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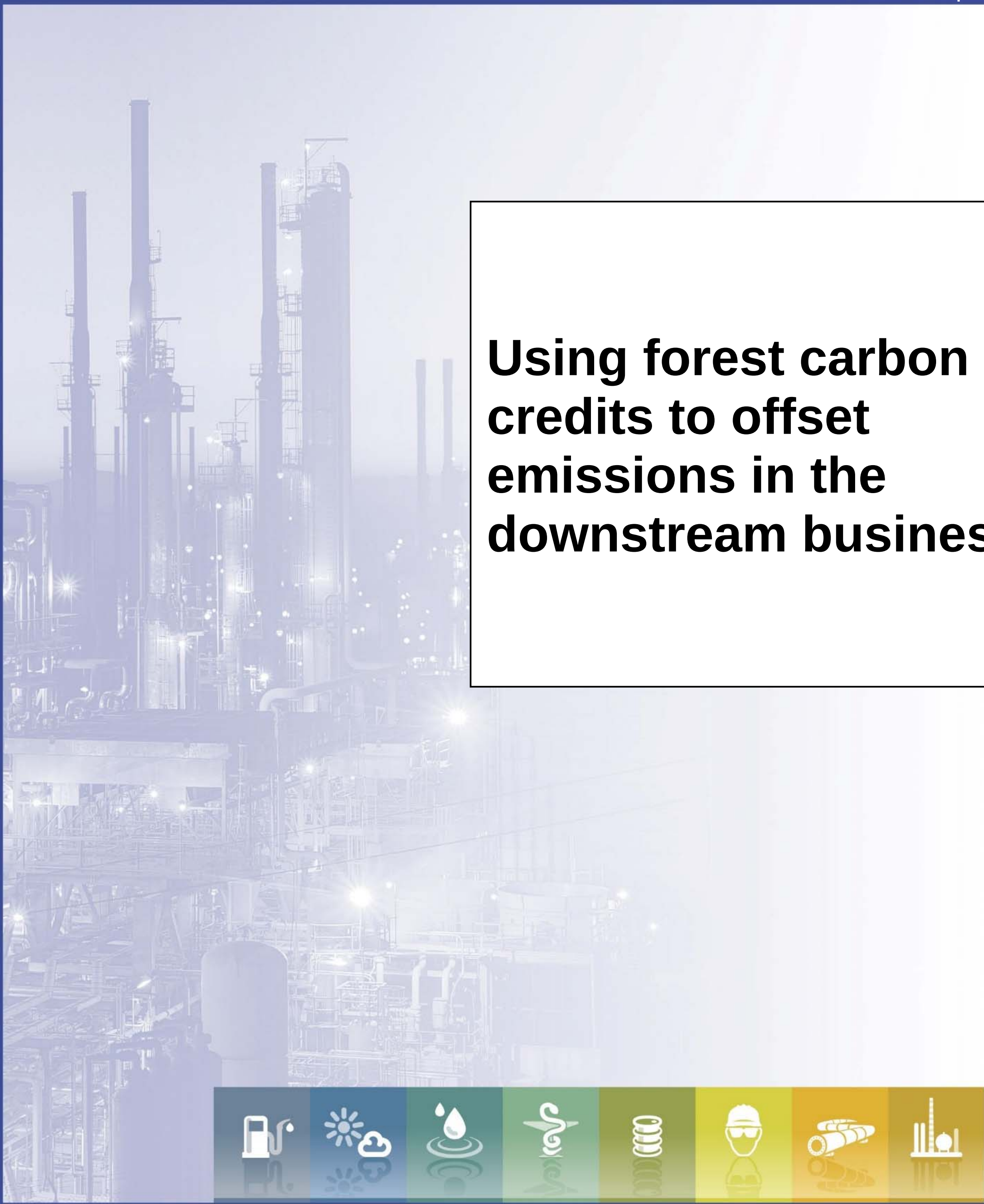

Using forest carbon credits to offset emissions in the downstream business

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Using forest carbon credits to offset emissions in the downstream business

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ABSTRACT

This report examines if and how forest carbon credits can potentially be used to offset emissions from the EU refining and road transport sectors. Forest carbon projects involve either forestation (capturing CO_2 from the atmosphere during the growth of the forest) and/or protection of forests that would otherwise be cut. In both cases, the projects reduce the overall level of CO_2 in the atmosphere. Forest carbon projects can generate credits that, once certified by an independent agency, can be sold on the carbon market.

There are two principal carbon markets: the compliance market and the voluntary market. The voluntary carbon market has an annual turn-over of around 70-80 million ton CO_2e. Around one third of the credits traded on the market are from forest carbon projects. The majority of forest carbon credits is generated in developing countries. Currently, there is oversupply on the market and prices of carbon credits are low, ranging from US$ 3 to 10 per ton CO_2 for forest carbon projects.

The largest compliance market is the EU Carbon Emission Trading Scheme (ETS), which includes the refining sector, but not emissions from road transport. In the ETS, forest carbon credits are not allowed to be traded or used as offsets. With a number of restrictions, forest carbon credits are traded in other compliance markets including those in California and New Zealand.

Based on an analysis of forest carbon markets and changes therein, several options to use carbon credits in the refining and road transport sector are explored in this report. It appears that current policy conditions are not conducive to the use of voluntary carbon credits in the refining sector. Voluntary carbon credits could be purchased to offset refinery emissions but they would not currently be recognised in the ETS.

A potentially more promising option is to develop ‘carbon neutral’ petrol and/or diesel for sale at retail stations, based on offsetting emissions with forest carbon credits. This would be a climate-friendly alternative for electric driving, particularly suitable for vehicle types for which electric driving is not a feasible option to reduce greenhouse gas emissions. The price of offsetting these carbon emissions is almost the same for petrol and diesel, and can be estimated (on the basis of Well-To-Wheel) to range from 1.5 eurocent per litre (assuming a carbon credit price of 5 euro/ton CO_2) to 3 eurocent per litre (for a carbon credit price of 10 euro/ton CO_2). These prices represent indicative lower and higher range values at which forest carbon credits are currently offered on the voluntary market.

Offering carbon neutral road fuel may present a business opportunity in terms of offering customers a climate neutral fuel option, at a minor fuel price increase. It may not need separate supply chains, which facilitates piloting and, if successful, scaling up. The option of offering carbon neutral fuel can be implemented in the current policy and regulatory setting and may be attractive to Concawe member companies. However a clear communication and implementation strategy is required. To support this, there is a need to confirm the environmental benefits of offsetting carbon from diesel and petrol vis-à-vis electric cars using life cycle assessment (e.g. considering effects of battery use and non-greenhouse gas emissions from cars, as well as co-benefits of carbon neutral fuel (e.g. protection of forest habitat and thereby biodiversity). At present, the amount of carbon credits available on the voluntary market would suffice to offset CO_2 emissions of around 7 billion litre of fuel, increasing to around 16 billion litre in 2020 if a willingness to buy is communicated in the short term to carbon project developers.

KEYWORDS

See glossary

INTERNET

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SUMMARY

World-wide, forests are both a major source and a major sink of carbon, depending upon ecological conditions as well as the management of the forest. Forest carbon projects can generate carbon credits by demonstrating that the project leads to reduced CO_2 emissions from deforestation and/or land use change (in the case of 'REDD[1]' projects) or by demonstrating that forestation or changes in forest management lead to an accumulation of carbon in the vegetation (and thereby a removal of CO_2 from the atmosphere). Once the carbon credits are certified by an independent agency, they can be sold on the carbon market.

There are two principal types of carbon markets: the compliance market and the voluntary market. There are several compliance markets operational world-wide, and additional markets are currently being designed. The largest compliance market is the EU Carbon Emission Trading Scheme (ETS), which includes the refining sector, but not emissions from road transport. In the ETS, forest carbon credits are not allowed to be traded. With a number of restrictions, forest carbon credits are traded in other compliance markets including those in California and New Zealand. There are several methodologies for verifying and certifying forest carbon credits, which are also accepted in these compliance markets.

The annual turn-over of the global voluntary carbon market has fluctuated, in the past years, between around 60 to 90 Mton CO_2e. Around one third of the credits traded on the market are from forest carbon projects. There are two principal types of buyers of these credits: (i) companies offsetting their emissions on a voluntary basis, generally driven by a mix of corporate social responsibility and marketing motivations; and (ii) retailers that sell carbon credits onwards to consumers, for instance people that want to offset emissions from air travel they are undertaking. Both groups purchase roughly half of the credits on this market. Suppliers of carbon credits include specialised companies that develop carbon projects (including forest carbon projects). Most of the forest carbon credits are generated in developing countries, where land is relatively cheap, forests grow fast due to climatic factors, and showing additionality of carbon credits is relatively easy given that many tropical countries are subject to deforestation. Currently, there is oversupply on the market. Prices of carbon credits are generally low, ranging from US$ 3 to 10 per ton CO_2 for forest carbon projects.

Both the compliance and the voluntary carbon market are highly dynamic. The EU compliance market is still being adjusted based on recent international developments including the entry into force of the Paris Agreement. In the context of the Paris Agreement, the EU is designing the Effort Sharing Regulation (ESR), which will involve compulsory emission reduction targets for member states. The proposed ESR would set national limits on Member States' GHG emissions for the 2021-2030 period in sectors not covered by the EU ETS. It is the successor of the Effort Sharing Decision (ESD) that covers GHG emissions in the period 2013-2020. LULUCF credits are likely to become part of the ESR (with restrictions on quantity and type), however it is unclear if this would include credits from outside the EU.

The main factor that may drive changes in the voluntary market is the aviation industry 'CORSIA' initiative, which would involve airline companies purchasing carbon credits in order to achieve the sector's aspirational goal of no net increase in CO_2 emissions from international aviation as off 2020. This would require a volume of credits, beyond 2020, which is several times the size of the current voluntary market volume.

[1] REDD = Reduced Emissions from Deforestation and forest Degradation)

Implementing the CORSIA initiative would depend upon an increase in the supply of carbon credits from the voluntary market. The carbon credit sector has shown to be very responsive to increases in demand in the past and may scale up the development of carbon credits rapidly if demand were to increase. The aviation sector may also tap into unused Clean Development Mechanism carbon credits (generated as part of the Kyoto Protocol), which are now offered by the UN Climate Change Secretariat under the label of the Climate Neutral Now (CNN) initiative. Several companies have endorsed the CNN initiative and purchased CDM credits. However, the additionality of the CNN credits, and thereby their actual impact on mitigating climate change, is debatable.

Based on an analysis of forest carbon markets and changes therein, several options to use carbon credits in the refining and road transport sector are explored. It appears that current policy conditions are not very conducive to the use of voluntary carbon credits in the refining sector. The sector is covered by the ETS, and needs to obtain carbon emission allowances for the total CO_2 emission of the sector. Voluntary carbon credits could be purchased to offset emissions but they would not currently be recognised in the ETS.

A potentially more promising option for Concawe member companies is to develop a 'zero carbon' or 'carbon neutral' petrol and/or diesel for sale at retail stations. Offering carbon neutral road fuel may present a business opportunity in terms of offering customers a climate neutral road fuel option, at a minor fuel price increase. The price of offsetting these carbon emissions is almost the same for petrol and diesel, and can be estimated (on the basis of Well-To-Wheel) to range from 1.5 eurocent per litre (assuming a carbon price of 5 euro/ton CO_2) to 3 eurocent per litre (for a carbon price of 10 euro/ton CO_2). These prices represent indicative lower and higher range values at which forest carbon credits are currently offered on the voluntary market. Carbon neutral petrol and diesel would, in line with 'green electricity' sold to households, probably not need separated supply chains as long as the sector commits to offsetting an amount of carbon equivalent to the carbon in purchased fuel. In addition, it can be implemented in the current policy and regulatory setting.

However a clear communication and implementation strategy is required. As part of this, there is a need to confirm the environmental benefits of offsetting carbon from diesel and petrol vis-à-vis electric cars using life cycle assessment (e.g. considering effects of battery use and non-greenhouse gas emissions from cars, as well as co-benefits of carbon neutral fuel (e.g. protection of forest habitat). At present, the amount of carbon credits available on the voluntary market would suffice to offset CO_2 emissions of around 7 billion litre of fuel, increasing to around 16 billion litre in 2020 if a willingness to buy is communicated to carbon project developers

1. INTRODUCTION

1.1. CONTEXT AND RATIONALE FOR THE STUDY

Context. Ecosystems including forests play an important role in the global carbon cycle. Ecosystems are defined as biological communities of interacting organisms and their physical environment (soil, water). Examples of ecosystems are temperate deciduous forests, coral reefs, or, in the interpretation of recent global assessments such as the Millennium Ecosystem Assessment (MA, 2005) plantations or annual croplands. By means of photosynthesis, plants sequester carbon dioxide (CO_2) to produce biomass. In various processes, ecosystems also emit CO_2 as well as methane (CH_4) and nitrous oxide (N_2O). Emissions and removals of greenhouse gases resulting from human-induced land use, land-use change and forestry activities are often referred to as LULUCF (Land Use, Land-Use Change and Forestry).

According to recent figures of the UK Tyndall Centre published in the context of the Future Earth Initiative [19], average annual emissions from LULUCF amounted to 1 $\pm$ 0.5 Gigaton (Gt) C per year in the period 2006-2015 (note that 1 Gt equals 1000 Mton). This compares to emissions from fossil fuel burning of 9.3 $\pm$ 0.5 Gt C per year, over the same period. The annual average uptake of CO_2 by terrestrial ecosystems, over the same period, was estimated in the same study at 1.9 $\pm$ 0.9 Gt C per year. Grassi et al. (2017) [12] however finds that emissions from LULUCF are almost equal to the sequestration from LULUCF (i.e. net emissions world-wide of 0.01 GtonCO_2e in 2010) illustrating that there remains uncertainty on carbon fluxes from LULUCF. In general, carbon uptake is substantially higher in forests compared to other ecosystems. At a global scale, boreal and temperate forests as a whole are net sinks of carbon whereas tropical forests, as an aggregate, are net sources. This is because most deforestation takes place in tropical forests whereas carbon stored in boreal and temperate forests is, overall, increasing, either due to expansion of forested area or increases in standing stock.

Whereas the role of deforestation has long been recognised there is increasing awareness of the role of peatlands in the global carbon cycle. Peatlands are characterised by their sponge-like soils composed of water and decomposing organic material. In preserved peatlands with high water tables, peat continues to accumulate because plant litter is inhibited from decaying by acidic and anaerobic conditions. When peatlands are drained, the water table decreases and bacterial activity leading to oxidation of peat commences, resulting in CO_2 emissions up to 100 ton CO_2 per hectare (ha) per year depending upon climate and drainage depth. In addition, there are fire risks in drained peatlands which may cause additional CO_2 emissions. Peat may have depths of 15 meters or more, and peat areas present very large stores of carbon in the soil. Some 3% of the world's land area is covered by peat. Countries particularly rich in peatland include Canada, Russia, Indonesia and Congo, and in the EU Finland, the UK and the Netherlands.

Over the past decades, a range of initiatives have been set up to enhance carbon sequestration in ecosystems and to avoid emissions from ecosystem change. Activities aimed at reducing emissions through preserving ecosystems, in particular when implemented in developing countries, are labelled 'REDD' (Reducing Emissions from Deforestation and Forest Degradation) or REDD+, with the + added to indicate that, among others, interests of local people including indigenous communities are explicitly considered in such programs. There are also carbon projects that involve the planting of trees in order to remove carbon dioxide from the atmosphere. A range of national and international initiatives on forest carbon have been developed, including several focussed on developing countries where most emissions in the LULUCF sector take place such as the UN-REDD partnership. These initiatives include government-to-government programs and market-based mechanisms. In general the viability of these various initiatives depends upon a combination of ecological (including additionality and leakage considerations), economic (including cost efficiency of carbon removals and benefit sharing with local people) and institutional (including regulations and market structures) elements. These aspects are described in more detail in the next chapters of this report.

There are as yet limited possibilities to trade carbon credits from ecosystems in carbon trading schemes. The European Carbon Emission Trading Scheme (ETS), by far the world's largest scheme covering around 45% of the EU's greenhouse gas emissions in 2016, focusses on large industrial installations and does not allow trading carbon from ecosystems. Several other compliance markets allow trading forest carbon credits, although with restrictions. The California ETS allows trading forest carbon credits generated in the US and in selected areas in other countries including in Brazil and Indonesia (as analysed in section 5.2). The New Zealand carbon trading scheme allows trading carbon sequestered in domestic forests. Carbon credits from reforestation and afforestation are also eligible under the global Clean Development Mechanism[1] (CDM). Under the CDM, emission-reduction projects in developing countries can earn certified emission reduction credits. These can be used by industrialized countries to meet a part of their emission reduction targets under the Kyoto Protocol. However, currently (January 2017) only 0.6% of all CDM credits is in the category 'reforestation and afforestation' [22]. The CDM has faced major challenges in terms of proving additionality and effectiveness, and its future is currently being debated also in the light of the Paris Agreement replacing the Kyoto protocol as the international community's main instrument to mitigate climate change.

Most carbon from ecosystems is currently traded in the voluntary market including both carbon credits from REDD and from reforestation and afforestation. The voluntary market for carbon credits from ecosystems is still relatively small, covering around one-third of the global voluntary market. The turn-over of the global voluntary carbon market varied over the past years, being 84 Mton CO_2e in 2015 and 63 Mton CO_2e in 2016. Carbon prices in the voluntary market have gone down in the past years since increases in demand have not kept up with increases in the supply of credits. Prices for forest carbon projects currently vary between US$3 to 10 per ton CO_2e (as discussed later in this report). In recent years methodologies for quantifying carbon credits from peat restoration have also become available, with prices for credits from peat potentially lower than from other LULUCF projects.

Rationale. Forest carbon credits are offered for prices that are low compared to the costs of reducing carbon emissions in the refining sector or in the European car fleet. Therefore, there is a rationale for examining if and how these credits are relevant, or can become relevant, for the European refining and road fuel sector, in the context of the current policy and regulatory environment. It is also relevant in this context that Concawe already commissioned work on developing a low carbon roadmap for the refining sector. Insights in the offsetting emissions potential of forest carbon are complementary to this activity in order to examine if and how a Zero Carbon Refinery can be achieved.

[1] the Clean Development Mechanism (CDM) is defined by Article 12 of the Kyoto protocol, and produces Certified Emission Reductions (CERs). One CER represents the successful emissions reduction equivalent to one tonne of carbon dioxide equivalent (tCO_2e).

1.2. OBJECTIVES

The specific objectives of this report are to assess:

(i) the size of the forest carbon market in relation to a) CO_2 emissions from European refining operations and b) road vehicle fuel emissions;

(ii) the costs of carbon offsets (expressed with various metrics including a comparison with transport related indicators such as CO_2 emissions per km or per litre of fuel);

(iii) the potential to use carbon forest offsets in the European Refining and Transport sector in view of potential institutional barriers

(iv) advantages and disadvantages of different possibilities to invest in forest carbon (including such options as buying (different types of) carbon credits in the market and working with specialised agencies to develop projects);

It needs to be noted that the matter covered in the report is complex. Forest carbon offsetting has multiple ecological, economic and institutional dimensions. Importantly, the regulatory setting for carbon markets is evolving rapidly, in particular since the Paris Agreement entered into force (November 2016). The implications of the recent withdrawal of the US from the Paris Agreement for the carbon market are as yet unclear. Hence, this document provides a state-of-the art analysis with the caveat that it is produced in a rapidly changing policy environment.

Note that the scope of the study is limited to storing carbon in forests. In production forests, part of the carbon will also be trapped in wood products that are produced with harvested wood (e.g. construction wood, furniture). Over time, part of this carbon will re-enter the atmosphere when the wood products are discarded. Specific models have been developed to study this effect. The net carbon storage in wood products as a function of product type is not further considered.

2. DEFINITIONS AND MEASUREMENTS OF FOREST CARBON

2.1. DEFINITIONS AND MEASUREMENT

2.1.1. Defining carbon stocks and flows

There are two key concepts in analysing forest carbon: stocks and flows. Stocks of carbon include carbon stored above and below ground in organic matter in the ecosystem, usually expressed in ton C per ha. This includes carbon stored in plant and tree stems, branches and leaves, roots and organic carbon fractions in the soil (see **Table 1**). The latter is particularly high in the case of peat which consists of a combination of water, organic material in various stages of decomposition and fractions of mineral soil. Carbon stored in rocks and minerals or subsoil assets such as coal, oil and natural gas are not included in this study.

Table 1. Organic carbon stocks

	Living biomass	Non-living biomass and soil
Above ground	Carbon in all living biomass above the soil: including stem, stump, branches, bark, seeds, and foliage.	Carbon in dead wood biomass and litter: includes carbon in wood lying on the surface, dead roots and stumps. It also includes biomass in various states of decomposition above the mineral or organic soil.
Below ground	Carbon in all living biomass of live roots: including roots and the below-ground part of the stump. Fine roots of less than 2 mm diameter are excluded, because these often cannot be distinguished empirically from soil organic matter or litter.	Soil carbon: organic carbon in mineral and organic soils (including peat) to a specified depth chosen by the reporting country.

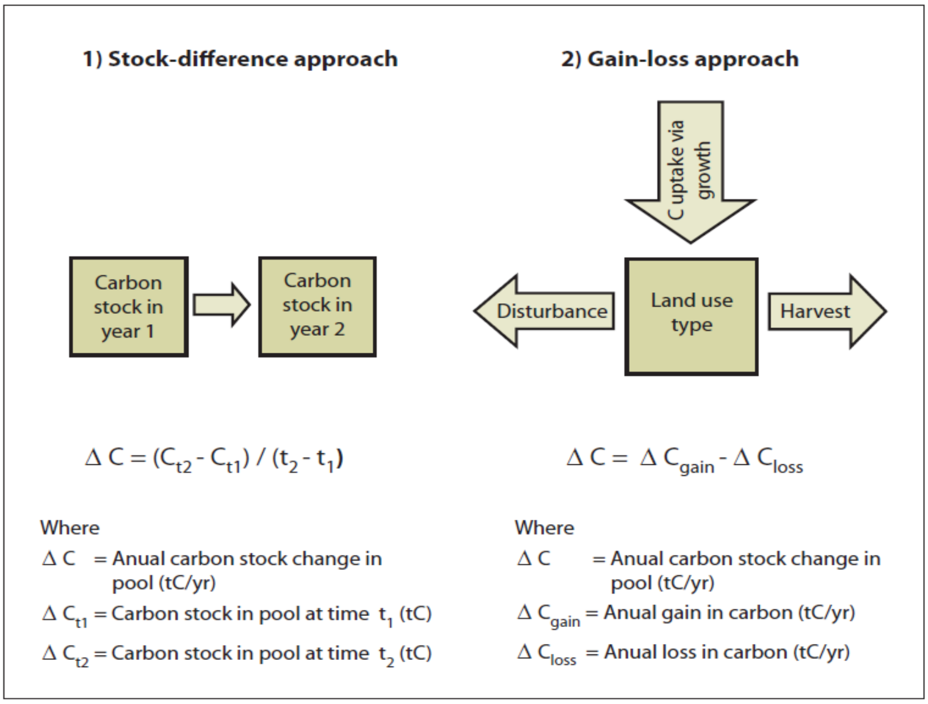
Source: based on IPCC (2003) Good Practice Guides and FAO Forest Resources Assessment Program guidelines 2005.

Carbon flows include sequestration in and emissions from ecosystems, expressed as either ton C/ha/year or ton CO_2/ha/year (with one ton C equivalent to 3.66 ton CO_2). Note that ecosystems can also emit other greenhouse gasses (GHGs), in particular N_2O (related to fertiliser use in croplands) and CH_4 (from both rice paddies and livestock). This note focusses on carbon in forests; N_2O and CH_4 are considered out of scope. There is very little if any N_2O and CH_4 emitted from forest ecosystems hence this does not alter the analyses conducted in the later sections of the report. Carbon is sequestered through photosynthetic activity and carbon can be lost due to fire and other removal of biomass e.g. through timber harvesting. The basis for analysing carbon sequestration in ecosystems are the Net Primary Production (NPP) and the Net Ecosystem Productivity (NEP), both expressed in kg C/ha/year. They are indicators for annual biomass growth in ecosystems. NPP equals the gross primary productivity (the total carbon that primary producers (plants) accumulate using photosynthesis) minus the autotrophic respiration (carbon respired by primary producers). NPP leads to biomass accumulation in the plant layer of the ecosystem. The ecosystem loses carbon through heterotrophic respiration (carbon respired by other organisms, usually by detritus feeders (in particular bacteria) that decompose dead material in the litter layer and the soil). The NEP equals the NPP - heterotrophic respiration. To analyse the carbon sequestered in the ecosystem it is also necessary to analyse the loss of carbon through fires, oxidation of peat and removal of biomass by people, e.g. in the form of timber harvesting. The net carbon sequestration in the ecosystem equals the NEP minus these other removals of carbon.

2.1.2. Measuring changes in carbon stocks and flows

There are two basic approaches to measure changes in carbon stocks and flows, see also **Figure 1**. In the '*Stock-difference* 'approach, the difference in carbon stocks in a particular pool at two moments in time is estimated. It can be used when carbon stocks in relevant pools have been measured and estimated over time, such as in national forest inventories. This approach can be applied to all carbon pools and is suitable for estimating emissions caused by both deforestation and degradation. The above-ground carbon can also be estimated using remote sensing images that allow correlating reflections in the visual light and from radar with standing biomass. In the '*Gain-loss approach'*, the net balance of additions to and removals from a carbon pool over time is estimated. Gains in individual pools result from growth and carbon transfer between pools (e.g. from living biomass to litter). Losses result from carbon transfer to another pool and emissions due to harvesting, decomposition or burning. This method is used when annual data on information such as growth rates and wood harvest are available.

Figure 1 Measuring changes in carbon stocks, based on Wertz-Kanounnikoff et al. (2008**)** [23].



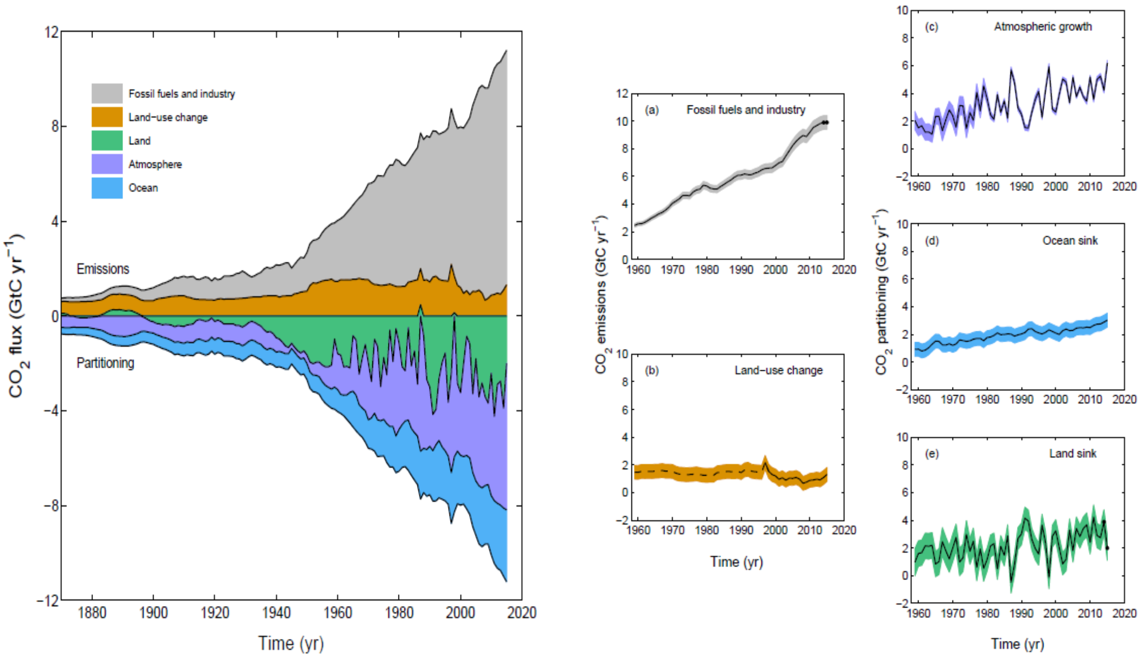
2.2. CARBON FLUXES FROM LAND USE IN RELATION TO GLOBAL CARBON FLUXES

2.2.1. Emissions and uptake from LULUCF

The concentration of CO_2 in the atmosphere has increased from approximately 277 parts per million (ppm) in 1750 to 400 ppm at present. The atmospheric CO_2 increase was initially primarily caused by the release of carbon to the atmosphere from deforestation and other land-use-change activities. Emissions from fossil fuels became the dominant source of anthropogenic emissions from around 1920, and their relative share has continued to increase until present [3]. Anthropogenic emissions occur on top of the natural carbon cycle that circulates carbon between the reservoirs of the atmosphere, ocean, and terrestrial biosphere on timescales from sub-daily to millennia [19].

The global carbon budget including the emissions and sequestration related to forest carbon is presented in **Figure 2**. **Figure 2** quantifies the CO_2 fluxes to and from the atmosphere, as well as the increase in CO_2 concentrations in the atmosphere over time (top right hand corner). The specific categories shown are: (i) fossil fuel combustion in all sectors and other industrial emissions including from cement production; (ii) emissions resulting from deliberate human activities on land leading to CO_2 emissions (LULUCF), as well as their partitioning among (iii) the growth rate of atmospheric CO_2 concentration, and the uptake of CO_2 by the CO_2 sinks in (iv) the ocean and (v) on land [19].

Figure 2 Global carbon budget (Source: [19])



Compared to emissions from industry, households and transport, the emissions from land-use change are the most uncertain component of the global carbon cycle. The emissions are prone to uncertainty because of a lack of data and because of remaining uncertainties in appropriate assumptions for the carbon loss methods (for example on autotrophic respiration rates and the accumulation of biomass in forests as a function of the age of forest stands). In these estimates, it is important to distinguish between gross and net carbon losses from deforestation and land use change (LULUCF). In the temperate zones at large, carbon sequestration exceeds emissions but in the tropics the emissions considerably exceed sequestration (even though in the tropics there is also important sequestration in particular where there is regrowth of degraded forests). Most studies estimate the contribution of tropical deforestation to global carbon emissions at between 1000 to 2000 Mton CO_2 (i.e. 1 to 2 Gton CO_2) per year (e.g. [14] [15] [19].

2.2.2. Emissions from peatlands

Peat degradation is only partly included in the estimates provided in **Figure 2**. The Future Earth Initiative [19] following the LULUCF definition includes only emissions from 'deliberate human activities'. Peat degradation leads to two types of emissions: (i) through peat fires; and (ii) through the oxidation of peat. Both effects occur after drainage of the peat. Emissions resulting from fire are always included in LULUCF estimates, however there is variation in the inclusion of emissions resulting from peat oxidation (they are not included, for example, in the emission estimates presented in **Figure 2**). Carbon emissions resulting from peat oxidation are in scope of emission estimates to be reported to the IPCC. However the IPCC emission factors are considered low compared to scientific assessments of those emissions [5] and there may also be uncertainty on the exact amount of drained peatlands in a country. Nevertheless, these emissions are relevant in both temperate and tropical countries. For example, in the Netherlands the majority of peat areas is drained and used for livestock grazing. The national CO_2 emissions from these areas due to peat oxidation (there are not generally any peat fires in the Netherlands) amount to around 7 Mton CO_2 per year. In Indonesia, a conservative, order of magnitude estimate of CO_2 emissions from peat oxidation is around 700 Mton CO_2 per year, assuming an estimated 8 million ha of drained peat, an average drainage depth of 90 cm, and associated CO_2 emissions of 85-90 ton CO_2/ha/year based on [13]. Note that emissions from peat fire are additional to emissions from oxidation. The occurrence of tropical peat fires varies strongly between years due to differences in rainfall patterns. In Southeast Asia, peat fires are particularly frequent in El Niño years such as 2015. Based on satellite-derived data on the burned area and on estimates of fuel consumption by peat fires, the Global Fire Emissions Database includes an estimate of the 2015 GHG emissions of Indonesian peat fires of 1,750 Mton CO_2 [24].

3. THE FOREST CARBON MARKET RELATIVE TO THE EUROPEAN REFINING OPERATIONS AND ROAD VEHICLE FUEL EMISSIONS

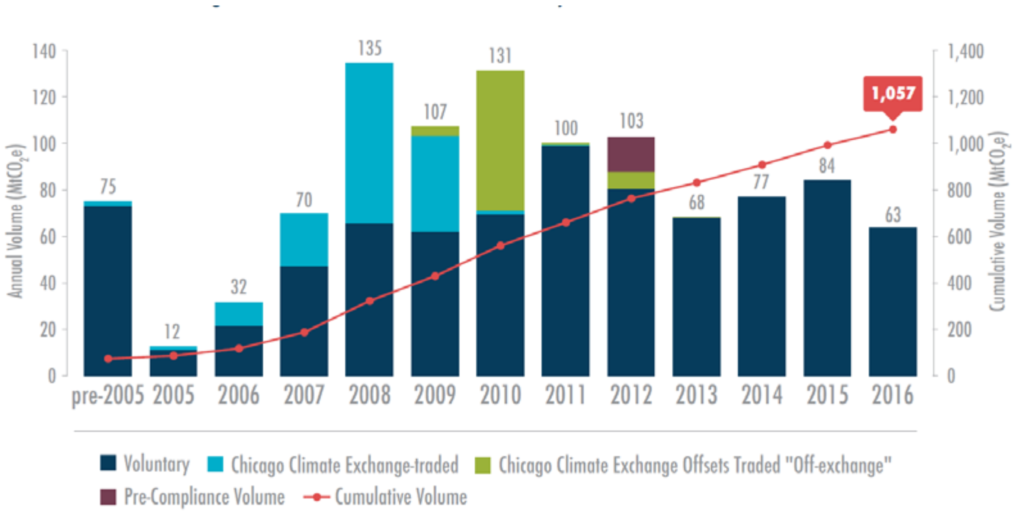
3.1. INTRODUCTION AND SCOPE

This chapters assesses the voluntary forest carbon market, and compares the carbon credits traded in the market to emissions from the EU refining sector and road fuel emissions. The chapter only considers the voluntary carbon market. The EU Emission Trading Scheme (ETS) does not allow trading forest carbon at present (but an assessment of potential new developments in the EU ETS is provided in Section 5.1). California's Cap-and-Trade Program is world's second largest carbon market. For a number of reasons (as discussed in Section 5.2) it seems likely that the California carbon market may not generate a high demand for forest carbon credits generated outside of the US in the near future. The New Zealand (NZ) ETS provides the opportunity to trade carbon credits from domestic forests planted after 1989 in the national ETS. However, the NZ ETS is not considered because it does not allow trading international credits. The New Zealand government ended trade of international credits in its domestic ETS on 1 June 2015 because these had become so cheap (at a low of less than 1 NZ$) that it eliminated incentives to generate national carbon credits. Forest carbon credits, in particular from reforestation and afforestation, are eligible under the UN Clean Development Mechanism (CDM). However, forest carbon only presents a very small portion of the CDM market (0.6% in volume), CDM is focussed on countries that want to acquire offsets not private sector actors, and the future of the CDM is highly uncertain at present since the mechanism is part of the Kyoto protocol. Therefore the CDM is not considered a potentially relevant mechanism for the EU refining sector. However, a spin-off of the CDM, the Climate Neutral Now initiative that offers voluntary carbon credits for sale including to the private sector, is relevant for this study. This initiative is described in section 5.4.

3.2. SUPPLIERS OF FOREST CARBON CREDITS IN THE VOLUNTARY MARKET

This section analyses forest carbon credits traded in the voluntary market. Credits originated from the voluntary CO_2 market are called Voluntary Emissions Reductions (VER). VERs are mostly used by companies who are looking to voluntarily offset the emissions generated during their business activities in order to reduce their carbon footprint. **Figure 3** below presents an overview of credits traded on the voluntary markets in the last decade. The Chicago Climate Exchange (CCX) traded volumes that included purchases by US buyers anticipating regulation. After the proposed cap-and-trade legislation failed to pass in the US in 2009, the CCX voluntary market was discontinued in 2010. CCX tonnes continued to be traded on a voluntary basis but the trade of offsets phased out in 2012. Pre-compliance credits are bought by actors that anticipate regulation requiring them to purchase credits. In 2012, pre-compliance volumes were documented in the lead-up to California cap-and-trade and Australia's (now repealed) carbon tax. The 2017 survey reported in the Forest Trends [9] state of the carbon market report (based on 2016 data) did not detect more recent pre-compliance activity for emerging compliance markets such as in South Africa, South Korea, or China [9].

Figure 3 Historical market-wide voluntary offset transaction volumes (source: [9])



A distinction is made between 'fully' voluntary credits and credits that are traded on a voluntary basis but with the expectation that they would be eligible in a compliance carbon market at a later point in time.

Table 2 below specifies the market dynamics of the 2016 voluntary carbon market and the proportion of this dedicated to forest carbon. The overview is based on a survey including 48.8 Mton CO_2e out of a total of 84.1 Mton CO_2e traded in the voluntary market [9]. Forest carbon includes investments in offsets from REDD (11.4 Mton CO_2e), tree planting (reforestation and afforestation) and agro-forestry (combining plantation crops with other agricultural activities such as annual crops or livestock). Of the non-forest carbon credits, by far the most important category was investments in wind energy. Of the surveyed transactions, offsets from wind energy equalled 12.7 Mton CO_2e with an average price of only US$1.9 per ton CO_2e. Methane landfill projects add up to 8 Mton CO_2e and projects involving clean cookstoves supplied 3 Mton CO_2e to market. The category 'other' in **Table 2** includes clean water, biomass, energy efficiency, transportation, fuel switching, waste heat recovery, ozone depleting substances, solar, livestock methane, large hydro and geothermal, all representing 1 Mton CO_2e or less in volume. In 2015, the largest supply came from the US (15.4 $MtCO_2e$), followed by the EU (11 $MtCO_2e$), India (6.6 $MtCO_2e$), Indonesia (4.6 $MtCO_2e$), Turkey (3.1 $MtCO_2e$), Kenya (3.1 $MtCO_2e$) and Brazil (3.1 $MtCO_2e$).

Only a small part of the forest carbon credits, some 3 to 5% of total forest carbon credits, is generated in Europe, see section 3.6.

Table 2 A snapshot of the 2016 voluntary carbon market presenting 60% of actual transactions in 2016 (source: [9])

Category	Physical volume ($Mton\ CO_2e$)	Monetary volume (million US$)	Price level (US$/ton CO_2e)
Forest carbon, *of which:*	12.1	67	5.1
- REDD+	9.7	41	4.2
- Tree planting	1.3	11	8.1
- Improved forest management	1.1	10	9.5
Non-forest carbon, *of which:*	28.7	79	2.8
- Wind energy	8.2	12	1.5
- Landfill methane	4.6	10	2.1
- Large-scale hydropower	3.8	0.8	0.2
- Energy efficiency – community based	2.4	12	3.7
- Clean cook stoves	2.3	12	5.1
- Other	17	32	1.9
Total	40.8	146	3.6

Note: the actual market volume in 2016 is 63.4 Mton CO_2e (compared to 84.1 Mton in 2015) and the actual market turn-over of transacted credits was US$191.3, (compared to US$278 million in 2015). The table excludes projects that did not provide a price for the credits in the survey and categories with less than three respondents. Hence the table can be seen as representative for the overall market, but the exact share of different project types in the overall market may nevertheless deviate from the proportions presented in **Table 2**. The amount of forest carbon credits traded in the voluntary market in 2015 can be estimated at approximately 26 Mton CO_2e (based upon the 2016 state of the carbon market report), and in 2016 it can be estimated at 12.1/40.8 * 63.4 = 18.8 Mton CO_2e.

3.3. CARBON VERIFICATION STANDARDS AND REGISTRIES

Almost all (99%) of offsets are verified by an independent third-party standard [9]. The most-used standard is the Verified Carbon Standard (VCS), which accounted for 58% of the new supply in 2016. In 2015, the Gold Standard issued 17%, the Climate Action Reserve (CAR) 8%, the American Carbon Registry (ACR) issued 3% and Plan Vivo issued 1%. Compared to 2015, the share of the VCS has strongly increased (from 46 to 58%).

The Verified Carbon Standard (VCS) standard is used for the majority of forest carbon credits given its early investment in developing verification processes for REDD (VCS covers both credits from tree planting and from REDD). VCS is also the only standard that facilitates trading carbon credits in peat. For example, the Indonesia (Central Kalimantan) Katingan peat forest project brought to market by the UK based company 'Permian' is supplying 12 Mton CO_2e to market in the coming years.

The VCS does not explicitly consider biodiversity and community impacts of carbon credits. Therefore, VCS credits in the domain of forest carbon are often also verified with the Climate Community and Biodiversity (CCB) standard. The CCB Standard identifies land management projects that deliver net positive benefits for climate change mitigation, for local communities and for biodiversity. The CCB Standard can be applied to land management projects, including REDD projects and projects that remove carbon dioxide by sequestering carbon through reforestation, afforestation, revegetation, forest restoration, agroforestry and sustainable agriculture. It covers aspects related to the complete project cycle from design through implementation and monitoring. In 2016, 23% of the VCS credits were also verified under the CCB.

The Gold Standard was developed by the WWF and other NGOs as a tool that can be used to develop “quality” carbon offsets. It offers the possibility to verify tree planting but not REDD projects. The Gold Standard has stricter requirements for additionality and stakeholder consultation compared to the VCS (without the CCB); for example, project developers must invite local people to two consultations on the project. The Gold Standard also facilitates quantifying co-benefits ranging from health and gender to water and biodiversity protection, so that projects can potentially sell co-benefits as a separate asset.

American Carbon Registry Validation and Verification. The American Carbon Registry (ACR) requires independent third-party validation and verification of all carbon offset projects following ACR Validation and Verification Guidelines. ACR Validation and Verification Guidelines allow verification of carbon credits from both REDD and reforestation.

The Plan Vivo Standard has been designed to be accessible for smallholder- and community-based projects. Plan Vivo can be used to certify afforestation/reforestation (only non-commercial plantations), agroforestry, avoided deforestation, and forest conservation and restoration projects. It allows verification and accreditation of carbon benefits as well as other ecosystem services such as watershed services and biodiversity conservation.

Once verified and issued, most carbon credits are registered in either the APX, ACR (see above) or the Markit registry. The APX VCS Registry is a platform for issuing, tracking and retiring Verified Carbon Units (VCUs). The APX Registry allows project developers to initiate the project registration process, upload documents and request issuance of VCUs. The Markit Registry allows account holders to manage global carbon, water and biodiversity credits in one centralised registry system. Most Gold Standard credits are registered on the Markit registry. ACR registers credits for the voluntary market, and also acts as an approved offset project registry for the California Cap-and-Trade program.

3.4. BUYERS OF FOREST CARBON CREDITS

The majority of buyers are private sector entities from North America (US and Canada) and Europe. The carbon market survey indicates that US buyers have a preference for credits from suppliers in the US and European buyers for credits from European suppliers. Within Europe, buyers from the United Kingdom, the Netherlands, and France purchased the largest amount of credits. The majority of carbon credits sold is generated in Asia (around one-third of all credits, in particular from India, South Korea and China).

Based on the outcomes of the Forest Trends survey, companies purchase at least around one-third of all emissions reductions. Most other buyers are ‘retailers’, selling credits on to either other companies or individuals, see below. Suppliers reported contracting the most tonnes to multinational corporations, followed by domestic corporations, and then small-to-medium enterprises [9].

The motivations of buyers vary. These include utilities that purchased credits in order to offer customers a carbon-neutral energy option, but there are also companies that want to raise their profile as a responsible business and/or demonstrate climate leadership [9]. Energy, transportation, and finance/insurance companies are the sectors that purchase most offsets. In 2015, the events/entertainment and services sectors also purchased a large volume of credits influenced by events such as the World Cup, the Olympics, and the Superbowl that are now carbon neutral, however the purchases from this sector were lower in 2016 [9]. In addition, service industries such as hotels are increasingly incorporating climate commitments into their brands. Forestry offsets are a favourite among most buyer sectors, but there are differences between sectors. Renewables composed 88% of total volume offset by the transportation sector, methane purchases made up 75% of events/entertainment offsetting, and non-methane gases comprised 57% of total volume offset by the services sector according to the 2016 Carbon Market Survey. Preferences of the energy sector are not published.

An important market segment is the ‘carbon offset retailers’. These companies purchase and sell credits to a variety of customers including small-to-medium businesses and consumers. There are still new entries of retailers on the market. For example, the non-profit organization Stand for Trees sells REDD+ offsets at a flat rate of $10/tonne.

3.5. EMISSIONS FROM THE EUROPEAN REFINERY SECTOR AND ROAD TRANSPORT EMISSIONS

The EU-28 Greenhouse Gas Emissions (GHG) by sector are provided in **Table 3**, for the year 2014. In 2014, the EU refineries emitted 115.3 Mton CO_2e, or about 2.6% of the EU total. CO_2 emissions from fuel use in the transportation sector (including aviation within the EU but excluding maritime transport) amounted to 1026 Mton CO_2e, or 23% of the total EU emissions. Of this, 845.3 Mton CO_2e is from road transportation. These emissions exclude fugitive emissions from fuels, which amount to 87 Mton CO_2e for all sectors.

Table 3 Annual greenhouse Gas Emissions (GHG) by sector in the EU-28; Mton CO_2 equivalent

	Total emissions	Energy related emissions							Non-energy related emissions
		Fuel combustion						Fugitive Emissions from Fuels	
		Energy industries			Other sectors				
		Public Electricity and Heat Production	Petroleum Refining	Other Energy Industries	Manufacturing and construction	Transport	Commercial/ institutional, Residential, Agriculture/ Forestry/ Fisheries		
EU-28	4 419.2	1 075.2	115.3	55.1	492.4	1 026.2	609.4	87.3	958.2
									0
BE	117.9	15.5	4.8	0.2	13.3	29.3	22.6	0.6	31.5
BG	57.7	28.1	0.9	0.0	2.8	9.0	1.8	1.0	14
CZ	126.8	46.7	0.8	5.6	10.0	18.0	10.7	4.0	30.9
DK	53.9	13.3	0.9	1.4	4.2	14.8	4.2	0.4	14.4
DE	924.8	318.0	17.7	10.6	119.7	185.7	124.7	10.5	137.9
EE	21.2	14.4		0.6	0.7	2.4	0.7	0.0	2.4
IE	60.5	10.8	0.3	0.1	4.3	13.6	8.1	0.0	23.2
EL	104.3	40.6	5.3	0.0	5.5	20.5	5.0	1.2	26.2
ES	342.7	62.4	11.8	1.5	40.4	93.7	37.1	5.0	90.8
FR	475.4	28.2	7.9	3.3	60.0	147.5	85.3	4.0	139.3
HR	24.8	3.1	1.3	0.2	2.6	6.0	2.9	2.0	6.8
IT	428.0	71.8	21.2	6.9	52.0	114.3	74.7	8.4	78.7
CY	9.2	2.9			0.7	2.6	0.5		2.5

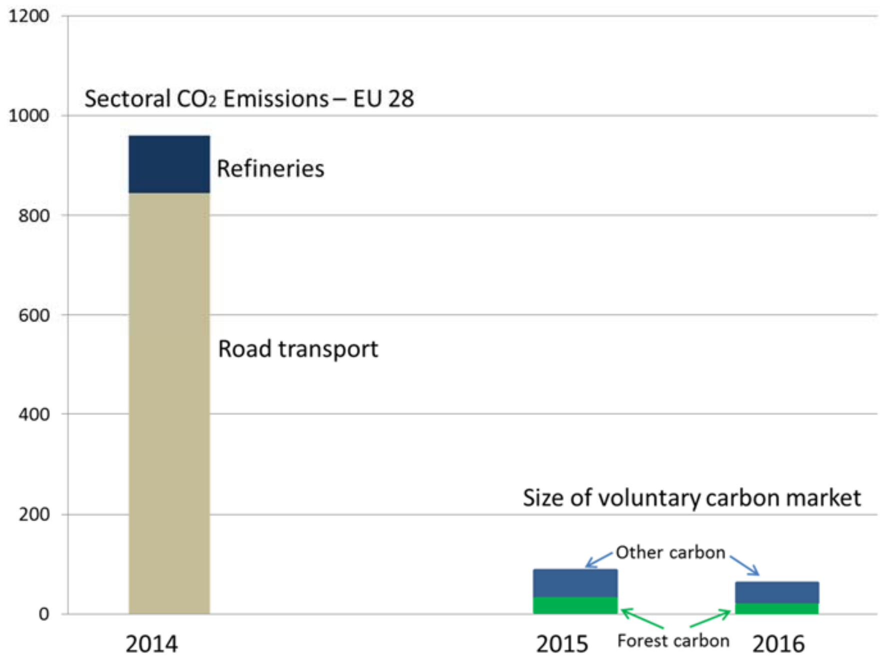
Table 3 Annual greenhouse Gas Emissions (GHG) by sector in the EU-28; Mton CO_2 equivalent

LV	11.6	1.6		0.1	0.7	3.3	1.4	0.1	4.3
LT	19.2	1.8	1.3	0.0	1.1	5.3	1.3	0.3	8
LU	12.0	0.7			1.1	7.4	1.5	0.0	1.3
HU	57.7	11.4	1.4	0.4	4.2	11.7	10.8	0.9	16.9
MT	3.3	1.6			0.0	1.0	0.2		0.5
NL	198.0	51.7	9.7	2.7	24.2	41.4	32.4	2.4	33.3
AT	78.3	6.7	2.7	0.2	10.5	24.2	8.5	0.5	24.9
PL	382.0	153.5	4.0	2.9	30.0	45.9	55.8	18.9	70.9
PT	67.6	12.4	2.1		7.7	18.7	4.4	1.6	20.6
RO	110.4	21.8	1.6	1.7	13.8	16.2	10.5	11.4	33.5
SI	16.7	4.4		0.0	1.6	5.5	1.4	0.4	3.4
SK	40.8	4.7	1.2	1.3	7.3	6.6	4.6	1.5	13.7
FI	61.1	16.5	2.6	0.3	8.5	13.0	5.3	0.1	14.8
SE	56.7	6.8	2.2	0.4	7.8	20.2	3.5	0.8	15.1
UK	556.7	123.8	13.5	14.8	57.5	148.4	88.7	11.4	98.4

3.6. COMPARISON OF FOREST CARBON CREDITS AND EU REFINING AND ROAD TRANSPORT EMISSIONS

Carbon market volumes. Based on the earlier sections in chapter 3, the size of the carbon market can be compared with the emissions of the EU refining and transport sector (on an annual basis). This is shown in **Figure 4**. Note that **Figure 4** compares the current emissions from the EU refining and road transport sectors with the current size of the global voluntary market. A comparison with the carbon credits generated in Europe is shown in the next section. Note also that the current market turnover of carbon credits is not the same as the amount of credits available for purchase. The availability of carbon credits including forest carbon credits is analysed below, at the end of section 3.6.

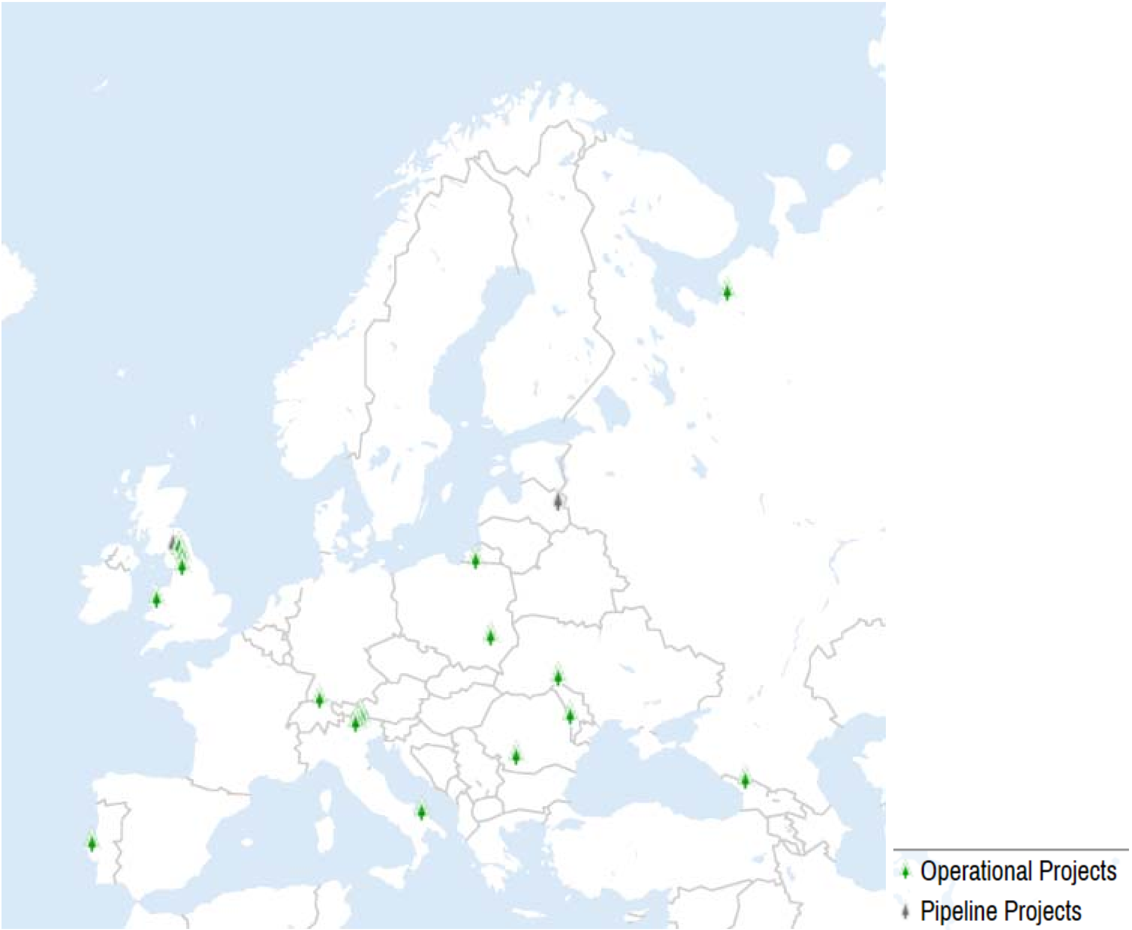
Figure 4 Comparison of annual EU carbon emissions in refining and road transport with the annual volume transacted in the global voluntary carbon market (see also Box 1 on page 38)



In general, the share of **European** forest carbon projects in the overall forest carbon market is small. The share of forest projects implemented in Europe in the global total was less than 8% in 2007 [10] and this figure is likely to be lower now given that REDD projects (which can only be implemented in a developing country) are the most important source of forest carbon credits at present [9]. **Figure 5** and **Table 4** present forest carbon projects in Europe. These include both ongoing and planned projects, with ongoing indicating that projects have started (but not that credits have necessarily been verified or are available for sale). Together there are 20 European forest carbon projects registered in the Forest Carbon portal. The projects together aim to market around 8.1 Mton of CO_2 credits over the lifetime of the projects. Not all of the credits are verified yet; currently at least 6 million of these CO_2 credits have been brought to market (see **Table 4**). Two of the projects are actively seeking buyers in January 2017 according to Forest Carbon Portal: (i) the Dvinsky Forest Conservation Project, Russia offering 2.7 Mton CO_2e; and (ii) the Warmian-Masurian Forestry Offset Project, Poland offering 0.5 Mton CO_2e). However it is likely that other projects may also offer credits if approached, and it is unclear to what degree credits in the two aforementioned projects have been sold already.

The forest carbon portal also specifies one project, the Portugese Terraprima and Portuguese Carbon Fund that aims to sequester carbon in agricultural land (specifically in pastures). The website of this project indicates that the project is generating 1 Mton of CO_2 in credits (http://www.terraprima.pt/en/sobre-nos/) [3].

Figure 5 European forest carbon projects (from the Forest Carbon Portal, accessed 30 January 2017 at http://www.forestcarbonportal.com/)



[3] The forest carbon portal mentions that this project is developing 120 Mton CO_2e offsets from 50,000 ha of land but given that this would amount to 2400 ton CO_2/ha which is ecologically impossible this is unlikely to be accurate

Table 4 Forest Carbon projects in Europe

Location	Developer	Size (ha)	Project Type	Status	Total reductions brought to market over project lifetime ($tCO_{2}e$)
United Kingdom	Woodland Trust	84	Afforestation or Reforestation	Pipeline	12,000
Warcop, CMA United Kingdom	Woodland Trust	160	Afforestation or Reforestation	Operational	90,382
Arkengarthdale, NYK United Kingdom	Yorkshire Dales Millennium Trust Lancaster UK	2	Afforestation or Reforestation	Operational, credits on market	5,902
Yorkshire United Kingdom	Yorkshire Dales Millennium Trust	32	Afforestation or Reforestation	Operational	30
Llanybydder, United Kingdom	Tree Flights	3	Improved Forest Management	Operational, credits on market	Not disclosed
SZ Switzerland	Oberallmeindkorporation Schwyz	7,379	Improved Forest Management	Operational	330,000
n/a, Various locations Italy	Azzero CO_2	100	Afforestation or Reforestation	Operational	Undisclosed
Comune di Cismon, Veneto Italy	CarboMark	15	Improved Forest Management	Operational	Undisclosed micro project
Veneto Italy	Regione Autonoma Friuli Venezia Giulia and Regione Veneto	301	Improved Forest Management	Operational	317 t CO_2
Comune di Caltrano, Veneto Italy	CarboMark	10	Improved Forest Management	Operational	Not disclosed, micro project
Comune di Lusiana, Vicenza Italy	CarboMark	1,230	Improved Forest Management	Operational	982
MT Albania	Albanian Ministry of Environment, Forestry and Water Administration	6,317	Afforestation or Reforestation	Operational	455,058
WM Poland	CO_2 Reduction Poland Sp Z.o.o, a subsidiary of Carbon Friendly™ Solutions Inc.	671	Afforestation or Reforestation	Operational, credits on market	500,000
Mazury, Poland	PrimaKlima -weltweit- e.V.	14	Afforestation or Reforestation	Operational	Not disclosed
DO Romania	National Forest Authority with support from World Bank Prototype Carbon Fund	6,728	Afforestation or Reforestation	Operational	1,018,161
Moldova	Moldsilva; Moldova State Forest Agency	1,310	Afforestation or Reforestation	Operational, seeking validation	145,917
Moldova	Moldsilva	8,157	Afforestation or Reforestation	Operational, credits on market	2,800,000
Area Feimanu, RZK Latvia	PrimaKlima – weltweit- e.V.	36	Afforestation or Reforestation	Pipeline	Not disclosed
Zugdidi Georgia	Agrigeorgia; Ferrero; Climate and Education Partnership (CEP)	3,000	Afforestation or Reforestation with hazelnut	Operational	10,000
ARK Russia	WWF Russia	50,000	Afforestation or Reforestation (with exotic species)	Operational, credits on market	2,700,000

Availability of voluntary carbon credits. The volume of credits to be purchased in the potential case of offsetting emissions from the refining or road transport sector would need to be commensurate with the emissions, as specified in **Figure 3**. Of particular relevance is the amount of available, i.e. unsold credits on the voluntary market both in the short term and in the coming years. According to Forest Trends [9], the parties reporting for the annual Voluntary Carbon market survey indicated that they have 56.2 Mton CO_2e in unsold credits available for purchase. These include forest carbon, renewables (especially wind), efficiency and fuel switching credits. The share of forest carbon credits appears to be commensurate with it's share in the overall market, i.e. around one third or 20 Mton CO_2e.

However, the amount of credits actually available may be considerably higher, including the amount of forest carbon credits. Since supply currently exceeds demand, carbon credit developers may not offer all developed credits on the market. This information is also difficult to reveal from carbon registries. For example, an assessment of the credits issued under the APX carbon registry (which has registered 650 projects, or 55% of all voluntary carbon projects as of 7 February 2017), shows that the APX included 154 new 'Agriculture Forestry and Other Land Use' projects that generate a total of 30 Mton CO_2e of unsold carbon credits. Out of these, only 6.7 Mton CO_2e verified carbon credits are currently offered on the market. It is unclear if the remaining 23.3 ton have been sold already or if they are planned to be offered on the market at a later point in time.

Noteworthy are projects offering (VCS) carbon credits in peat, because there is a large amount of credits that could be generated in tropical peatlands (as analysed in Section 2.2). In Europe, a project in Belarus is reported to be under development which will bring several 100,000 ton CO_2 credits to market in the coming year. In the case of tropical peatlands, the Indonesia Rimba Raya project (30,000 ha) has marketed several 100,000 tons of carbon credits from peatlands. However, the most advanced project on peat, both in terms of volume and in terms of verification methodology applied, is the Indonesia peat project 'Katingan', brought to market by the UK-based company Permian (covering a peat area of around 150,000 ha). This project has brought 12 Mton CO_2e VCS verified offsets to market (of which an unpublished amount is sold already). In the coming years the project is expected to generate several additional Mton CO_2 credits.

Hence, as a preliminary indication, based on the APX registry and the data from Forest Trends [9], it can be assumed that in 2017 some 60 - 90 Mton of new credits is likely to be generated in the voluntary market. This will include around 20-30 Mton CO_2e of forest carbon credits. Of the forest and other credits, perhaps around half has been sold already. In addition, there is a reservoir of at least 56.2 Mtons CO_2e of unsold credits that has accumulated from previous years. However, the market for forest carbon credits appears somewhat stronger than for other types of credits (given co-benefits such as biodiversity impacts, and as evidenced by the higher prices and the comparatively lower stock of unsold credits in the APX registry). Hence, the best estimate that currently can be made is that currently some 15 to 30 Mton of verified voluntary carbon credits from forest carbon projects is available (of which less than 1% from the EU). All these are certified projects, yet there are likely to be quality differences between credits, in terms of risks of leakage, permanence, local social conflicts. Hence, prior to purchasing any credits further screening is required, for instance by a third-party company specialised in developing such credits.

It needs to be noted that currently the demand for voluntary credits is low compared to supply [9]. It is believed that project developers could rapidly ramp up supply in response to a demand signal. For instance, when the California market announced that it would accept early-action offsets this led to an increase in credits issued of 11% in the same year (representing credits that can be attributed to the increase in demand of this market). It is possible that demand may strongly increase as of 2018 or 2019 depending upon developments in the CORSIA. In 2015, a forecast including scenario study was published on the supply and demand of carbon credits in the period 2015-2025 [20]. Based on an elaborate analysis of ongoing and planned projects, this study forecasted the potential supply of REDD credits in the period 2015-2025 to be on average 70 to 80 Mton CO_2e/year, which is a major increase compared to current supply levels. Including retroactive crediting of emission reductions, the potential supply of all types of credits, for the overall period 2015-2025 was estimated in the same study at 918 Mton CO_2e. Demand was estimated between 429 and 1188 Mton CO_2e depending upon, in particular: (i) developments in aviation; (ii) developments in the California carbon market where REDD+ credits from specific states in Brazil, and a specific province in Indonesia (Aceh) are already admitted to the market; (iii) developments in the Brazil domestic carbon market; and (iv) the potential admission of international REDD credits on the Australia carbon market.

On average, it takes around 2.5 years to develop a carbon credit project from start to bringing verified carbon credits to market [9]. This means there is some delay in increases in supply following an increase in demand. Hence, overall, the coming years face an oversupply of carbon credits whereas after 2020 the market may change and face either an over- or undersupply compared to demand.

4. ECONOMIC AND INSTITUTIONAL CONSIDERATIONS

4.1. COSTS OF CARBON OFFSETS CURRENTLY ON MARKET

The costs of carbon credits vary strongly with the type of credit. As indicated in **Table 2** above, carbon credits from wind energy are the cheapest at on average US$1.5 per ton CO_2e (down from US$1.9 per ton CO_2e in 2015), which is unsurprising given that wind energy projects generate returns from electricity production and the costs of the offsets reflect the net costs after sale of electricity. A challenge with wind projects is demonstrating the additionality of the project, i.e. that the wind energy turbines would not be built without the financial benefits from carbon credits. A question is if, with falling prices of wind turbines both on-land and offshore, proving additionality remains possible in the future.

In general, costs of forest carbon projects include (i) costs for acquiring land; (ii) costs for forest management including planting and/or rehabilitation; (iii) transaction costs related to project design, verification, registration and sale of carbon credits; and (iv) costs related to negotiating and benefit sharing with local land users (in some countries for example Indonesia it is mandatory to share benefits with local people). Transaction costs are typically between US$1.5 to 3 per ton CO_2e depending upon the standard used, the area and the size of the project (efficiencies of scale apply). In the case of forest carbon credits, project developers may gain additional income for instance from sustainable timber logging or non-timber forest product harvesting, or from selling biodiversity or watershed management credits.

These costs and potential co-benefits are reflected in the price of forest carbon credits offered on the market. The prices of these credits vary from on average US$ 4 per ton CO_2 for REDD+ projects to US$ 10 per ton CO_2 for improved forest management. Afforestation and reforestation (tree planting) projects average US$8 per ton CO_2. The low price for REDD+ projects can be explained by the notion that avoiding trees to be cut is generally cheaper than planting trees (and ensuring that trees, when planted, actually survive and mature).

There is no data on the costs for which carbon credits from European forest carbon projects are for sale. An indication for one project is given by the Moldova ‘Moldsilva’ project. This project adopts three renewable 20-year crediting periods for a total project period of 60 years. The project expected to generate revenue from the sale of timber from thinning and from the sale of CDM Certified Emission Reduction (CER) credits over the first 20-year crediting period. The cost of implementation the project during the first 11 years (2002-2012) is estimated at US$18.74 million (according to information provided by the project developer ‘Moldsilva’ on the Forest Carbon Portal). The (planned) amount of credits to be brought to market amounts to 2.8 Mton CO_2e. Hence, the costs amount to US$ 6.7 per ton CO_2e (and the sales prices will need to be higher).

In general, it seems likely that, as also illustrated by the Moldsilva case, the costs of forest carbon credits in Europe are higher than in developing countries, for the following reasons. First, land will in many cases be cheaper in developing countries compared to in particular West Europe (rural land prices may of course be lower in Eastern Europe or Scandinavia). Second, forests grow much faster in wet tropical climates compared to European climates where plant growth stops during the winter and even in summer incoming solar radiation driving photosynthesis is lower. Third, important for forest carbon projects is demonstrating that the project will create additional carbon sequestration, i.e. the removal of carbon from the atmosphere beyond what would have happened without project implementation (termed 'additionality'). In the case of Europe, much of the continent is experiencing a gradual increase in forest cover, due to marginal agricultural land being reverted to forest land and a gradual increase in forest biomass in high latitudes related to climate change. Additionality is harder to establish in the EU compared to a situation where there is a rapid loss of forest cover as is the case in many developing countries (of course, in specific cases additionality can also be proven in the EU as is indicated by the projects listed in **Table 4**).

4.2. COSTS OF FOREST CARBON CREDITS EXPRESSED PER KM OF ROAD TRANSPORT

Tank-to-Wheel (TTW) Emissions. Following EU Regulation [7] on passenger cars, average CO_2 emissions from new cars should not exceed 130 g CO_2 per kilometre by 2015 and should decrease to 95 g CO_2 per kilometre by 2020. The 2015 CO_2 emission standards correspond to a fuel consumption of around 5.6 litres per 100 km (l/100 km) of petrol or 4.9 l/100 km of diesel. Targets have also been set for new vans. Targets for 2015 and 2020 are mandatory, and manufacturers will have to pay penalties if their average emission levels are above the target[4]. According to data provided by manufacturers, as stated in EU (2014), the average emissions level of a new car sold in 2014 was 123.4 g CO_2/km, below the 2015 target. Emissions are currently still based on a standardised approval test cycle (i.e. the New European Driving Cycle) under laboratory conditions and actual on-the-road emissions have been known to deviate from reported emissions in some cases.

Hence, for this report, TTW emissions from JRC [17] are used. For diesel cars, TTW emissions are assumed to amount to 120 g CO_2e/km for diesel, and 140 g CO_2e/km for petrol.

Assuming a price of carbon offsets of € 5 per ton CO_2e, the costs required to compensate the TTW CO_2 emissions from road transport amount to 120 x 5 / 1000000 = € 0.0006 per km for diesel cars and 140 x 5 / 1000000 = € 0.0007 per km for petrol cars. Expressed on a per litre basis, this amounts to, assuming 4.9 litre / 100 km for diesel, 0.0122 euro/litre diesel. For petrol this amounts to, assuming 5.6 litre/100 km, 0.0125 euro per litre petrol[5].

Clearly, doubling the price of offsets to € 10 per ton CO_2e would lead to a cost of € 0.024 / litre (i.e. 2.4 eurocent per litre) to offset TTW carbon emissions for diesel and € 0.025/litre for petrol. Note that these prices (5 respectively 10 euro per ton CO_2) represent indicative lower and higher range values at which forest carbon credits are currently offered on the voluntary market.

Well-to-tank (WTT) emissions. The calorific value of diesel fuel is roughly 45.5 MJ/kg (megajoules per kilogram), slightly lower than petrol which has a caloric value of 45.8 MJ/kg. However, diesel fuel is denser than petrol and hence contains roughly 36.9 MJ/litre compared to 33.7 MJ/litre for petrol [1]. Following JRC [18], the WTT emission of diesel can be estimated at 15.5 g CO_2e/MJ and that of petrol at 13.9 g CO_2e/MJ. Hence, the average WTT emissions are 572 gCO_2e per litre for diesel and

[4] The penalties will be based on the calculation of number of grams per kilometre (g/km) that an average vehicle registered by the manufacturer is above the target, multiplied by the number of cars registered by the manufacturer [8].

[5] Alternatively: 1 litre of petrol weighs around 750 gram. Petrol consists for 87% of carbon, or 652 gram of carbon per litre of petrol. This amounts to 652 * 3.66 = 2386 gram of CO_2/litre. The costs of offsetting these emissions, at 5 euro/ton CO_2 are: 2386 10^{-6} * 5 = 0.012 cent per litre

468 gCO_2e per litre for petrol. In other words, for diesel, offsetting the WTT emissions would cost 572 * 5 / 1,000,000 = 0.00286 euro per litre. For petrol, offsetting WTT emissions would cost 468 * 5 / 1,000,000 = 0.00234 euro/litre. **Table 5** presents an overview.

Table 5 Costs of compensating WTT emission, per litre fuel

Costs of carbon credits	5 euro / ton CO_2		10 euro / ton CO_2	
	Diesel	Petrol	Diesel	Petrol
Well-to Tank	0.0029	0.0023	0.0057	0.0047
Tank-to-Wheel	0.0122	0.0125	0.0244	0.0250
Well-to-Wheel	0.0151	0.0148	0.0301	0.0297

Clearly, it cannot be expected that total CO_2 emissions from road transport can be offset in the foreseeable future, if only because the volume of offsets is not available. For comparison, if 5% of the 2014 EU-28 road transport emissions would be compensated, this would costs, at 5 euro/ton CO_2, 5% * 1026.2 * 5 = € 257 million per year and involve around 51 Mton of carbon credits. Chapter 6 describes a scenario for bringing ‘carbon neutral’ fuel to market assuming that such fuel may be sold at a premium.

5. INSTITUTIONAL DEVELOPMENTS RELEVANT FOR FOREST CARBON OFFSETTING IN THE EU

5.1. DEVELOPMENTS IN THE EU EMISSIONS TRADING SCHEME

Basic principles of the ETS. The EU ETS was established on 1st Jan 2005. The EU ETS is currently by far the biggest trading scheme for GHG emission allowances in the world. The ETS includes emissions from 12,000 European power stations and industrial plants in 30 countries, which are allocated European Allowances (EUAs) that can be traded on the ETS. The EU ETS is based on the "Cap and Trade" principle. In order to keep their emission level within the cap, companies can either reduce their emissions or buy additional EUAs. If companies have surplus certificates, they can either keep them for future needs (banking) or sell them. In April of each year each participating company has to surrender sufficient certificates to cover their total emissions in order to avoid paying fines.

The EU ETS is composed of three trading phases. Phase I was from 2005 to 2007. During this period 100% of allowances were allocated to the participating companies for free. Phase II was from 2008 to 2012. Companies received free allowances to cover on average almost 90% of their overall CO_2 emission and had to cover the other 10% through auctions, brokers, exchanges or CDM/JI projects (see next section). The third phase is from 2013 to 2020. During this phase there are tighter limits on the use of offsets concerning amount and project types. By 2020, up to 70% of allowances is expected to be gained through auction. Free allowances are expected to be further reduced in the ETS beyond 2020.

The operators within the ETS may reassign or trade their allowances by several means: (i) privately, moving allowances between operators within a company and across national borders over the counter; (ii) using a broker to privately match buyers and sellers; and (iii) trading on the spot market of one of Europe's climate exchanges. When each change of ownership of an allowance is proposed, the national registry and the European Commission are informed in order for them to validate the transaction.

CO_2 emissions from aviation have been included in the EU emissions trading system (EU ETS) since 2012. Under the EU ETS, all airlines operating in Europe are required to monitor, report and verify their emissions, and to surrender allowances against those emissions. Currently, the EU ETS includes emissions from flights within the European Economic Area. Policy debate on including flights leaving for or entering the EU from destinations outside the EEA is still ongoing. The outcomes of this debate are likely to depend in part upon the ICAO achieving its targets on limiting CO_2 emissions from international aviation discussed in Section 5.5.

Use of international credits in the EU ETS. Like the Kyoto trading scheme, the EU ETS allows a regulated operator to use carbon credits in the form of Emission Reduction Units (ERU) to comply with its obligations, under a number of conditions. One EUA equals one tonne of CO_2, and is identical to the equivalent "Assigned Amount Unit" (AAU) of CO_2 defined under Kyoto. Kyoto Certified Emission Reduction units (CERs), produced by a carbon project that has been certified by the UNFCCC's Clean Development Mechanism (CDM) Executive Board, or Emission Reduction Units (ERUs) certified by the Joint Implementation project's host country or by the Joint Implementation Supervisory Committee, are accepted by the EU as equivalent. However their use in the ETS is subject to a number of conditions, which in part depend upon the phase of the ETS, as discussed below.

Participants in the ETS can use international credits from CDM and JI towards fulfilling part of their obligations under the ETS until 2020, subject to the following qualitative and quantitative restrictions:

Qualitative restrictions. Credits are accepted from all types of projects, except

•nuclear energy projects

•afforestation or reforestation activities (LULUCF) including REDD+ projects

•projects involving the destruction of industrial gases (HFC-23 and N2O).

Credits from hydroelectric projects exceeding 20 MW of installed capacity can only be accepted under certain conditions. In addition, the use of new project credits/CERs after 2012 is prohibited, unless the project is registered in one of the least developed countries (LDC).

Quantitative restrictions. EU legislation specifies maximum limits up to which operators under the ETS may use eligible international credits for compliance in phase 2 and phase 3. The minimum threshold a member state can apply (i.e. the maximum amount of credits that participants in the ETS in a specific country can supply based on credits from JI or CDM is around 10% (see for details [6]). The initial international credit entitlements for each participant in the system for phase 2 and 3 combined are determined by Member States and then approved by the Commission in line with the relevant legislation.

In total, participants in the EU ETS used 1.058 billion tonnes of international credits in phase 2 (2008-2012). Since phase 3, CERs and ERUs (only from LDC countries) must be exchanged for EU allowances. Operators must request the exchange of CERs and ERUs for allowances up to their individual entitlement limit set in the registry.

5.2. CALIFORNIA'S CAP-AND-TRADE PROGRAM[6]

California's Cap-and-Trade Program is the world's second largest carbon market. It applies to large electric power plants, large industrial plants and, as of 2015, fuel distributors, covering nearly 85 percent of the state's total GHG emissions. Emission allowances are distributed by a mix of free allocation and quarterly auctions and the cap on GHG emissions is scheduled to decrease by three percent annually from 2015 through 2020. A maximum of 8% of allowance obligations can be offset with carbon credits following specific protocols. Forest carbon offsets[7] are recognised in the system, provided that credits are generated in the US or selected states in other countries (e.g. two states in Brazil, and one province in Indonesia). The system covers

[6] The US Regional Greenhouse Gas Initiative (RGGI) mandatory cap-and-trade program covers nine states in the north-eastern US, and only includes the power sector. It is therefore considered out of scope for this report.

[7] Californian forest carbon offsets need to comply with the Compliance Offset Protocol U.S. Forest Projects ('Forest Offset Protocol'). The Forest Offset Protocol provides offset project eligibility rules; methods to calculate an offset project's net effects on GHG emissions and removals of CO_2 from the atmosphere (removals); procedures for assessing the risk that carbon sequestered by a project may be reversed (i.e. released back to the atmosphere); and approaches for long term project monitoring and reporting.

both California and, as of January 2014, the Canadian province of Quebec. Ontario is exploring the possibility of joining as well. At one point, six other U.S. states and two other Canadian provinces were considering joining, but these dropped out. The system sets a minimum price for allowances, and that minimum rises each year. Allowances in the most recent auction (autumn 2016) sold for the floor price of $12.73 per metric ton of greenhouse gases. Prices will automatically increase to about $13.50 per ton in the first auction in 2017.

The California Cap-and-Trade program currently faces three challenges. First, there is uncertainty over the implications of the election of the new US president. Second, there are legal issues, resulting from a long-running lawsuit filed by the California Chamber of Commerce that seeks to have the system declared an illegal business tax that should have required a two-thirds vote of the legislature to take effect. Oral arguments in the case are scheduled to begin early 2017. Third, there is an oversupply of allowances on the market. The state's industries have been able to reduce their greenhouse gas emissions faster than expected. As a result, companies don't need to buy as many allowances as the state has made available. Consequently, there has been relatively little trade in the market in 2016, and the amount of offsets bought by entities participating in the California Cap-and-Trade system on the voluntary market has been low. Considering these challenges and that only selected states in several countries can supply credits, it does not seem likely that a high market demand for voluntary credits including from forest carbon can be expected in the near future.

5.3. THE PARIS AGREEMENT

The Paris Agreement's central aim is to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius[8]. Additionally, the agreement aims to strengthen the ability of countries to deal with the impacts of climate change. On forests, the Paris agreement specifies:

Article 5.1. Parties should take action to conserve and enhance, as appropriate, sinks and reservoirs of greenhouse gases as referred to in Article 4, paragraph 1 (d), of the Convention, including forests.

Article 5.2. Parties are encouraged to take action to implement and support, including through results-based payments, the existing framework as set out in related guidance and decisions already agreed under the Convention for: policy approaches and positive incentives for activities relating to reducing emissions from deforestation and forest degradation, and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries; and alternative policy approaches, such as joint mitigation and adaptation approaches for the integral and sustainable management of forests, while reaffirming the importance of incentivizing, as appropriate, non-carbon benefits associated with such approaches.

On international transfer of carbon mitigating efforts, the agreement specifies:

Article 6.1. Parties recognize that some Parties choose to pursue voluntary cooperation in the implementation of their nationally determined contributions to allow

[8] Excerpt from: http://unfccc.int/paris_agreement/items/9485.php

for higher ambition in their mitigation and adaptation actions and to promote sustainable development and environmental integrity.

Article 6.2. Parties shall, where engaging on a voluntary basis in cooperative approaches that involve the use of internationally transferred mitigation outcomes towards nationally determined contributions, promote sustainable development and ensure environmental integrity and transparency, including in governance, and shall apply robust accounting to ensure, inter alia, the avoidance of double counting, consistent with guidance adopted by the Conference of the Parties serving as the meeting of the Parties to this Agreement.

Article 6.3. The use of internationally transferred mitigation outcomes to achieve nationally determined contributions under this Agreement shall be voluntary and authorized by participating Parties.

Article 6.4. A mechanism to contribute to the mitigation of greenhouse gas emissions and support sustainable development is hereby established under the authority and guidance of the Conference of the Parties serving as the meeting of the Parties to this Agreement for use by Parties on a voluntary basis. It shall be supervised by a body designated by the Conference of the Parties serving as the meeting of the Parties to this Agreement,

Hence, notably, the Pairs Agreement does not preclude carbon offsetting using international credits derived from forest carbon, provided, inter alia, that such credits are (i) authorised by participating parties; (ii) foster sustainable development and ensure environmental integrity and transparency, including in governance; and (iii) shall apply robust accounting to ensure the avoidance of double counting.

Article 6 of the Agreement also provides for a newly to be designed mitigation mechanism to replace existing mechanisms (such as CDM and JI) and provide for certification of emission reductions for use towards nationally determined commitments. In 2018, Parties will take stock of the collective efforts in relation to progress towards the goal set in the Paris Agreement and to inform the preparation of nationally determined contributions.

5.4. THE 'CLIMATE NEUTRAL NOW' INITIATIVE

Climate Neutral Now (CNN) is an initiative of the United Nations Climate Change secretariat. The initiative invites organizations to take the 'Climate Neutral Now Pledge'. This pledge consists of four steps: (i) measure greenhouse gas emissions; (ii) reduce them as much as possible; (iii) report greenhouse gas emissions; and (iv) compensate those which cannot be avoided with UN certified emission reductions. To date, Microsoft, Adidas, Sony and M&S participate in this initiative.

The CNN initiative is building upon the Kyoto CDM mechanism. With the Kyoto Protocol gradually being phased out the demand for CDM credits collapsed. However, there are still a number of new projects that have started supplying CDM credits to market. These projects were originally initiated in the recent past with the aim of obtaining co-funding for investment through the sale of CDM credits. **Table 6** presents an overview of all projects currently offered by the Climate Neutral Now initiative (1 February 2017), with most of the projects from either China, Chile or India. Note that, effectively, these have now become voluntary carbon credits. There is only one project in the agricultural sector, the Methane capture and combustion from swine manure treatment for Pocillas and La Estrella in Chile. There are no forestry projects in the CNN portfolio. Currently, supply as offered by the CNN is very limited, however this could be scaled up in case demand increases, there is still an important reservoir of CDM credits that could be brought to market should there be a buyer, as discussed in Section 6.2. However, additionality of these credits is of concern. Additionality was checked at the point in time the credits were developed for the CDM following the applicable verification mechanisms. However, it is unclear if and to what degree additionality remains if the credits are now used in a different scheme, in particular since most of the projects that generate the credits will have started operating already. This may also vary between projects (e.g. some projects would perhaps generate more offsets if credits are sold since additional financial resources for these projects enable expansion of project activities, as may be the case with cooking stove projects). New CDM credits are no longer generated.

Table 6 Projects offering CDM verified credits through the Climate Neutral Now initiative

Category	Number of Projects	Approximate volume of credits available (ton CO_2e)	Indicative price (US$/ton CO_2e)
Agriculture	1	46,000	2.4
Biomass for energy	6	83,000	3-3.5
Cooking stoves households	1	2000	4.5
Hydropower	8	147,000	0.7-5
Solar	1	700	5
Public transport	1	39,000	1.5
Waste handling and disposal (including methane from landfills)	7	170,000	0.4-2.5
N2O gas reduction	1	15,000	2.3
Wind energy	7	216,000	0.5 to 2.0
Total	33	719,000	

5.5. DEVELOPMENTS IN THE AVIATION INDUSTRY

Domestic and international aviation together account for approximately 2 per cent of global CO_2 emissions; with around 1.3 per cent of this from international aviation. In 2012, aviation represented 13% of all EU transport CO_2 emissions, and 3% of the total EU CO_2 emissions. It was also estimated that European aviation represented 22% of global aviation's CO_2 emissions [8]. Emissions from flights within the European Economic Area are included in the ETS.

Environmental trends including emissions are regularly assessed by the International Civil Aviation Organization [16], a UN agency established to manage the administration and governance of the Convention on International Civil Aviation (Chicago Convention). ICAO Council's Committee on Aviation Environmental Protection (CAEP) forecasts a continued growth in aviation emissions in the coming decades, based on projected annual improvements in aircraft fuel efficiency of around 1 to 2 per cent in combination with traffic growth of around 5 per cent per year. This implies international aviation fuel consumption will grow somewhere between 2.8 to 3.9 times by 2040 compared to the 2010 levels [16].

In October 2013, the 38th Session of the ICAO Assembly adopted Resolution A38-18, which resolved that ICAO and its Member States, with relevant organizations, would work together to strive to achieve a collective medium term global aspirational goal of keeping the global net CO_2 emissions from international aviation from 2020 at the same level (so-called "carbon neutral growth from 2020"). The Assembly also defined a basket of measures designed to help achieve the ICAO's global aspirational goal. This basket includes aircraft technologies such as lighter airframes, higher engine performance and new certification standards, operational improvements (e.g. improved ground operations and air traffic management), sustainable alternative fuels, and market-based measures (MBMs). However, in line with the overall trends indicated in the previous paragraph, the aggregate environmental benefit achieved by non-MBMs measures will be insufficient for the international aviation sector to reach its 'aspirational goal' of carbon-neutral growth from 2020 (IACO website, accessed 20 January 2017).

In response, ICAO is currently designing a global market-based mechanism (GMBM) to reduce airline emissions. This mechanism is complementary to ongoing efforts to enhance fuel efficiency and decrease carbon emissions in the sector. As of 2020, ICAO aircraft operators will need to purchase offsets to meet the carbon reduction target for the industry. The most up-to-date proposal (August 2016) involves the phased implementation of the GBMB mechanism: voluntary participation by States in the pilot phase and first phase, followed by the second phase in which all other States except for exempted ones will participate. ICAO's Air Transport Bureau estimates that airlines covered by the GMBM will generate an offset demand for between 288 $MtCO_2e$ and 376 $MtCO_2e$ by 2030 depending on how effectively they are able to reduce emissions by other means [16].

The first implementation phase is scheduled to begin in 2021, but ICAO aims to develop guidance for "Emissions Unit Criteria" by 2018. A key element of the GMBM is the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). The CORSIA, in effect, creates an additional market for carbon credits that can be used by airline operators to meet the objectives set out under the agreement [16]. CAEP has already outlined some basic criteria for the inclusion of offsets in the GMBM, including that they should be additional; permanent; based on a credible baseline; have a transparent chain of custody; safeguard against leakage; do no net harm; and are not double-counted. Part of the task of upcoming ICAO negotiations will be to determine which programs meet those criteria since, as the ICAO presentation notes, "an early decision on eligible emissions units under the GMBM would help the market to be ready to respond to international aviation demand."

One of the defining features of the CORSIA is that it acknowledges best practices across the entire carbon crediting sector, potentially broadening the set of carbon credits airline operators will be able to purchase and retire for compliance. Specifically, ICAO is considering relying not just on one GHG credit program, but on all those that meet a set of criteria (known as the Emissions Unit Criteria, or EUC) including credits generated through CDM.

Many of the standards currently active on the voluntary carbon markets are lobbying for inclusion, arguing that they meet CAEP's criteria and are already working closely with compliance markets such as California's. Some environmental groups, including Ecosystem Marketplace's publisher Forest Trends, are pushing specifically for the inclusion of REDD offsets in the GMBM, with an eye to the transition towards scaled-up avoided deforestation under the UNFCCC. Folded standards such as the Verified Carbon Standard, the Gold Standard, the American Carbon Registry, or the Climate

Action Reserve into an ICAO market-based mechanism would greatly enhance demand for carbon credits.

5.6. POTENTIAL IMPLICATIONS OF RECENT DEVELOPMENTS IN CARBON MARKET

Currently, forest carbon credits are included in CDM, but with the replacement of the Kyoto Protocol by the Paris Agreement the future of CDM (and Joint Implementation) is unclear. Potentially, CDM and JI may be integrated in some form or another in a new mechanism for the Paris Agreement. Such a mechanism would then have to avoid the pitfalls of the CDM and JI mechanisms, such as ensuring additionality of projects, transparency in monitoring and reporting [21]. A question is how forest carbon credits would be considered in such a mechanism and if their inclusion would potentially allow trading forest carbon credits on the EU ETS in the future.

It is noteworthy that new proposals from the Commission for the post-Paris Agreement under the Effort Sharing Regulation (ESR), as currently discussed in the EU Parliament, would include credits from LULUCF. The ESR will involve compulsory emission reduction targets for member states for the 2021-2030 period in sectors not covered by the EU ETS. It is the successor of the Effort Sharing Decision (ESD) that covers GHG emissions in the period 2013-2020. Current proposals by the Commission and the parliament set a limit on the amount of credits that can be generated with LULUCF (the limit itself is under discussion at the time of writing of this report), and require member states to ensure the permanence of land or forest removals of carbon used to offset emissions under the ESR.

6. ADVANTAGES AND DISADVANTAGES OF DIFFERENT POSSIBILITIES TO INVEST IN FOREST CARBON

6.1. INTRODUCTION

This section presents the different possibilities to invest in forest carbon including potential advantages and disadvantages of each feasible option. There is specific consideration of the European forest potential for geographical consistency. The advantage and disadvantages are discussed in section 6.2 in terms of technical criteria (related to the evaluation of carbon credits, as considered in a carbon verification process) and operational criteria (relevant for the potential purchase of credits by the EU refining and/or road transport sector). The report also discusses how this alignment may change as a function of ongoing revisions of the EU carbon market, however until the point in time decisions have been taken only provisional guidance can be provided. Section 6.3 compares different types of forest carbon credits. Section 6.4 briefly explores two concrete potential options for the refining sector to enter the (forest) carbon market, as a basis for further discussion.

6.2. CRITERIA FOR THE ASSESSMENT OF STRATEGIC OPTIONS TO EXPLORE CARBON OFFSETS

Based on a review of current experiences in the carbon market, the following criteria can be established:

Technical criteria: aspects that are considered in the verification process

Additionality of credits. Additionality is a key feature of all carbon credit schemes. An additionality test assesses whether a project or activity creates 'additional' emissions reductions that would not have occurred in the absence of the incentive. Developments that are likely to have occurred in the absence of the project are labelled the baseline of the project. Additionality is important to ensure that a credit scheme does not pay for emissions reductions that would have occurred anyway. Specific investment types require specific approaches to define the baseline and additionality. For example, in the case of REDD projects it needs to be shown that there is a substantive risk that a forest would be logged or converted in the absence of the project.

Leakage of credits. Leakage occurs when economic activity is shifted as a result of emission control and, as a result, emission abatement achieved in one location is diminished by increased emissions in unregulated locations. Leakage is relevant for both REDD and reforestation and afforestation projects. For example, if large landowners or countries agree to preserve their forests, wood processors might simply shift their harvests to neighbouring landowners or countries. As a result, the total harvest (total deforestation) might be unchanged, even though particular landowners or countries might have avoided deforestation in a specific forest.

Permanence of carbon credits. Permanence refers to whether the net benefit of an action, such as carbon removed from the atmosphere, will remain fixed for a long period, or whether the process may soon be reversed. Permanence is of particular importance when emission reductions or removals from REDD are used as offsets – if the forest underlying the offset is destroyed the offset will also be compromised. In the case of GHG standards for land use, permanence refers to the longevity of a carbon pool and the stability of its stocks, given the management and disturbance of the environment in which it occurs. The risk of non-permanence (also referred to as “reversals”) describes the possibility of reversing climate benefits through the loss of forest carbon biomass, for example through a fire or pest outbreak that releases carbon back into the atmosphere. Reversals are sometimes categorized as “intentional vs. unintentional” referring to whether it was anthropogenic (i.e. induced by human activity, such as harvesting) or a natural disturbance (e.g. a hurricane). However, there are challenges in attributing and separating natural from man-made effects on emissions.

Positive local benefits (to local communities). In particular in developing countries, institutional and market arrangements may not always sufficiently safeguard the livelihoods and forest use by local communities including indigenous people. This may for example be related to traditional use rights which may not be sufficiently guaranteed in the form of ownership or officially recognised user rights. Some countries explicitly request benefit sharing with local communities in carbon credit regulations, such as Indonesia. In any case care needs to be taken that potential carbon projects selected by the downstream sector do not infringe upon rights and livelihood opportunities of local people. This requires the use of an appropriate verification mechanism such as CCB or Gold Standard, as well as further screening of (verified) projects by independent agencies selected by the sector for the risk of local adverse impacts prior to purchasing any carbon credit.

Operational criteria: considerations when purchasing carbon offsets

Verification mechanism. The verification mechanisms described previously in this report all consider the above requirements. The Gold Standard is likely to be the strictest, and also considers local community benefits as an additional criterion. However the amount of credits issued under the Gold Standard is much smaller compared to the credits under the VCS standard, with total Gold Standard credits issued in 2016 in all categories amounting to 10.5 Mton CO_2e. Therefore, use of VCS standard credits with, for forest carbon, additional verification on the basis of the CCB can be considered. CDM credits have faced criticism in the past, for instance with regards to the additionality created with the carbon credits. The current pipeline as proposed in the Climate Neutral Now (CNN) Initiative has been screened somewhat more rigorously, but additionality remains a concern given that many of the projects proposed in the CNN initiative have been implemented already as discussed above.

Cost-effectiveness. Cost effectiveness can be expressed in terms of the costs per unit CO_2e emission avoided. These costs relate to the actual investment costs of the project but also to the transaction costs (for verification, monitoring, and registering the credits), as discussed in section 4.1. In 2015, the average costs of carbon offsets as offered on the voluntary market, was around US$3.8 / ton CO_2e (all project types). This price is not likely to have changed markedly in 2016, given that there has not yet been any major increase in demand for credits. The prices of forest carbon credits vary from on average US$ 4 per ton CO_2 for REDD+ projects, to US$8 per ton CO_2 for afforestation and reforestation projects, to US$ 10 per ton CO_2 for improved forest management projects. Prices of carbon credits available through the Climate Neutral Now platform (where currently no forest carbon credits are offered) are in the same order, varying between US$ 0.4 and 5 per ton CO_2e. Overall, the costs of carbon offsets are much lower than to the costs of emission reductions in refineries[9].

Availability of credits. In section 3.6, the availability of carbon credits on the voluntary market in 2017 is estimated at around 15 to 25 Mton of verified voluntary carbon

[9] Costs of emission reductions through CO_2 capture and storage in industry typically range from US$50 to 110 per ton CO_2.

credits from forest carbon projects (of which less than 1% from the EU). These credits all represent one ton of CO_2 removed from the atmosphere. In addition, some 50 to 70 Mton of CO_2 credits from other types of projects (wind energy, cooking stoves, hydro etc.) will be available. The share of credits from the EU is likely to be higher for these other types of carbon credits, but unlikely to exceed 15% of the total. The supply of credits could rapidly increase if a strong signal was given to carbon credit developers that additional supply would be purchased (e.g. by working with specialised companies to develop new credits and commit upfront to purchasing (part of) these credits). Some companies may have projects that are halfway through the process of bringing carbon credits to market and that could be brought forward in case there is demand for the credits, or have easy access to new projects with a conducive regulatory environment. These companies could already supply additional credits in 2018 and 2019. For projects that need to be developed from the start, it is likely that it will take 2 to 3 years from project initiation to bringing credits to market. Hence, the following supply could be assumed, as a preliminary estimate pending further market research (which would require contacting specific companies to enquire about the availability of credits), see **Table 7**.

Table 7 Carbon credits potentially available on the voluntary market (preliminary estimate)

Year	Forest carbon credits	Other carbon credits
2017	15-25	50-70
2018	15-30[/1]	50-100[/2]
2019	20-35[/1]	50-150[/2]
2020	20-100[/1]	50-200[/2]

Key: [/1] the upper range of the estimate may be achieved by working with carbon credit developers in order to speed up the delivery of new credits; [/2] very hard to establish given the uncertainty in the development of the cost of wind energy (which may become competitive in the coming years thereby eliminating the additionality of such projects) and the developments in the EU ETS and California ETS (both have restrictions on the use of forest carbon credits but less so on other types of credits).
In the longer term (>2020), it can be noted that the volume of carbon offsets that can potentially enter the market can be very high, at least several 100 Mton of CO_2e per year considering the amount of carbon emissions from tropical deforestation and forest degradation, peat oxidation and peat fires (which well exceeds 1000 Mton CO_2/year, see Section 2.2). However such a large volume will only be brought to market if suppliers anticipate demand for such credits.

For **CDM (CNN) credits**, the total amount of credits offered at present is less than one Mton CO_2e, representing carbon reductions generated in recent years with CDM certified projects that have not been sold on the compliance markets under the CDM mechanism. However, the total supply could be much larger given that there is a large reservoir of unsold CDM-compliant carbon credits (CERs). The total reservoir that could be brought to market if demand were there can be estimated at around several 100 Mton CO_2e [25]. Note that forest carbon projects present a small minority of these credits, which is otherwise made up of amongst others wind energy credits, industrial gasses, energy efficient cooking stoves, methane capture in landfills, etc., and that additionality of part of these credits is somewhat debatable affecting also the degree to which these credits are appreciated by civil society, see below. The aviation industry has issued a study on the availability of CDM-based CERs to mitigate additional emissions from aviation as of 2021 [2]. This study was motivated by the concern, during the development of GMBM, that there may be a lack of carbon credits to offset ICAOs demand. The assessment showed that the pipeline of existing CDM projects includes around 1240 Mton CO_2e of potentially eligible projects, which could cover this demand for a period of at least 8 years even if eligibility criteria for certain project types and vintages are introduced. The assessment considered that projects involving Cement, Coal bed/mine methane, energy efficiency, fugitives, geothermal, landfill gas, methane avoidance, PFCs and SF6, small hydro, solar, tidal and small-scale wind energy could tentatively be considered eligible. The assessment excluded afforestation and reforestation (due to concerns about additionality based on the CDM verification procedures, which differ from those of VCS and Gold standard), biomass energy, fossil fuel switch, HFCs, large hydro and large-scale wind. The excluded projects add up to over 5 Gton CO_2e. Note that the share of LULUCF projects including reforestation and afforestation in the CDM pipeline is very small (<1%).

Acceptability. Acceptability of the credits by society at large including the NGO sections[10] engaging in climate change is a consideration for any potential activity involving offsets of carbon emissions in the oil refining and road transport sectors. In general, a number of NGOs are critical towards the use of carbon offsets from forestry, based on the argumentation that such credits are not necessarily permanent (the forests may be cut in the future) and that it could reduce the incentives to reduce emissions at the source. The validity of such arguments is debatable and at the very least context dependent, yet there is a need to consider such aspects in the development of a potential strategy. Clearly, where refineries and potentially also car manufacturers can claim to apply Best Available Technologies (BAT) the case can be made that offsets are not replacing investments in emission reductions in the sector. In addition, forest carbon credits potentially generate large co-benefits such as contributing to biodiversity conservation or lifestyles of indigenous people, if the offset projects are properly designed and implemented, and this is verified by an appropriate verification standard (such as VCR + CCB or the NGO-supported 'Gold Standard'). In addition, transparency on actions taken by the sector to offset emissions is important. This may involve offering publicly accessible information including monitoring of achievements and reports (on-line) on specific results obtained (e.g. on the amount of carbon sequestered using verified credits and on the specific areas where these credits were achieved).

[10] Of relevance here is the Climate Action Network; a network of NGOs working on climate change issues with some 1100 members in more than 120 countries.

6.3. COMPARISON OF FOREST CARBON CREDITS

In view of the need to consider the availability of carbon credits it seems improbable that a sufficient amount of forest carbon credits to offset a substantial share of emissions from the European refining section or road transport can be traced from European forests. The total number of certified voluntary European forest credits that is currently being brought to market amounts to less than 4 Mton CO_2.

It may well be that the ESR increases the future demand for credits generated in the EU forest and agricultural sectors, and thereby provide the incentives to also increase supply of these credits. Yet a critical issue remains the baseline, in particular in Europe where the trend in most countries is towards an increasing forest cover and emissions for reduced deforestation cannot be claimed. Hence, all EU forest carbon credits need to come from planting forests in currently not-forested areas, which is likely to be expensive and for which only limited land may be available in most European countries. Prices and quantities that would become available, over time, are hard to predict. Overall, given the small voluntary market volumes currently available and the inherent constraints to EU forest carbon credits, they are not very promising as a specific investment option for the refining and or road/transport sector at this point in time.

Table 8 presents a comparison of the scoring of the four options open to obtain international (i.e. outside of EU) carbon credits for the refining and road transport sectors, based on the criteria specified in the previous section. In addition to CDM credits (which include two types, i.e. with and without Gold Standard), and credits purchased on the voluntary market, the option 'Development of own credits' is added. This involves working with specialised companies to develop new credits. This option provides more opportunities to select offset types and locations, and may lead to offsets at lower prices. However, more time is needed, it may take between 1 to 3 years to develop a (forest) carbon project from scratch. The option is also added to show the fall-back position in case there is a sudden, steep increase in demand for credits, for instance in case the aviation industry starts requiring credits as of 2020 in order to offset growth in CO_2 emissions related to a growth in international airline traffic (as seems likely based on currently available information).

Table 8 Comparison of options to offset carbon emissions - general ranking with precise scores in all categories dependent upon the individual project

	CDM credits offered through the Climate Neutral Now initiative - regular	CDM credits offered through the Climate Neutral Now initiative – Gold Standard	Credits purchased on voluntary market	Development of own credits
Additionality	-	+ +	+ +	+ +
Leakage	depending upon project	+	+	+
Acceptability	0 [/1]	++ [/1]	++	++ (in particular if verified with Gold Standard or CCB)
Costs	1-5 euro/ton CO_2	3-5 euro/ton CO_2	3-10 euro ton CO_2	2.5-5 euro/ton CO_2 (potentially)
Timing	+		++	-
Availability of credits	++	-	+	++

1/ An advantage of using the Climate Neutral Now is that four other companies have chosen this pathway; a disadvantage is the lack of additionality and that some NGOs are critical of the CNN except when gold standard credits are used. Also it is not sure if new CDM credits will be offered in the future because the Kyoto protocol will only remain in place until 2020, and discussions on new mechanism that could replace CDM in the context of the Paris Agreement are still ongoing (and may take several years to conclude).

6.4. RECOMMENDATIONS AND POTENTIAL OPTIONS TO EXPLORE

Based on the analysis conducted in the previous chapters and sections in this chapter, the following tentative options for exploring the use of carbon offsets in the downstream sector can be provided, as a basis for further discussion.

With regards to the type of credits to be considered. It is recommended to not prioritise exploring the use of CDM CNN carbon credits ('CERs'), in spite of the use of this mechanism by four companies. The reasons are as follows. First, there is at present too much uncertainty surrounding the future of CDM CNN credits; it is unclear if CDM as an instrument will still exist beyond 2020 when the Kyoto protocol ceases functioning. Second, additionality is unproven for part of the CERs, and further screening by the sector is required to select credits that are additional including the Gold Standard CERs. This is likely to be a complex process, and may also lead to a low volume of qualifying CERs (CERs with gold standard currently available are at most around 1 or 2 Mton CO_2e, and do not include any forest carbon projects). Third, there is remaining debate in civil society on CDM credits (except gold standard CERs) and the use of these credits to offset emissions in the refining or fuel sector may be receive a sceptical response by NGOs. Hence, it is recommended to, for the time being, only consider certified credits in the voluntary market. Whereas the Gold Standard credits may be prioritized in order to align the offsetting strategy with NGO interests, there are insufficient number of Gold Standard credits available, and the use of VCR credits is required. These credits are undergoing a sufficiently thorough verification to be assured of additionality (including limited leakage and permanence), in particular when combined with the CCB standard (in the case of forest carbon projects). However there have been cases where VCR certified projects have received a negative press and it is recommended to still pursue an internal screening if VCR credits were to be purchased.

With regards to the type of projects to consider in purchasing offsets. First, it needs to be noted that the current supply of forest carbon (or other) offsets from Europe is insufficient to satisfy any substantial demand from the refining or fuel sector. The potential inclusion of emission reductions in LULUCF generated in the EU in the ESR post 2020 would increase the demand for such credits (and consequently also supply), but would not necessarily increase the amount of credits available under the voluntary market (where prices are in general lower than on compliance markets). Forest carbon credits are at the moment among the most popular credits among buyers in view of the co-benefits they generate, and the surplus of unsold credits seems to be a little lower than for other projects. World-wide, the short-term availability of forest carbon credits can be estimated at 15-25 Mton CO_2e, and the total (forest + other types) short-term availability of verified credits in the voluntary market at around 65-95 Mton CO_2e. Yet, forest carbon credits are potentially the most relevant for the sector, given (i) the possibility to substantially scale up the development of new forest carbon credits; (ii) the absence of credible alternatives at sufficient scale, with the exception of wind energy which may have a future challenge in demonstrating additionality (as discussed in Section 6.2); and (iii) the co-benefits that forest carbon credits generate (e.g. biodiversity conservation, which may support marketing of products for which emissions are offset). In the case of a pilot project, it could also be relevant to consider projects generating carbon offsets in peat, such as the Permian Katingan project (around 12 Mton CO_2e) in view of the large carbon reservoir of tropical peatlands, their potential to use them for carbon offset projects and the biodiversity co-benefits that they provide. Permian has not provided any indication of the potential price of the credits, but the costs for developing the credits could be estimated at around US$ 3 to 5 (based on initial CBAs of the author of comparable projects in the same area).

With regards to offsetting in the refining industry. It is important to note that the refining section is regulated by the EU ETS. Carbon credits on the voluntary market cannot be used in the ETS. Hence, voluntary carbon markets can only be used to go beyond emission reductions required under the EU ETS. An issue is that, if this strategy is pursued, first carbon emission allowances have to be purchased in the ETS (in addition to allowances that are allocated for free to the sector). Voluntary carbon credits could then be purchased to offset the same emissions. In this way the sector would pay twice for the same carbon emissions (once to ETS and once for voluntary carbon credits that are not recognised in the ETS). In addition, there would be a need to look at the volume of credits on the market in relation to the carbon emissions from the refining sector. The European refineries emitted 115.3 Mton CO_2e in 2014. This is more than the volume of carbon credits currently brought to the voluntary market on an annual basis. Hence, this option would need to involve either offsetting the emissions only of a part of the sector, or working with specialised agencies to increase the supply of carbon credits to the market over time.

With regards to offsetting emissions in road transport. Emissions from road transport in the EU exceed by a factor 8 the amount of credits currently available on worldwide voluntary market (but are in the same order of magnitude as the offsets that would be required by the aviation sector's CORSIA initiative to offset emissions from international flights if this would materialise). A concrete option that could be examined in this context is if a 'carbon-neutral petrol' could be offered to customers. This option involves offering petrol and diesel at retail stations (potentially at a separate 'green' pump) for which carbon emissions (Well-to-Wheel) would be offset using forest carbon, at a cost of around 1.5 to 3 cent per litre. This could be an alternative for electric vehicles, at relatively low cost to the customer (and at potentially little cost to the sector). This carbon-neutral petrol would need careful marketing. For example, a general principle in environmental mitigation is that first impacts are avoided where possible, second impacts are reduced, and third (the residual) impacts are offset. Hence, a company interested in testing carbon neutral fuel may consider demonstrating that energy efficient processes are used to produce the fuel (i.e. impacts are avoided and reduced where possible, and offsets are used for residual emissions). In addition, it is important that carbon emissions are offset using independently verified credits that also generate local benefits. It may be recommendable to consider prior engagements with selected NGOs in order to launch such a product, and to start at a small scale in a specific country. In terms of technical management of flows, it is accepted in the case of supplying carbon neutral electricity that electricity generated from renewable sources is mixed with other types of electricity by utilities (and that there is a certain amount of offsetting of emissions in the case of carbon neutral electricity supply), which offers a precedent for such a products. This option is further clarified in Box 1 below.

Carbon credits from voluntary carbon markets including carbon credits developed outside of the EU are likely not to be eligible for the ESR, and will therefore not necessarily count towards the efforts that EU member states need to pursue to reduce greenhouse gas. Especially if there is transparent reporting on carbon benefits and co-benefits generated by such credits to customers, this may provide an additional motivation for customers to purchase carbon neutral petrol. If their purchase of carbon neutral effort would count towards ESR efforts, they may have the feeling that their government needs to do less effort to reduce carbon emissions because of their purchase of carbon neutral petrol (in other words, the additionality of their action is larger since voluntary carbon credits purchased to offset emissions from driving a car are not included in the ESR).

With regards to the timing of activities. At the moment, the carbon market is a buyers' market. There is likely to be room for negotiation in prices, and project developers may be interested in committing to scaling up activities to generate offsets under favourable conditions. This would change if the CORSIA will go ahead as currently suggested, when markets may anticipate a fast increase in demand for voluntary credits as of 2020 onwards.

With regards to suitable pilots. If it were to be considered to test the offsetting approach in terms of how customers and regulators would view using offsets in the Downstream sector, there are several pilot projects that generate substantial amounts of carbon (>5 Mton CO_2e, at low costs (less than 4 euro per ton CO_2) and that generate important co-benefits and have low risks related to permanence or additionality. Starting with such projects may open the way for building acceptance of the approach. An example of such a project is the Permian Katingan project (where the NGO Wetlands International acts as technical advisor). This project has an estimated 10 Mton CO_2 offsets for sale in the coming two years, enough to compensate CO_2 emissions in 3300 million litre fuel. However it may be advisable to purchase credits from a basket of projects in order to spread risks that projects wouldn't deliver on the credits. It could also be considered to establish a specific agency at arm's length of the sector in order to purchase offsets at an amount equivalent to the amount of CO_2 emitted from carbon-neutral petrol. Such an agency could allow full transparency in transactions conducted, and could enhance credibility by working together with specific environmental NGOs.

BOX 1 CARBON NEUTRAL PETROL

A potential option to explore is if 'carbon-neutral' petrol can be offered at retail stations in order to meet consumer demand for such a product. A case would need to be built that the product is delivered through Best Available Technology (i.e. most energy efficient) refining in combination with offsetting residual carbon emissions. This option could be attractive from a marketing point of view, i.e. by offering customers a new product: driving their car while offsetting CO_2 emissions (and while avoiding some of the auxiliary environmental impacts of battery driven electric vehicles). This is similar in approach to the sale of 'green' natural gas to households in the Netherlands by various utilities, which involves offsetting, using carbon credits, the emissions resulting from the use of the natural gas.

The costs of offsetting residual carbon emissions of petrol can be estimated to range from 1.5 eurocents per litre (when credits can be purchased for on average 5 euro/ton CO_2) to 3 eurocents per litre (assuming carbon credits can be purchased for on average 10 euro/ton CO_2). Offering this product to customers would not involve major changes to the supply chain, since, as in the case of 'carbon neutral electricity' supplied to households in the EU it can be argued that the environmental benefits of the sold product can be attributed to the sold product even if it enters the supply chain mixed with regular (i.e. not carbon neutral) petrol.

The table below presents a first indication of the potential availability of international voluntary forest carbon credits and the amount of petrol for which emissions can be offset. Note that the availability of credits is in part driven by the creation of demand for carbon credits and realising the potential will require working with carbon project developers.

Year	Indicative availability of global forest carbon credits (million ton CO_2 credits)	Litres of fuel for which emissions can be offset with forest carbon credits (million litres)
2017	20	6,640
2018	25	8,300
2019	30	9,960
2020	50	16,600
Post 2020	>100	At least 33,200

7. GLOSSARY

BAT	Best Available Technology
CAEP	Committee on Aviation Environmental Protection
CCB	Climate Community and Biodiversity carbon credit standard
CCX	Chicago Climate Exchange (carbon market)
CDM	UN Clean Development Mechanism (based on the Kyoto Protocol)
CER	Certified Emission Reductions (certified under the CDM mechanism)
CNN	Climate Neutral Now initiative of the United Nations Climate Change secretariat
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
EUA	European Allowances (to emit carbon dioxide)
ESR	Effort Sharing Regulation (proposed by the EU Commission as part of its strategy to participate in the Paris Agreement)
ERU	Emission Reduction Unit certified by the Joint Implementation mechanism
ETS	Emission Trading Scheme
GMBM	Global Market-Based Mechanism (part of aviation strategy to reduce GHG emissions)
GHG	Greenhouse Gas Emissions
Gold Standard	Carbon standard proposed by a number of environmental NGOs
ICAO	International Civil Aviation Organization
JI	Joint Implementation mechanism (part of the Kyoto Protocol)
LULUCF	Land Use, Land-Use Change and Forestry
Mton	Megaton or million ton
NEP	Net Ecosystem Productivity (gross carbon sequestration in ecosystems, with net carbon sequestration equal to NEP – carbon losses due to fires, peat oxidation and biomass removal)
NPP	Net Primary Production (sequestration of carbon in plant biomass)

REDD Reducing Emissions from Deforestation and Forest Degradation

VCS Verified Carbon Standard (for quality assurance of carbon credits)

APX Registry for carbon credits

Markit Registry for carbon (and other environmental) credits

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