PA and several SDG indicators.

5. Discussion: Efficacy of the Voluntary Carbon Market

The previous chapters exemplified the complexity of and interdependencies between causes of anthropogenic climate change, equity implications, carbon markets as mitigation response and the challenges of clean cooking. This part summarizes findings and answers the research question to what extent voluntary carbon offsetting acts as an effective mitigation tool for developing countries in a context of clean cookstove programs. Hereby, effectiveness is assessed on one hand quantitatively in terms of GHG mitigation and finance requirements to abate atmospheric CO_2e concentrations. On the other hand, efficacy is qualitatively discussed with regards to structures and ethical underpinnings of climate action. Moreover, overlaps between mitigation and sustainable development are evaluated and conclusions from the case study borrowed as empirical support.

Globally, 2.5 billion people continue to rely on traditional biomass to meet household cooking needs. Traditional cookstoves produce unvented smoke and lead to life-threatening IAP. In Nepal alone, excessive CO, $PM_{2.5}$ and BC concentrations cause 23,000 premature deaths per year. In addition, fuelwood collection poses risks to personal safety, curbs education and income-generating work, and deteriorates forests. By reducing these risks and pressures, improved cookstoves yield multiple health (SDG 3), economic (SDG 10), and climate (SDG 13) benefits, and empower women (SDG 5). Additionally, traditional biomass burning produces GHGs and BC that contribute to climate change. The global potential for GHG ER from ICS projects is estimated between 270 $MtCO_2e$ and 1,000 $MtCO_2e$ per year, depending on the technologies applied and the type of ER calculations.

Hence, cookstove programs constitute one of several mitigation activities required to achieve the 2°C goal of the PA. Clean cooking provides evidence for the nexus and correlation between climate action and sustainable development. In Nepal, research has shown that one two-pothole mud ICS reduces annual fuelwood consumption by up to 2,300 kg, CO_2e emissions by one to three tonnes per year, and $PM_{2.5}$ and CO concentrations by 63 and 60 percent respectively. The defined co-benefits illustrate that 'building mitigative and adaptive capacity relies to a profound extent on the same factors as those that are integral to equitable and sustainable development.' (IPCC 2014, 288) In this sense, cookstoves are decisive in both abating a rising atmospheric CO_2 concentration and advancing several SDGs.

Notwithstanding the identified ‘win-win’ situation of ICS programs, there exists a large global funding gap of at least four billion USD per year. (SE4All 2017b) Therefore, a plethora of actors have focused on the carbon market to monetize the benefits of ICS projects. The GACC, for instance, had promoted 116 M stoves by 2017 and garners carbon market backing for future activities. With an average price of 11 USD per tCO_2e, the voluntary carbon market could generously close the funding gap, and in addition generate net finances for implementing countries. In Nepal alone, with this price cookstoves and the carbon market could create 33- 100 M USD in annual revenue. In fact, improvements are even possible in households that already own an ICS because of the poor efficiency of previous ICS models. To reach Nepalese government goals stove substitution from two-pothole mud stoves to alternative models may even be required. The CDM’s AMS-I.E (Chapter 3.2) methodology could calculate further ER from fuel switching, i.e. to electric stoves. Against this background, carbon finance fosters not only access to clean energy, but also entrepreneurship while decreasing donor dependency.

In the past, the compliance market received mixed political signals and therefore faces uncertainty; hence it is worthwhile to investigate the voluntary carbon market which is less exposed to changing administrations. In 2016, 71 percent of transacted VCOs originated in developing countries and generated tangible rent for them. In this vein, effectiveness of offset revenue for issuing countries has been demonstrated, if used for transitioning to a low-carbon economy. (World Bank 2017, 34). Nepal represents a case in point since proceeds of the carbon market are channelled into the CREF. Eighty percent of carbon revenue supports the same technology that generated the credits in the first place. However, the price range for VCOs in 2016 stretched from only 0.5 USD to 50 USD and curbed these efforts. Consumers paid on average 4.7 USD and project developers received only 1.7 USD per tCO_2e. (Hamrick and Gallant 2017a) This is far from the estimated real external costs of one tCO_2e emitted and the 11 USD that interviewees deemed necessary for profitable mitigation projects. By 2020 the World Bank calculated 40- 80 USD per tCO_2e as imperative for a tangible 2°C goal. Hence, it appears that the current VCO market fails to meet mitigation requirements in terms of practical financing for mitigation project implementing entities. Nevertheless, the price differentiation between projects and standards is noteworthy. The GS, for instance, explicitly incorporates at least three SDGs and earns a premium price. This is valuable insight for developing countries to increasingly focus on co-benefits of climate action.

Another advantage of the voluntary carbon market is that outcomes must be measurable and additional. The stringent standards of the VCO scheme, as exemplified by the GS, provide confidence in the integrity of a country’s climate policy. The differentiation and focus on co-benefits within the VCO market allow to extend the traded commodity beyond the tCO_2e mitigated and consolidate the SDGs. Certainly, criticism has been voiced on additionality being a flawed concept because VCO projects are measured against a hypothetical baseline. This is partly supported by the present case study since the majority of cookstove programs occurred without carbon finance. However, it is also not possible to assess on the contrary how many more ICS would have been distributed with additional carbon funding. The case study further supports the insight that carbon markets enable environmental entrepreneurship and capacity building. In Nepal the most obvious examples are the Climate and Carbon Unit at the AEPC and the strengthening of the CRT/N. Both evolved as key players in renewable energy promotion, partly due to their involvement in the carbon market.

Regarding the administrative burden and fees of VCO, results are mixed. Interviewees argued that high transaction costs, especially for the CDM, bar potential project developers from market entry and thus climate action. The case study illustrated that in Nepal participation in the VCO scheme is deterred by a lack of pre-financing and high administrative fees. This is supported by findings of the World Bank (2017) that high transaction costs with upfront costs of 70,000- 100,000 USD for a CDM project discouraged mitigation projects. The research showed that the voluntary scheme implies lower transaction costs and is therefore more attractive to small and medium-scale projects. Especially LDCs such as Nepal oftentimes engage in activities of only a couple thousand CERs and hence cannot afford an expensive certification process. The flexibility and comparatively low administrative burden make the voluntary market appealing for both governmental actors and environmental entrepreneurs.

In absolute terms, global anthropogenic GHG emission levels were 49 $GtCO_2e$ in 2010 (IPCC 2015) and 53 $GtCO_2e$ in 2014 (UNEP 2016), out of which around forty percent remained in the atmosphere and added to the cumulative carbon budget. (IPCC 2015) Subtracting GHG sinks and removal from the atmosphere, there remains a global carbon budget of 800 $GtCO_2e$ if the climate system should remain within 2°C warming. In this sense, the emissions gap represents an authoritative estimate of additional reductions necessary to ensure this goal. Arguably, until 2030 an additional 12- 14 $GtCO_2e$ in anthropogenic GHG emissions need to be abated. (UNEP 2016) Certainly, the 63.4 $MtCO_2e$, only 0.063 $GtCO_2e$, retired within the VCO scheme in 2016 comprise a drop in the ocean, or literally a few molecules in the atmosphere. As of today, VCO does not have the potential to meaningfully reduce and sequester GHG emissions, and narrow this emissions gap. In fact, global anthropogenic GHG emissions have even risen since the introduction of carbon markets in the early 2000s. The 1.6 billion CERs cumulatively issued by 2016 and the more than one billion offsets of the voluntary market ostensibly have had a marginal effect. Nevertheless, VCO provides important structures for compliance markets and sector-based approaches such as the aviation sector's CORSIA.

Notwithstanding shortcomings, carbon offsetting holds essential ethical advantages as mitigation instrument. Those who emit large amounts of GHG partly contribute to the harmful effects of climate change in developing countries, such as sea-level rise, drought, food insecurity and an altered hydrological cycle. Distributive and compensatory justice provide strong arguments for a moral obligation to first reduce own emissions and then offset the remainder. In fact, international cooperation in mitigation per se implies equity concerns. The VCO scheme offers an opportunity for individual actors such as companies, governments, NGOs and individuals to engage in ethical acts and move towards 'carbon neutrality'. Additionally, the market is expected to lead to more GHG reductions at a lower cost. Still, this theoretical strength of the voluntary market has not yet translated to palpable transactions and scaled up projects in developing countries. In the end, voluntary carbon offsetting schemes do not represent an effective climate change mitigation tool for developing countries in quantitative terms. Moreover, the case study showed that climate action was a minor motivation for cookstove programs in Nepal, where mostly improved health concerns fuelled projects. (cf. Appendix A) GHG ER constituted a welcomed co-benefit and not vice-versa. In fact, the Nepali NDC for the PA hardly acknowledges carbon offsetting as mitigation instrument and criticizes the low prices per tCO_2e abated.

The VCO's foundation of equity principles and structural reform may still be viewed as effective instruments. Carbon markets are important in capacity building and improving livelihoods. In essence, the case study illustrates that Nepali stakeholders are well-aware of the climate and development challenges the country faces, such as energy poverty and technological challenges. In this regard, voluntary offsets help introducing new expertise and actors such as the GACC, NGOs and stove entrepreneurs. The voluntary carbon market provides a strong advantage for the country by offering premium prices for i) LDCs and ii) co-benefits. The importance of co-benefits of climate mitigation emerges as a particularly strong rationale and basis for sectoral action, financed by voluntary carbon offsets. This is especially relevant to note for Nepal, where only 35,800 of 1.47 M distributed cookstoves to date received carbon market funding. To conclude, VCO constitute a viable, if only complementary, option in developing countries' mitigation portfolio, as long as the market itself pertains viable.

Furthermore, some suggestions for reform and improvement may be advanced to render VCO for developing countries more effective. First, market actors should provide pre-financing for small-scale projects to abate risks and uncertainties for project developers. This could be done i.e. through pre-identified buyer-seller relationships. Next, it would be more efficient for offset suppliers to bundle several projects and activities in one process. This is partly acknowledged by the CDM Board through 'programmatic crediting and streamlined additionality assessments.' (World Bank 2017, 66) However, the GS and other market actors do not allow for bundling because of verification concerns.

Essentially, a stable and robust price for voluntary offsets is required for private sector and government confidence in the profitability of abatement investments. One option could be carbon market management by public reserves to tackle price volatility. (cf. World Bank 2017, 67) This way a price floor could be supported and even increase buyers' demand by more realistically reflecting the externality of one tCO_2e. Lastly, it is necessary to closely follow the negotiations on the implementation of PA Art.6 and the possibility of a connected global carbon market with linked standards. A clearing of the alphabet soup of CERs, EUAs, JI, GS, VCS and plenty more could benefit the market. Together with current and future regulatory discussions, i.e. around CORSIA with a purported demand of 2.5 $GtCO_2e$, linkage will largely define the role of the VCO scheme in the future.

With regards to cookstove programs, it would be valuable to include all emissions and substances that exert a radiative forcing on the global climate. Foremost, involving CH_4 and BC emissions into the testing procedure, such as the WBT, and eventually standards would more realistically reflect the climate benefits of ICS. Standardization organizations such as the CDM and GS should stand in continued dialogue with science. BC has been found to rank amongst the largest climate forcing species. However, relevant benchmarks from the GACC, the WBT and NIBC2016 all exclude the substance. Solid biomass cooking fuels have been identified as a major BC source, adding 1,300 of a total 7,500 Gg BC per year. The GWP of BC is disputed, but larger in areas with high albedo surfaces such as the ice-capped Himalayan ranges of Nepal. To conclude, it would be advantageous to reflect BC reductions of ICS in carbon certificate issuance.

Lastly, cookstove programs need to carefully evaluate technologies. As shown in the case study, cultural preferences may override ER. Although two-pothole mud stoves have low efficiencies and do not meet WHO standards they were preferred over portable designs. Solar cookstoves, for instance, achieve substantially more GHG ER but find no acceptance in Nepal. Hence, the effectiveness of VCO mitigation measures depends not only on market parameters, but also on cultural factors and the local context.

6. Conclusion

Present and future generations experience anthropogenic climate change with significant risks and consequences. Developing countries contribute only marginally to global cumulative emissions, yet suffer most from their negative impacts due to increased exposure and little adaptive capacity. Hence several distributive and compensatory equity concerns arise, encapsulated under the concept of ‘climate justice’. Such intrinsic justice considerations underpin carbon markets and financial transfers from the polluter to those affected, and are *inter alia* recognized in the UNFCCC and PA Articles 6 and 9. Carbon finance does not constitute development aid, but a market mechanism for the global common ‘climate’. This way, voluntary offsets provide an operative channel of restitution for carbon footprints and an ethically founded emissions abatement instrument.

This thesis asked to what extent such voluntary offsets constitute an effective mitigation tool for developing countries, linking the issue to cookstove promotion. The empiric core included discussion of (voluntary) carbon markets and clean cooking as a global development and climate challenge. The concepts and findings were tested in a case study about socio-political, technical and economic aspects of carbon credits and cookstoves in the LDC Nepal.

First, VCO schemes have demonstrated a mixed track record in achieving ER. The voluntary carbon market transacted 63.4 $MtCO_2e$ in 2016 and a maximum of 135 $MtCO_2e$ in 2008. This represents a trivial amount against the additional emissions reductions necessary to ensure the 2-degree goal of 12 to 14 $GtCO_2e$ for 2030. In fact, since the introduction of carbon markets in the early 2000s, global GHG emissions have increased even faster. However, ongoing policy debates about the implementation of the PA’s Article 6 and CORSIA provide profound opportunities for scaling up the VCO market, and hence raise the bar for climate projects in developing countries. Another advantage of VCO is its relative independence of politics and changing administrations because of the market’s decentralized character. Moreover, common standards such as the Gold Standard and the Verified Carbon Standard constitute comprehensive methodologies and frameworks for assessing and transparently verifying CO_2e reductions. To conclude, voluntary offsets have been ineffective in providing large-scale ER of GHGs in developing countries, yet may serve as elemental structure for future mitigation frames.

In Nepal, more than three million households continue to rely on firewood as cooking fuel. The case is exemplary for the more than 2.5 billion people worldwide who use solid biomass for daily cooking, which is associated with drudgery for women, deteriorating health, high pollutant emissions and unsustainable harvest of forests. Replacing three-stone fireplaces with improved stoves annually saves up to 2,300 kg of fuelwood per household in Nepal and reduces climate-harming CO_2, CH_4 and BC emissions. Carbon finance has played a role by changing the funding dynamic for projects that traditionally depended on donor aid. However, prices are too low and deterred at least two projects in the country.

In 2016, at least 34 $MtCO_2e$ in global GHG emissions were saved by offset-financed cookstoves. The estimated ER potential worldwide lies considerably higher at 1,000 $MtCO_2e$ per year. Hereof, the VCO scheme and particularly the Gold Standard have been pivotal by focusing on SDG co-benefits and providing a premium price. The general price of VCOs, however, declined in past years with an average for project developers of 1.7 USD per tCO_2e in 2016. This value greatly deviates from the 11 USD necessary for project implementing entities to cover their costs. The low costs per credit considerably limit the voluntary carbon scheme's attractiveness and hence effectiveness.

The case study revealed that the current VCO scheme requires some reform to improve its efficacy in developing countries, and LDCs in particular. Pre-financing and a price floor for credits would abate risks and uncertainties about a project's revenue. Moreover, bundling of small-scale projects would benefit further expansion and revenue generation. Another important aspect is incorporating BC measurements and consequently reductions in offset verification. The substance possibly comprises the second largest climate forcing species and solid biomass burning adds 17- 25 percent to its total emissions. Cookstove programs could earn more credits with a BC parameter in the crediting methodologies. The case study further showed that Nepal is well-entangled with international stakeholders and applies standardized procedures. By 2030 it aims to provide at least Tier-3 stoves to all households, for instance by electric stove promotion. However, this calls into question the additionality of offsets, which is automatically granted to LDCs. Indeed, only 35,800 of the 1.47 M promoted stoves in Nepal received carbon funding. Nevertheless, stakeholders responded that VCO represents an incentive to disseminate clean and improved stoves because it fills a funding gap. Lastly, some parameters for real ER remain outside the market, such as political stability, cultural acceptance and linkage.

This thesis highlighted several issues for future research. First, it is necessary to explore the GWP of BC emitted by cookstoves and subsequently associated climate benefits of ICS. A novel methodology for calculating the offsets accounting for BC would certainly be valuable. Second, the debate about additionality of VCO projects has not conclusively ended. Additional research with an empirical analysis about the role of carbon credits in cookstove promotion could shed light into the driving forces behind mitigation projects. Lastly, further researching linkage between different carbon standards would be beneficial to eventually design a global carbon scheme as a reliable option for mitigating anthropogenic climate change.

In conclusion, voluntary carbon offsetting constitutes a drop in the ocean in absolute global emissions reductions and only complements other mitigation activities to achieve the necessary GHG emissions cuts for the 2-degree goal. However, the voluntary market empowers environmental entrepreneurs in developing countries and establishes capacities for mitigation activities. These structures and associated standards comprise important foundations for compliance market activities and potentially for a future linked global or sectoral mechanism. Moreover, VCO offers flexibility for project developers because of different standards and differentiation between activities. Importantly, cookstove programs within the voluntary scheme highlight synergies between climate action and the Sustainable Development Goals. Finally, on a local scale, carbon offsets enable climate action and clean technology proliferation. Carbon financed cookstove projects are effective on the ground in reducing exposure to indoor air pollution, empowering women, diminishing pressures on forests and thereby improving livelihoods.

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Appendix A

Interview # A	Place, Date: ICIMOD Patan, 10th of April 2018
Institution: Global Alliance for Clean Cookstoves (GACC)	Role: Nepal Country Program Manager
1. General Questions	
1.1 What does your institution do in the field of carbon offsetting and/or Improved Cookstoves (ICS)?	The GACC is not active in carbon offsetting schemes. Its main focus lies on public health promotion and behavior change communication. The INGO works directly with i) the government actors AEPC, CRT/N and Ministries ii) the supply side private sector and iii) the end buyers of ICS. GACC Nepal was only established in early 2017 and aims at supporting the stakeholders in clean cooking solutions. It acts as networking platform and support for enterprises.
1.2 How many ICS projects in Nepal are financed with carbon credits? (estimate)	(AEPC has exact data) There exist at least three cookstove projects that receive carbon credits, run by the CRT/N and SNV. The largest international initiative by the Nepali government and international donors have been the two ESAP programs (1997-2012).
1.3 To what extent is Carbon Offsetting a climate change mitigation strategy?	Carbon offsetting is relevant. However, the price for credits has to increase for the feasibility of projects. Moreover, the user accessibility to technology should be improved. The stove technology has to be in accordance with user demands.
2. Questions about Voluntary Carbon Offsetting (VCO)	
2.1 What is your experience with VCO?	n/a
2.2 Who are the relevant actors (project developers, verifiers, financial flows)?	The AEPC coordinates the carbon offsetting programs in Nepal. It is the Designated National Authority for international organizations, such as the UNFCCC. Other important actors are international donours such as the KfW, Norway, DANIAID, UK Department for International Development, UN Development Program
2.3 Have you worked with the Gold Standard/ Verified	No.

Carbon Standard? What are the experiences?	
2.4 How are the tCO_2e traded?	n/a
2.5 How could the VCO market carry more sustainable development incentives? How relevant is the price for a tCO_2e?	The price for a tCO_2e is essential for project developers. GACC works with private cookstove enterprises and for them the price is a main argument to enter the market. The VCO market gains attractiveness with increasing prices. The women who cook are not ready to pay a lot of money (more than 20 USD) for cookstoves. Especially, since the awareness for indoor air pollution and environmental damage is lacking.
3. Questions about Clean/ Improved Cookstoves	
3.1 What are the relevant social and environmental factors of ICS in Nepal?	In Nepal, cooking is exclusively considered a female chore. It frequently also occurs that girls cannot go to school because they have to help their mothers collecting firewood and cooking. It takes up to five hours of the day just to collect the firewood fuel and cooking represents another key component of rural life. Therefore, indoor air pollution (especially CO and $PM_{2.5}$) is the most relevant social factor for ICS. Levels are up to 200 percent higher than the WHO threshold. Environmentally, the excessive use of firewood for cooking depletes the forests. Moreover, GHG and VOC emissions can be reduced. In urban areas, the situation is better because many Nepalese use LPG or electricity for cooking.
3.2 What is the development potential of ICS?	So far, more than 1 million cookstoves have been distributed with ESAP I and II (1999-2012). The ICS have been mostly artisan built 2-pot hole mud stoves with a chimney. The 2011 national census found that out of a total of 5.3 million Nepali households, 3 million still require improved cookstoves. Therefore, the development potential of ICS is very large in Nepal. However, the caution and user skill are crucial for the actual success of reduced stove emissions. For instance, cleaning and maintenance of the stoves is important.
3.3 How are emissions factors in a project calculated?	The RETS is responsible for testing all portable cookstoves. Moreover, the GACC relies on the measurement equipment

	developed by Kirksmith. For own emissions factor calculations, GACC employs consultants who monitor the factors on-site.
3.4 What are the technologies most frequently applied?	The old method is a three-stone fire with firewood fuel. As an improvement, in the Southern Terai region people use biogas. In urban areas such as the Kathmandu Valley and Pokhara LPG is used. Induction is a governmental area of interest because it would reduce dependency on LPG imports. ESAP I focused on mudbrick stoves with chimney. They save up to one third of fuel. Portable metal cookstoves have only lately gained traction. Solar powered cookstoves are not suitable, because in Nepali cooking culture is not outside.
3.5 How much fuel and greenhouse gas emissions can be saved with ICS?	A lot. Every stove saves at least 30 percent of GHG emissions and there are around 3 million households which require improvement. The AEPC government strategy is that Nepal is indoor air pollution by 2022. Measurements by GACC show that with the Tier I technology around 40 percent of pollution remains indoor and 60 percent evade into the atmosphere.
3.6 What is the biggest obstacle to clean cooking in Nepal?	A lack of international donors and interest by both the international community and national government. Access to information and finance is very poor. Interest rates are high around 16 percent. It is difficult for private sector companies to enter the cookstove market. There is too little awareness among rural Nepali population for indoor air pollution and the benefits of clean cooking.

4. Other Comments/ Follow-Up	
How is a clean cookstove defined as opposed to an Improved Cookstove?	A clean cookstove has defined emissions factors for CO, $PM_{2.5}$ and VOC. There is work for an ISO Standard. Improved Cookstoves are not ‘clean’, but improve the air quality.
Do the households have to pay for the cookstoves?	Yes, the households have to pay the cookstove, depending on their own contribution. One stove is between 1000- 2000 Nepali Rupees. However, the training and awareness campaign is funded by donours.

<table>
<tr><td colspan="2">Interview # B Place, Date: Bhaktapur, 9th of April 2018</td></tr>
<tr><td colspan="2">Institution: Himalayan Naturals Ltd. , Private Company | Role: Managing Director</td></tr>
<tr><td colspan="2">1. General Questions</td></tr>
<tr><td>1.1 What does your institution do in the field of carbon offsetting and/or Improved Cookstoves (ICS)?</td><td>The company produces charcoal and biomass pellets. The expertise lies with community based projects. Currently, the briquettes are used more for barbecue, tandoori and heating. However, Himalayan Naturals Ltd. is part of the Nepal Alliance for Clean Cookstoves.

Plants and biomass are processed by pyrolysis and turned into biomass pellets. Biomass is taken from community forests and transported to the factory in Bhaktapur. The heating value is around 5000-6500 kcal/ [kg] Eventually, the charcoal pellets are sold to the market. We developed a carbon project with the German Atmosfair but stopped after the PDD.</td></tr>
<tr><td>1.2 How many ICS projects in Nepal are financed with carbon credits? (estimate)</td><td>There were some in pipeline by the CRT/N and the AEPC has a large-scale program. However, not certain about the numbers.</td></tr>
<tr><td>1.3 To what extent is Carbon Offsetting a climate change mitigation strategy?</td><td>Currently, it does not represent an effective climate change mitigation strategy. Voluntary carbon offsetting is considered a luxury good and depends on the economic state. It is more a ‘fun’ item that can be discarded if necessary.</td></tr>
<tr><td colspan="2">2. Questions about Voluntary Carbon Offsetting (VCO)</td></tr>
<tr><td>2.1 What is your experience with VCO?</td><td>Some NGOs have been successful in distributing stoves. However, for private companies the knowledge about the carbon market is lacking. Companies do not start because of carbon credits, but because of market opportunities. We had one project in pipeline, but because of an incompetent consultant could not proceed with the PDD and emissions reductions calculations.</td></tr>
<tr><td>2.2 Who are the relevant actors (project developers, verifiers, financial flows)?</td><td>Project developers are companies and INGOs. Validators are individual consultants from abroad (India, Germany) Global brokers such as MyClimate are important but the contact is difficult.</td></tr>
<tr><td>2.3 Have you worked with the Gold Standard/ Verified Carbon</td><td>Yes, we started working with the Gold Standard. You have to pay a fee to register and then upload legal documents. Once in the registry, you may upload the PDD (developed</td></tr>
</table>

Standard? What are the experiences?	by a consultant). This is a lengthy and expensive process for a company. Unfortunately, our consultant was not good and the project stopped.
2.4 How are the tCO_2e traded?	The company only reached the PDD level and validation/ verification was not conducted. The GS would have verified and then carbon credit trade would have been possible.
2.5 How could the VCO market carry more sustainable development incentives? How relevant is the price for a tCO_2e?	The price is very relevant. If it was more than 11 USD validation would be profitable. Also, the regulatory carbon market should be bigger and a security of buyers is necessary.
3 Questions about Clean/ Improved Cookstoves	
3.1 What are the relevant social and environmental factors of ICS in Nepal?	Cooking is the most basic socio-economic aspect of life in Nepal. Important factors are commercial viability, indoor air pollution and environmental protection.
3.2 What is the development potential of ICS?	Around 70 percent of Nepali households use firewood for cooking. With a growing GDP per capita, the situation will improve due to economic advancement. There exists a large demand for clean, efficient and cost-effective ICS. However, the supply-driven solutions by the AEPC do not meet the demand.
3.3 How are emissions factors in a project calculated?	RETS tests emissions factors. The government asks for the certificate when giving subsidies. The testing is good in Nepal, and also done for other countries such as Bangladesh.
3.4 What are the technologies most frequently applied?	In the past, the mud-chimney stoves were highly promoted. Now, metallic portable stoves are preferred. LPG has also been growing, but is not an officially promoted technology.
3.5 How much fuel and greenhouse gas emissions can be saved with ICS?	Since biomass is a renewable carbon neutral technology, a lot of GHG emissions can be saved. As a project developer, you also have to prove that forest regeneration is provided.
3.6 What is the biggest obstacle to clean cooking in Nepal?	-Inaccessibility of remote areas and poor economic development. -there is no developed clean cooking market in Nepal. The supply-driven market does not meet consumers' demands.

4 Other Comments/ Follow-Up

Why did the ICS carbon project you developed not proceed?	The Langtang project did not work since the ground reality did not match our technology solution. The ICS are expected to be as convenient as LPG. There exists no stove sophisticated enough for biomass pellets. Cooking must be reliable and users do not want compromises.

Interview # C	Place, Date: Bhaktapur, 11th of April 2018
Institution: Independent Consultant; Former CRT/N, AEPC	Role: ICS and CDM expert
1. General Questions	
1.1 What does your institution do in the field of carbon offsetting and/or Improved Cookstoves (ICS)?	I used to work for the CRT/N, AEPC and Winrock International. In every position, I worked in ICS and CDM project development. I was responsible for the whole project from baseline calculations to completing the PDD and validation.
1.2 How many ICS projects in Nepal are financed with carbon credits? (estimate)	I am aware of the Terai ICS Carbon project, that was the first cookstove carbon project in the country. Another CRT/N project collapsed in 2010. The AEPC receives carbon credits for ICS with an unknown amount.
2. Questions about Voluntary Carbon Offsetting (VCO)	
2.1 What is your experience with VCO?	The compliance and the voluntary carbon markets act in a similar way. However, there exist less rigid formalities with the voluntary market. It is more flexible which is highly relevant for developing countries like Nepal. The GS pays a premium price which helps. The expensive validation process (approx. 30,000 USD) for the compliance market bars the entry for many developers. Since the voluntary carbon market is cheaper it is more attractive for small enterprises.
2.2 Who are the relevant actors (project developers, verifiers, financial flows)?	-CRT/N; AEPC: has increased its influence because of centralization. The Programmes of Activities under the UNFCCC make on the one hand administration of ICS projects easier, but on the other bars the entry of other actors. The AEPC was previously under the Min. of Environment and is now under the Min. of Energy, which raises questions about continuity; The Min. of Environment is the UNFCCC Designated National Authority.

2.3 Have you worked with the Gold Standard/ Verified Carbon Standard? What are the experiences?	Yes, when the GS had just started. We wrote a project idea note, gathered the baseline scenario data and completed the PDD. The validation was undertaken by UNFCCC appointed consultants. It took 7- 8 months to get validated. The GS did not finance in advance, which constituted a problem. There is a financial barrier and uncertainty and it is crucial to know the buyer beforehand. They can help pre-financing. In Nepal, ICS projects are small-scale with only around 5,000 CERs generated. 70,000 CERs are a maximum. The additionality is automatically given for South Asian countries.
2.4 How are the tCO_2e traded?	After validation, the project developer may request to verify the CERs monthly, quarterly or annually; it depends on the financial feasibility. The credits so issued may then be sold to a buyer on the compliance market, or also voluntary market. With the latter, the GS is the most frequent option.
2.5 How could the VCO market carry more sustainable development incentives? How relevant is the price for a tCO_2e?	-Stability of price -Cheaper administrative costs -pre-financing
3. Questions about Clean/ Improved Cookstoves	
3.1 What are the relevant social and environmental factors of ICS in Nepal?	There is a traditional culture of three-stone fireplaces, especially since firewood is 'easy and cheap'. Local production of mud artisan stoves carries the advantage of local employment and bottom up approaches. There is a growing awareness that a chimney improves the situation. 'Fancy' rocket stoves cost 35-50 USD and are too expensive for most families, they prefer to invest savings in cellphones.
3.2 What is the development potential of ICS?	There is a huge potential. Due to remittances, people want to upgrade their households and lifestyles. Cooking is the most basic chore you must do in Nepal, therefore efforts should be strengthened. There exist around 3 million households that require ICS.
3.3 How are emissions factors in a project calculated?	AMSIIG was the methodology used for the Terai ICS Carbon project.
3.4 What are the technologies most frequently applied?	Previously, the 2-pot hole mud stove was the preferred option because it is cheap and locally built. Around 80 percent of ICS include this technology. Rocket portable

	stoves are five times more expensive and have only lately gained traction. LPG signifies more of a social status – culture is important.
3.5 How much fuel and greenhouse gas emissions can be saved with ICS?	1 – 2 tons of CO_2e per year per stove.
3.6 What are the biggest obstacles to clean cooking in Nepal?	Behaviour change is difficult to achieve. There exist several cultural factors. The cooking place is worshipped as a sacred place and the old three stone fireplace forms part of the identity for many. Also, in many Hindu families the family temple/altar is in the kitchen. Lastly, the donour dependency is a large problem, since people wait for ICS to come for free and be distributed. 'Donours make you paralyzed' and they distort the market. The value of ICS increases when you pay for it.

4 Other Comments/ Follow-Up	
What is the role of international donours in ICS and carbon projects?	Donours do not finance VCO market projects because of a conflict of interest. If a project becomes successful, the donours lose their own purpose. They should give Nepal not the fish, but the fishing rod.

Interview # D	Place, Date: Patan, 11th of April 2018
Institution: Royal Norwegian Embassy Kathmandu	Role: International Donour Country
1. General Questions	
1.1 What does your institution do in the field of carbon offsetting and/or Improved Cookstoves (ICS)?	Norway supports the different development programs in Nepal and was last involved with NRREP until 2017. As international donour it assists ICIMOD and the GACC in their implementing programs to combat air pollution and promote clean cooking. The latest project is the Urban Health Initiative. Norway has not been involved with carbon offsetting.

1.2 How many ICS projects in Nepal are financed with carbon credits? (estimate)	Through NRREP and the ESAP programs carbon credits were generated by ICS. The generated funds were channeled into the Central Renewable Energy (CRE) Fund by the AEPC. The program supported 458,482 cookstoves.
1.3 To what extent is Carbon Offsetting a climate change mitigation strategy?	Carbon offsetting and pricing should be discussed as one possible climate change mitigation solution.
2. Questions about Voluntary Carbon Offsetting (VCO)	
2.1 What is your experience with VCO?	n/a
2.2 Who are the relevant actors (project developers, verifiers, financial flows)?	AEPC, ICIMOD, WHO, CRT/N, International Community
2.3 Have you worked with the Gold Standard/ Verified Carbon Standard? What are the experiences?	n/a
2.4 How are the tCO_2e traded?	n/a
2.5 How could the VCO market carry more sustainable development incentives? How relevant is the price for a tCO_2e?	Norway supported the ESAP programs and NRREP to foster sustainable development in Nepal. Since there occurred some financial irregularities with the latter the support ended in 2017. Political stability and reliability are crucial components for cooperating for sustainable development, such as with ICS projects.
3. Questions about Clean/ Improved Cookstoves	
3.1 What are the relevant social and environmental factors of ICS in Nepal?	Indoor air pollution, mostly by $PM_{2.5}$ and CO, constitutes a huge problem. Moreover, deforestation and illegal logging lead to environmental degradation. ICS play a role to tackle these issues and also empower women.
3.2 What is the development potential of ICS?	75 percent of the population in Nepal enjoy some kind of energy access and the government goal is to reach 99 percent by 2030. This is also their country target for SDG 7. This means that electricity and grid connection can foster electric cooking in the future. In Nepal, 40 percent of people live in urban areas and could be priority groups for electric cooking.

3.3 How are emissions factors in a project calculated?	From Norway's perspective, this is done by consultants and external auditors.
3.4 What are the technologies most frequently applied?	The 2-pot hole mud/ clay stove with a chimney; Biogas cookers through NRREP; and electric cooking standard is in working process now. LPG is widely used and considered an 'improved' technology, but not funded by public programs.
3.5 How much fuel and greenhouse gas emissions can be saved with ICS?	n/a
3.6 What is the biggest obstacle to clean cooking in Nepal?	There are cultural and educational factors. Some people do not trust the modern technologies and whether the taste is the same. There is much skepticism about change. Moreover, there is a lack of awareness on the health implications of open fire cooking and the smoke generated.

4 Other Comments/ Follow-Up	
What is your comment on the role of international donours in ICS and carbon offsetting?	There exist more than 40,000 INGOS in Nepal, who are active in varying degrees. This is a large amount to be coordinated. As for ICS, subsidies do not constitute a sustainable solution because of dependencies that are created. An open market could replace the public programs potentially more effectively. This is true for the entire clean cookstove value chain from development to distribution. The public- private partnership is key to reach the SDGs.

Interview # E	Place, Date: Thamel, 12th of April 2018
Institution: Carbon Offset Expert and former CRT/N	Role: Cookstove Project Coordinator
1. General Questions	
1.1 What does your institution do in the field of carbon offsetting and/or Improved Cookstoves (ICS)?	First, I worked for several years for the CRT/N. Then I had a two-year contract working on a cookstove project that had a UK buyer. The INGO Winrock verified 2000+ stoves. I was responsible for the Chitwan Carbon Offset Project. Afterwards, I moved to the UK and used my seven years

	experience in ICS project development for working on carbon offsetting projects.
1.2 How many ICS projects in Nepal are financed with carbon credits? (estimate)	In the Terai Project, which was the first ICS carbon project in Nepal, 39,672 credits were generated of which approx. 20,000 also got sold. The Chitwan project was much smaller with 2000+ stoves sold. There was another Winrock project with around 5,000 stoves promoted and voluntary carbon credits generated. SNV supported CRT/N with the implementation of a project in the West. Around 100,000 stoves were disseminated and registered with the GS. In Nepal the voluntary carbon market procedure largely follows the compliance market.
1.3 To what extent is Carbon Offsetting a climate change mitigation strategy?	For developing countries such as Nepal there continue serious development challenges, such as indoor air pollution. Carbon offsetting is a good opportunity to generate finances/ income for sustainable development solutions. There still exists a lot of potential.
2. Questions about Voluntary Carbon Offsetting (VCO)	
2.1 What is your experience with VCO?	I worked with VCO companies and supported projects. On the UNFCCC website there are Nepal's official CDM projects.
2.2 Who are the relevant actors (project developers, verifiers, financial flows)?	AEPC; NGOs; Winrock; ICIMOD; CRT/N; SNV; private companies with limited possibilities
2.3 Have you worked with the Gold Standard/ Verified Carbon Standard? What are the experiences?	The CRT/N Terai ICS Carbon Project was registered under the GS. Co-benefits and aspects such as gender equality, sustainable development, additionality were important to register with the GS. After the PDD, the Min. of Environment is usually contacted as UNFCCC Designated National Authority (DNA). However, this is not necessary for VCO GS projects. Still, government endorsement is desirable. One key benefit of the VCO market is that it is less bureaucratic and the GS assigns an independent validator.
2.4 How are the tCO_2e traded?	For the VCO market there exist different pathways, since it is a highly decentralized market. One way is the registry under the GS. Since Nepal is a UN Least Developed Country its credits are preferred and receive a premium price. The

	benefit of a broker is that he knows the buyers better, but direct project developer- buyer relationships give financial security.
2.5 How could the VCO market carry more sustainable development incentives? How relevant is the price for a tCO_2e?	The focus on co-benefits such as women empowerment/ sustainable development and employment is a key advantage and should be promoted. Advance payment/ upfront finance would help to develop more projects since loans are very difficult to receive in Nepal. Lastly, the price differences between offsetting projects constitute a problem. I.e. Chinese and Indian VERs are much cheaper.
3. Questions about Clean/ Improved Cookstoves	
3.1 What are the relevant social and environmental factors of ICS in Nepal?	Indoor air pollution, women empowerment (by reducing their workload by 2-3 hours per day and improving health), employment for local artisans, less burns and accidents with ICS, less deforestation, less air pollution and reducing GHG emissions.
3.2 What is the development potential of ICS?	Around two-thirds of households use firewood as fuel and require ICS solutions. LPG and electricity are growing, but face difficulties. There is a large urban-rural divide.
3.3 How are emissions factors in a project calculated?	One cookstove reduces around 1- 1.5 tCO_2e per year. This number can certainly be improved by more efficient cookstoves. The η of a traditional stove is less than ten percent and ICS reach η =25- 30 percent. The calculation depends on the stove efficiency and fuel use.
3.4 What are the technologies most frequently applied?	Since pre-fabricated stoves are generally socially not accepted, locally built mud stoves with readymade combustion chambers have been frequently applied. Each stove carries an engraved unique register number. Biomass briquettes, firewood and biogas are the most frequently used cooking fuels. Now, pre-fabricated rocket stoves become more popular. LPG is a symbol of prestige and some only use it for guests since it is costly. Oftentimes, people do not use chimneys because of tradition and heating.
3.5 How much fuel and greenhouse gas emissions can be saved with ICS?	Most can be saved with electric stoves. Essentially, you can multiply the efficiency with the potential. Certainly, a lot could be saved.

3.6 What is the biggest obstacle to clean cooking in Nepal?	- There are different standards of stoves. Local manufacturers struggle to reach the legally required η of at least 25 percent. -Financial Aspects: there exists a donour dependency and cookstoves are not enough of a government priority. -Culturally: there is a lack of awareness for IAP and the fireplace is considered a traditional social meeting place, especially during cold periods. Many women suffer from asthma, but do not believe this is due to cooking.

4. Other Comments/ Follow-Up	
	Project developers really have to push users to actually take and use the ICS. More awareness raising is necessary, since currently people are more willing to spend a lot of money on mobile phones but not 2,000 Nepalese Rupees on an improved cookstove.

Interview # F	Place, Date: Patan, 13th of April 2018
Institution: Alternative Energy Promotion Center (AEPC)	Role: Director Policy Planning
1. General Questions	
1.1 What does your institution do in the field of carbon offsetting and/or Improved Cookstoves (ICS)?	The role of the AEPC is to promote renewable energy technologies in all areas of Nepal. The AEPC fosters emissions reductions and registers these projects as carbon projects under the CDM mechanism. Regarding ICS, the AEPC together with partners has developed Programmes of Activities (PoAs) and implemented the ESAP I + II and the NRREP programs.
1.2 How many ICS projects in Nepal are financed with carbon credits? (estimate)	Overall, with the two ESAP programs, the NRREP and additional programs, an estimated 1.4 million cookstoves have been promoted in Nepal. This includes the post-earthquake assistance which distributed mostly portable stoves. Of these, all stoves distributed in the Terai and the portable stoves received carbon credits. The details and PDDs can be viewed on the UNFCCC website.

1.3 To what extent is Carbon Offsetting a climate change mitigation strategy?	Carbon Offsetting helps LDCs such as Nepal to implement renewable energy and ICS projects. The UNFCCC has special assistance, such as a discount on fees, for LDCs. The AEPC implemented eight CDM projects so far.
2. Questions about Voluntary Carbon Offsetting (VCO)	
2.1 What is your experience with VCO?	As can be seen on the UNFCCC website, the AEPC has mostly worked with CDM projects. The procedure mostly follows the voluntary offsetting cycle. First, the PDD is developed as the main document and submitted to the Designated National Authority (DNA). In Nepal, the DNA is the Ministry of the Environment. Next, the Letter of Approval (LoA) leads to the registration of the offsetting project. The validation leads to the verification after a certain time period, generally six months or one year. The verified CERs are then issued and can be sold to the market.
2.2 Who are the relevant actors (project developers, verifiers, financial flows)?	AEPC as focal agency; CRT/N; Winrock International; Sahas Nepal and RUTPAN
2.3 Have you worked with the Gold Standard/ Verified Carbon Standard? What are the experiences?	Yes, there has been one biogas project registered under the Gold Standard. The benefit is a premium price, which is good for the project developer. However, it may be more difficult to find buyers. The GS places a priority on co-benefits.
2.4 How are the tCO_2e traded?	See point 2.1. Also, the Certified Emissions Reductions (CERs) are placed in the UNFCCC or GS registry. However, the AEPC as developer must find the buyers, which have been the World Bank, KfW Bank and Atmosfair. Especially, the latter has been keen on purchasing Nepali CERs. However, in the AEPC experience, not all CERs have been sold. It is important to have a buyer before issuance of the credits.
2.5 How could the VCO market carry more sustainable development incentives? How relevant is the price for a tCO_2e?	The price of the carbon credit is very relevant for project developers such as the AEPC. There exist at least two ICS projects in the pipeline, but since the price is low they do not proceed. The VCO market is attractive for small project developers because administrative costs and the procedure are easier to handle. It is crucial to know the buyer before verification of credits. Moreover, pre-financing is an important aspect for LDCs such as Nepal.

3. Questions about Clean/ Improved Cookstoves	
3.1 What are the relevant social and environmental factors of ICS in Nepal?	75 percent of households in the country use solid biomass as fuel for cooking and the traditional three stone fireplace continues to be the most applied technology. This leads to high indoor air pollution, which is a large problem. There exists an extensive Nepal IAP Study 2008/09 which contains more detailed numbers. With ICS the drudgery for women can be reduced, such as collecting firewood and the danger of accidents.
3.2 What is the development potential of ICS?	The 2011 census revealed that approximately four million households use solid biomass as main cooking fuel. Due to related adverse effects, the long-term strategy is to replace firewood with electricity from hydropower plants.
3.3 How are emissions factors in a project calculated?	CRT/N and RETS calculate the emissions factors. On average, one ICS saves around 1.53 tCO_2e per year.
3.4 What are the technologies most frequently applied?	Out of the 1.4 mio stoves promoted since 1999, around 90 percent were locally built mud stoves. Less than 10 percent were metallic portable stoves. All the 50,000 stoves distributed to earthquake victims in 2015 were a portable metallic design. The policy goals are biogas, biomass in ICS and eventually electricity. LPG has gained popularity, but has not received government subsidies or promotion.
3.5 How much fuel and greenhouse gas emissions can be saved with ICS?	-
3.6 What is the biggest obstacle to clean cooking in Nepal?	Users compare cookstoves to mobile phones. Both are daily use products, however the perceived value differs largely. Although the importance in penetration is similar, cookstoves are not a ‘sexy’ product. Another problem is that firewood is considered a free fuel. People in rural areas do not pay for the firewood and any substitute would be more expensive on an individual level. There is also a lack of awareness of the negative health effects of traditional cooking. A last obstacle is funding. Both, private sector involvement and new donours are crucial in scaling up efforts.

4 Other Comments/ Follow-Up

What is the CRE Fund?	It was created through the NRREP and is financed by carbon earnings and development partners. Essentially, it replaces pure subsidies with carbon credit money. By law, 80 percent of the fund's earnings must be channeled into the development of the same technology. 18 percent go into technical support and 2 percent for others and administration.

Interview # G		Place, Date: Lalitpur, 18th of April 2018
Institution: Centre for Rural Technology, Nepal (CRT/N)		Role: ICS Expert and Executive Director
1. General Questions		
1.1 What does your institution do in the field of carbon offsetting and/or Improved Cookstoves (ICS)?	The CRT/N operates one of two testing facilities for ICS, where the emissions of CO, $PM_{2.5}$ and the efficiencies η are measured. It is also involved with the product development and labelling of stoves and biomass fuels. The CRT/N is a recognized NGO that frequently partners with the AEPC, i.e. in the implementation of the ESAP and NRREP programs. Currently, it runs two programs with ICS. First, there is a World Bank funded project on users' acceptance and user friendliness of ICS. Second, the WEE project, funded by ENERGIA, aims to establish grassroot women economic empowerment. The CRT/N is mostly concerned with advocacy and awareness raising activities on the demand side. On the supply side, it assists in linking bulk demands with suppliers.	
1.2 How many ICS projects in Nepal are financed with carbon credits? (estimate)	There have been two carbon projects linked to ICS with the CRT/N. The target was to promote 42,000 ICS within the WEE project (without generating carbon credits). Until 2017, 28,176 ICS were disseminated. Another main project was the Terai Carbon Project, where more than 10,000 ICS were promoted and received credits under the Gold Standard. There was another project with SNV in the pipeline to promote 150,000 cookstoves in the Western Development Region. However, it stopped because of a lack of funding.	
1.3 To what extent is Carbon Offsetting a climate change mitigation strategy?	With a higher price, carbon offsetting becomes attractive for implementing organizations.	

2. Questions about Voluntary Carbon Offsetting (VCO)	
2.1 What is your experience with VCO?	Carbon credits did not fulfill their promise because the price is too low. In Nepal the CERs generated are too little so that the administrative burden and fees do not pay off.
2.2 Who are the relevant actors (project developers, verifiers, financial flows)?	AEPC, local government (currently large changes), manufacturers of metallic portable ICS.
2.3 Have you worked with the Gold Standard/ Verified Carbon Standard? What are the experiences?	VCO has not been successful for the CRT/N because there were verification issues. The Gold Standard pays a premium price, but the administrative difficulties proved too large.
2.4 How are the tCO_2e traded?	n/a
2.5 How could the VCO market carry more sustainable development incentives? How relevant is the price for a tCO_2e?	For smaller programs the process is too long. Moreover, the validators and verifiers are too expensive. The CRT/N would reconsider developing projects if the carbon price was higher – at least 11 USD per credit. The VCO market would also become more attractive through bundling, so that one administrative procedure is valid for multiple projects. Direct links between the credit buyer and project developer and less bureaucracy would further incentivize the VCO market. The voluntary carbon market could be more attractive than the compliance market through an easy, unbureaucratic procedure and price and purchase guarantees.
3. Questions about Clean/ Improved Cookstoves	
3.1 What are the relevant social and environmental factors of ICS in Nepal?	Lower emissions would help improving the quality of life, especially for women. ICS combat indoor air pollution and improve health. They also empower women, since they become healthier and spend less time collecting fuelwood. Through the WEE program, women also become more exposed to society. Lastly, ICS helps to combat deforestation.
3.2 What is the development potential of ICS?	More than three million households are in need of ICS, based on the 2011 census data. They primarily rely on fuelwood and cow dung for energy supply. However, there is not enough manufacturing potential in Nepal. The country requires more R&D for the entire value chain to meet the future demand.

3.3	How are emissions factors in a project calculated?	The CRT/N relies on the GACC developed methods. It applies the water boiling test, where water is boiled with a cold start, hot start and also remained at simmering. The standard protocol allows to measure fuel use, emissions of $PM_{2.5}$, CO. BC has only been measured once upon request. The efficiency definition of an ICS is provided by the GACC document on Water Boiling Tests.
3.4	What are the technologies most frequently applied?	Previously, the preferred technology were two-pot hole mud stoves. They were locally built artisan clay structures. However, the quality control and maintenance proved problematic. Now, portable cookstoves are preferred. They are centrally built metallic stoves and distributed and better meet the WHO standards.
3.5	How much fuel and greenhouse gas emissions can be saved with ICS?	The CRT/N does not calculate the GHG emissions reductions, but only the efficiencies. We work with the GACC tier system and the NIBC2016 National Standard.
3.6	What is the biggest obstacle to clean cooking in Nepal?	The CRT/N has researched in depth this topic and there exist several barriers. Through interviews, we found out that users do not only care about reduced fuel consumption, less IAP and faster cooking. In fact, other parameters such as durability, simultaneous cooking and multiple purpose are key to users. Especially, multi purposes such as animal feed cooking, space heating and place for festivities are important and frequently not taken into account by developers. Next to these social barriers, there exist policy barriers. The main obstacle is the lack of coordination between different governmental agencies and international actors. Economically, more appropriate financing mechanisms are necessary. Many potential users do not have suitable financial means to purchase clean cookstoves. Interventions are also needed to scale up cookstove and sustainable biomass fuel production.

4 Other Comments/ Follow-Up

Interview # H	Place, Date: Lalitpur, 19th of April 2018
Institution: Renewable Energy Testing Station (RETS)	Role: Lab testing engineer
1. General Questions	
1.1 What does your institution do in the field of carbon offsetting and/or Improved Cookstoves (ICS)?	RETS is the certified testing station for all renewable energy technologies. After certification, the AEPC is implementing ICS projects and uses RETS results. There exist two different tests. Namely, the Product Introduction Test that is applied before stoves are produced or imported in bulk. Second, the Random Sampling Test. The current standard is the NIBC2016 that contains ten parameters on $PM_{2.5}$, CO emissions, efficiency, safety and durability. Efficiency has to be at least 25 percent for portable stoves and 20 percent for chimney models.
1.2 How many ICS projects in Nepal are financed with carbon credits? (estimate)	Not sure. The RETS has been involved in one ICS carbon project in cooperation with SNV in the West of Nepal.
2. Questions about Voluntary Carbon Offsetting (VCO)	
2.1 What is your experience with VCO?	n/a
2.2 Who are the relevant actors (project developers, verifiers, financial flows)?	n/a
2.3 Have you worked with the Gold Standard? What are the experiences?	n/a
2.4 How are the tCO_2e traded?	n/a
2.5 How could the VCO market carry more sustainable development incentives?	n/a
3. Questions about Clean/ Improved Cookstoves	
3.1 What are the relevant social and environmental factors of ICS in Nepal?	Indoor air pollution is a large problem, mostly caused by traditional cookstoves that have an efficiency of less than 10 percent. Moreover, three times the fuel may be saved with ICS. The reduced fuelwood use leads to time savings and combatting deforestation.

3.2 What is the development potential of ICS?	Three million households in Nepal rely on tradition three stone fireplace cooking. The very varying and mountainous geography makes LPG and electricity supply difficult and solid biomass/ firewood constitutes a primary energy supply. High-level technology remains too costly.
3.3 How are emissions factors in a project calculated?	RETS calculates emissions per solid mass [kg] per MJ energy delivered to the pot. The levels of $PM_{2.5}$/ MJ and CO/ MJ are measured. CO_2 is also recorded, but not published, since the focus lies on IAP. Black Carbon is currently not measured. The Water Boiling Test is the standard procedure.
3.4 What are the technologies most frequently applied?	RETS has certified 37 models of ICS, however it does not have data how many models are sold and distributed. More recently, the focus has been on metallic portable rocket stoves. The chimney stove was more popular previously. Solar and gasifiers play no prominent role.
3.5 How much fuel and greenhouse gas emissions can be saved with ICS?	The minimum efficiency η is 25 percent. Compared to traditional cookstoves this means fuelwood saving of approximately 67 percent. The CO_2 reductions are not explicitly reported.
3.6 What are the biggest obstacles to clean cooking in Nepal?	There is a lack of awareness with users. This is crucial, since dissemination under a program has not always led to usage. Upon monitoring, we found that many villagers (up to two thirds) do not frequently use the ICS after promotion.
4 Other Comments/ Follow-Up	