What does the Paris Agreement mean for climate policy in the Netherlands?

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NEW CLIMATE INSTITUTE

September 2016

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Project number
16040

commissioned by Stichting Greenpeace Nederland

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Samenvatting in het Nederlands

Het in december 2015 aangenomen Parijsakkoord eist van ieder land ambitieuze maatregelen om te zorgen dat de door het broeikaseffect veroorzaakte opwarming van de Aarde ver onder de 2°C blijft, en om te streven naar een opwarming van maximaal 1.5°C. Dit is in lijn met wat de klimaatwetenschap ons leert over de vereisten om potentieel desastreuze gevolgen voor de leefomgeving te voorkomen.

In deze korte analyse vertalen wij de globale ambitie van het Parijsakkoord naar concrete, sector-specifieke doelen die toepasbaar zijn op de Nederlandse context. Dit is gedaan door voorspellingen en projecties van de ontwikkelingen van relevante indicatoren uit verscheidene gezaghebbende bronnen te vergelijken met de vereisten voor het behalen van de langetermijndoelen van het Parijsakkoord.

Kernbevindingen

Om in lijn te blijven met de langetermijndoelstellingen van het Parijsakkoord, en de grotere verantwoordelijkheid van rijke landen om broeikasgasuitstoot te verminderen in beschouwing nemend, moet Nederland een transitiepad inslaan waarin **alle energie- en industrie-gerelateerde CO_2-uitstoot tussen 2025 en 2035, d.w.z. binnen 20 jaar, tot nul daalt**. Op sectoraal niveau betekent dit dat:

- ...dat tegen 2025 – 2035 **100% van de energievraag** door duurzame bronnen moet zijn gedekt;
- ...dat uiterlijk in 2025 **100% van de elektriciteit** door duurzame bronnen moet worden geproduceerd. Dit omvat o.a. dat **alle kolencentrales uiterlijk in 2020 zijn uitgezet**;
- ...dat het **wagenpark van personenauto's** tussen 2025 en 2035 **geheel moet komen te bestaan uit elektrische voertuigen** (aangedreven door duurzame stroom, gerelateerd aan de eis hierboven) of andere vormen van nulemissievoertuigen, en **uiterlijk in 2025 alleen nog nulemissievoertuigen verkocht mogen worden**;
- ...dat het **aandeel van gas** in de vraag naar warmtevoorziening in de **gebouwde omgeving** van haar huidige niveau van meer dan 90% tot nul moet worden gereduceerd tussen 2025 en 2035, en de warmtevoorziening steeds meer gedekt moet worden door stadsverwarming en lucht- en bodemwarmtepompen, waarbij ook een hoge renovatiegraad van gebouwen wordt behouden om te zorgen dat deze voldoen aan de hoogste isolatie- en efficiëntiestandaards;
- ...dat de **industrie** de hoogstmogelijke efficiëntie- en productiestandaards moet volgen (mogelijk met technologieën voor CO_2-afvang en -opslag), **en meer ambitie moet tonen** in het vinden van nieuwe methoden om efficiëntie te verhogen;
- ...dat de uitstoot van CO_2 in de **landbouw**, met name door **broeikassen**, tot nul moet worden teruggebracht tussen 2025 en 2035, door aan de energievraag te voldoen met duurzame bronnen (zoals boven vermeld) of ingrijpende krimp van de glastuinbouwsector;
- ...dat op de langere termijn maatregelen moeten worden genomen om de uitstoot van **methaan en lachgas in de landbouw** te verminderen en tot nul terug te brengen tegen 2080-2085.

Als de opwarming van de Aarde tot gemiddeld 1.5°C – 2°C beperkt moet worden, mag de mondiale broeikasgasuitstoot een zeker "CO_2-budget" niet overschrijden. Een groot deel van dit budget is echter al verbruikt: als de mondiale uitstoot van 2014 wordt doorgezet, zal het binnen 10-20 jaar op zijn. De cumulatieve uitstoot in de rest van deze eeuw is dus doorslaggevend voor het bereiken van het temperatuurdoel. Het idee van een CO_2-budget laat weliswaar in theorie toe dat 'negatieve emissies' – d.w.z. het grootschalig verwijderen van CO_2 uit de atmosfeer, bijv. met biomassa – de eisen aan uitstootvermindering versoepelen, maar dit zou een gok zijn op de toekomstige beschikbaarheid van de nodige technologieën en de enorme hoeveelheid land die nodig is voor de productie van biomassa. Op dit moment zijn negatieve emissies technologisch noch economisch haalbaar. Gezien de wetenschappelijke consensus m.b.t. gevaren van klimaatverandering, kan het als onverantwoord gezien worden om op opties te vertrouwen die nog niet haalbaar zijn. Hierdoor benadrukken wij in dit rapport de vereisten aan uitstootvermindering zonder negatieve emissies als optie in beschouwing te nemen.

Summary in English

The Paris Agreement, adopted in December 2015, calls for increased ambition by all nations worldwide in order to limit global warming to well below 2°C above pre-industrial temperature and to pursue efforts of limiting it to 1.5°C. This would be in line with what climate science tells us is needed to avoid potentially catastrophic environmental consequences.

In this short analysis, we translate the global ambition of the Paris Agreement into concrete sectoral targets applicable to the Netherlands. This is done by comparing projected pathways of climate-relevant indicators from various authoritative literature sources to what would be needed in order to be compatible with the Paris Agreement's long-term goals.

Key messages

In order to be compatible with the long-term goals of the Paris Agreement, while at the same time taking into account rich countries' responsibility to reduce greenhouse gas (GHG) emissions faster than the world average, the Netherlands needs to embark on a pathway that ensures that **all energy- and industry-related CO_2 emissions are reduced to zero by 2025-2035** – i.e. within the next two decades. On a sector-specific level, this means

- …that **100% of energy demand** should be covered by renewable sources by 2025 – 2035;
- …that **100% of electricity generation** has to come from renewable sources at the latest by 2025. This includes a **complete phase-out of coal latest by 2020**;
- …that the **total personal vehicle fleet** should come to consist of **100% electric vehicles**, or other forms of zero-emission vehicles, between 2025 and 2035 (along with a decarbonized power sector as above), and that new sales of personal cars are 100% zero-emission at the latest by 2025;
- …that the **demand for gas for heating in residential and commercial buildings** must be reduced from its current levels of more than 90% of demand to zero between 2025 and 2035, shifting the supply towards district heating and/or air and ground heat pumps, while maintaining a high renovation rate for buildings to ensure high insulation and energy efficiency standards;
- …that **industry** has to comply with the highest possible energy efficiency and emission intensity (possibly using carbon capture and storage technology) and production standards and **improve its efforts** to find ways of increasing efficiency beyond what is currently possible;
- …that CO_2 emissions from **agriculture**, in particular from the **greenhouse sector**, should be reduced to zero between 2025 and 2035, by shifting to renewable sources (as per the energy demand target mentioned above) or by radical shrinking of the greenhouse sector;
- …in the longer term, that measures need to be introduced to reduce the **non-CO_2 emissions from agriculture** (methane and nitrous oxide) to zero by 2080-2085.

If global warming is to be limited to 1.5°C – 2°C, worldwide GHG emissions must not exceed a certain "CO_2-budget". A large part of this budget has, however, already been exhausted: if the world keeps emitting at 2014 levels, the budget will be spent within 10-20 years. The cumulative emissions of greenhouse gases in the rest of this century are thus the decisive factor for achieving the temperature goals. The concept of a "CO_2 budget", in theory, allows for the possibility of using 'negative emissions' – i.e. large-scale removal of CO_2 from the atmosphere, e.g. through biomass – in order to relax the requirements on emission reduction efforts. However, this would constitute a bet on the necessary technologies, as well as enormous amounts of land to produce biomass, being available in the future. Negative emissions are neither technologically nor economically feasible at the moment. Given the scientific consensus on the risks of climate change, it can be seen as irresponsible to rely on currently unavailable options. In this report, we therefore emphasize the requirements on emission reductions without taking negative emissions into account as a viable option.

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1. Introduction

The Paris Agreement of December 2015 is considered to be a major success in international climate negotiations. It is the first time that an international climate treaty contains national emission reduction targets and measures from close to 200 countries. The Paris Agreement is centred around two long-term goals:

1) **The long-term temperature targets:** The Paris Agreement aspires to keep global warming "well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C" (UNFCCC 2015b).
2) **Net zero emissions:** in order to reach the temperature targets, global emissions of greenhouse gases (GHGs) should decrease as fast as possible, such that they reach "net zero" in the second half of the century (meaning that sources do not produce more GHGs than is removed by sinks). As per the Paris Agreement, "In order to achieve the long-term temperature goal (...) parties should aim to reach global peaking of greenhouse gas emissions as soon as possible (...) and undertake rapid reductions (...) so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century") (UNFCCC 2015b).

The Paris Agreement also calls for ambitious, nationally appropriate actions. Accordingly, almost all countries have put forward intended nationally determined contributions (INDCs) that define each country's measures and targets for emission reduction. However, current assessments of countries' INDCs indicate that, if implemented, they would fall short of the long-term temperature targets (UNEP 2015; Rogelj et al. 2016). Countries will thus need to enhance their ambition in line with the Paris Agreement's goals and in line with what is nationally appropriate.

In this report, we translate the global ambition of the Paris Agreement to the policy context of the Netherlands. As an EU member state, the Netherlands' long-term INDC goal is an 80%-95% reduction of GHG emissions by 2050. However, this target is based on 2°C compatibility (den Elzen & Höhne 2008), which the Paris Agreement goes much beyond. Thus the ambition gap is large: The Netherlands has signed the Paris Agreement, whose goals cannot be reached with the INDC. As climate change is likely to have potentially significant impacts on the Netherlands, i.e. through rising temperatures, changing rainfall patterns, and sea level rise (KNMI 2015), it can be seen as in the national interest to contribute to global climate ambition with stronger action for emission reductions in line with the Paris Agreement.

We present here concrete sectoral goals for the Netherlands that are in line with the Paris Agreement. The analysis has been done by comparing projected pathways of climate-relevant indicators from various authoritative literature sources, which take into account possible future developments in policy and technology, with what would be needed for the Netherlands to remain consistent with the Paris Agreement's long-term goals.

In chapter 2, we describe global emission scenarios compatible with the long-term temperature goal of the Paris Agreement, and how these can be applied to the Dutch context. In chapter 3, we describe sector-level developments, expectations, and possible future pathways for various policy-relevant indicators and their progress towards compatibility with the Paris Agreement. This provides a roadmap on sector-level for the Netherlands of the degree by which ambition has to be increased in order for the Netherlands to do their part in ensuring the Paris Agreement's ambitions can be achieved. Chapter 4 gives a concise overview of the findings. Finally, elaborations on the consulted literature are given in the Appendix.

2. Global and national climate ambitions

2.1 By when do global emissions need to reach zero?

While the Paris Agreement and its preparation process have raised the global long-term ambition for climate change mitigation and GHG emission reduction, the current level of national action under the Paris Agreement is still not in line with the agreed global long-term goals.

In this section, we briefly describe the results from the Climate Action Tracker project[1], which combines results from (inter)national studies with own estimates of the effect of the latest implemented policies on emission reductions. The expected future GHG emission levels are used to calculate the corresponding global temperature increase ranges using the simple carbon cycle-climate model MAGICC (Meinshausen, Raper, et al. 2011; Meinshausen, Wigley, et al. 2011; Hulme et al. 2000) in a probabilistic mode. The results are given in Figure 1.

The Climate Action Tracker found that, without any climate policy, GHG emissions would increase further during the course of the century ("Baseline" in Figure 1). With currently implemented energy and climate policies in all countries, global GHG emissions would stabilize in the second half of the 21st century and lead to a temperature increase of around 3.6°C by 2100 ("Current policies" in Figure 1). With full implementation of INDCs by all countries as pledged by the Paris Agreement, global emissions could start to decline in the second half of the century and lead to a temperature increase of 2.7°C by 2100 (increasing thereafter) or lower, if the conditional INDCs are also taken into account ("pledges and INDCs" in Figure 1). However, in order to limit temperature increase to well below 2°C or to 1.5°C (lowest scenarios in Figure 1), much deeper emission reductions are needed.

A given temperature increase is basically determined by the cumulative GHG emissions during the course of the century, and a large share of the "carbon budget" corresponding to 2°C and 1.5°C of warming has already been used up. Therefore, many modelling scenarios assume that active removal of CO_2 from the atmosphere will occur in the second half of the century through creating negative CO_2 emissions by using Carbon Capture and Storage (CCS), mainly through the use of biomass (BECCS) (see Box 1 on negative emission technologies and BECCS).

In order to stabilise the climate, global greenhouse gas emissions eventually have to reach zero. The timeframe in which global emissions would have to reach zero generally depends on three factors: a) the temperature goal and the probability of reaching it, b) whether or not negative emissions are assumed or not, and c) the question which particular emissions and sectors are under scrutiny.

On the basis of modelled scenarios that *allow negative emissions*, global emissions of *all* greenhouse gases in *all* sectors would have to reach zero roughly by 2100 in order to stay within a "likely" (66%) probability of limiting temperature increase to 2°C, as shown in Figure 2. In order to limit temperature increase to 1.5°C with a "medium" (50%) probability, this timeline is moved forward roughly to 2070-2080 (Figure 2). Most 2°C scenarios used negative emissions to some extent, all scenarios that limit temperature increase to 1.5°C or below rely on negative emissions.

[1] www.climateactiontracker.org

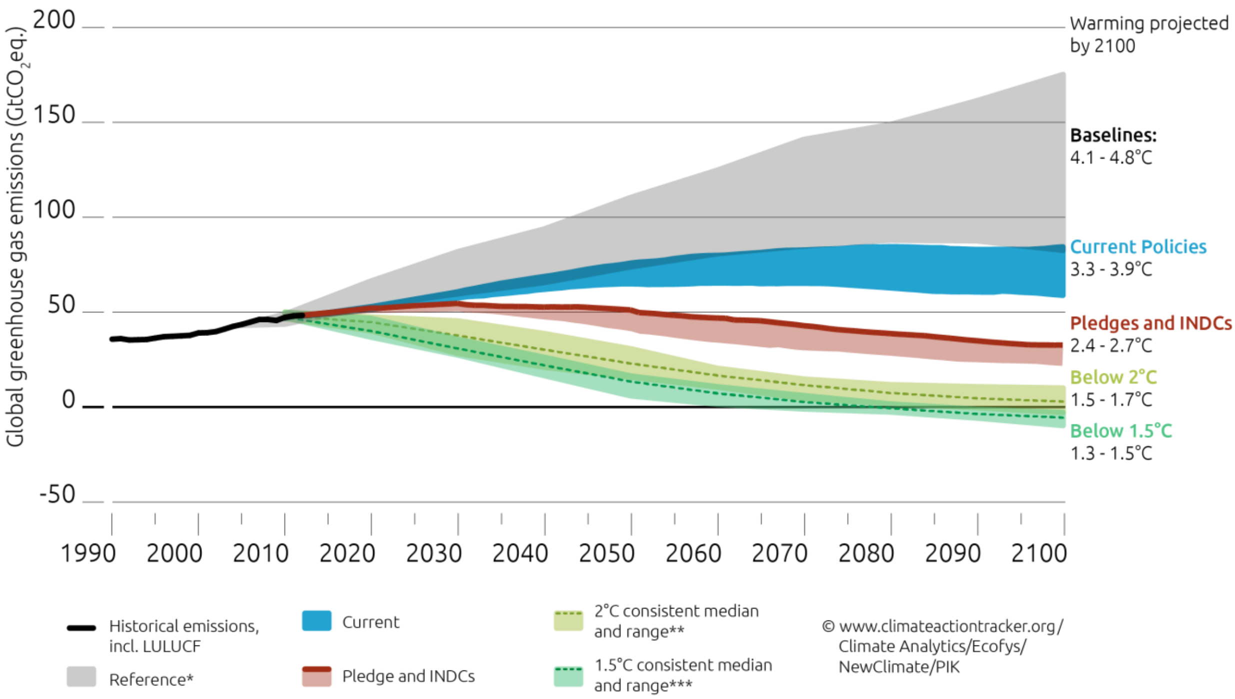

Figure 1: Global greenhouse gas emissions under different scenarios and resulting temperature increase by 2100 (Jeffery et al. 2015).
* 5%-95% percentile of AR5 WGIII scenarios in concentration category 7, containing 64% of the baseline scenarios assessed by the IPCC.
** Greater than 66% chance of staying within 2 °C in 2100. Median and 10th to 90th percentile range. Pathway range excluded delayed action scenarios and any that deviate more than 5% from historic emissions in 2010.
*** Greater than or equal to 50% chance of staying below 1.5 °C in 2100. Median and 10th to 90th percentile range. Pathway range excludes delayed action scenarios and any that deviate more than 5% from historic emissions in 2010.

The global modelling scenarios generally assume that emissions from energy production and use, as well as process emissions from industry (hereafter together referred to as “energy- and industry-related emissions”), can be reduced faster than CO_2 emissions from deforestation and non-CO_2 emissions from, for instance, agriculture and land-use. Therefore, energy- and industry-related emissions would have to be reduced to zero on an even shorter timeline. In order to stay within a “likely” (66%) probability of limiting temperature increase to 2°C, global energy- and industry-related CO_2 emissions would have to reach zero between 2060 and 2080 (median ca. 2065, Figure 2). For limiting temperature increase to 1.5°C with a “medium” probability (50%), energy- and industry-related emissions would already have to reach zero between **2050** and **2060** (median ca. 2055), as shown in Figure 2, and of course even earlier for higher probabilities.

If we *do not allow for the possibility of negative emissions*, an alternative pathway can be considered by assuming a linear decrease of the available CO_2 budget leftover for 2°C / 1.5°C compatibility from current levels. This gives a timeline for reducing CO_2 emissions to zero by roughly **2055** to keep warming below 2°C with 66% probability, and by **2035** to keep warming below 1.5°C with 50% probability (without distinguishing between energy- and industry-related CO_2 emissions and those from deforestation, see Figure 2). We elaborate on this approach in Box 2.

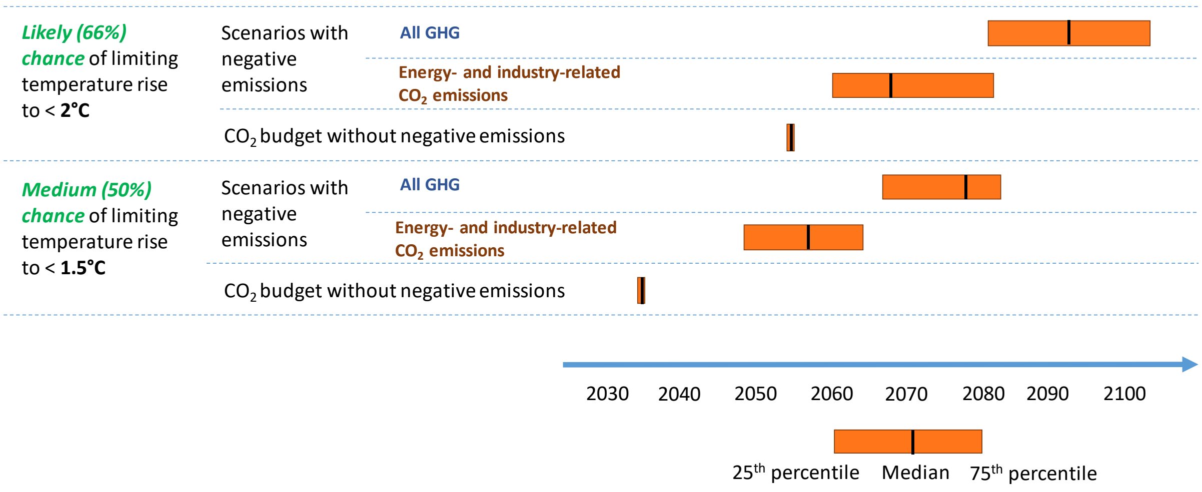

Figure 2: The ranges (25th to 75th percentile and median) in which emissions (all GHGs or energy- and industry-related CO_2 emissions) would have to reach zero in order to be compatible with a 66% chance of limiting warming to 2°C and a 50% chance of limiting warming to 1.5°C, respectively (Greenpeace & NewClimate Institute 2016; based on Rogelj et al. 2015).

The Paris Agreement calls for action to keep global warming to "well below 2°C" with efforts to "limit the temperature increase to 1.5°C". Thus, using 2°C as an upper bound is not in line with the Paris Agreement. In this report, compatibility with the Paris Agreement is therefore defined as being *in line with reducing emissions to zero in the timeframe between what is required for 1.5°C and what is required for "well below 2°C".*

We interpret the timeframe for "well below 2°C" as being the midpoint of the timeframe between 1.5°C with 50% chance and 2°C compatibility with 66% chance, a simplification that gives a clear indication of what would be needed to be truly in line with the objectives of the Paris Agreement. This is indicated schematically in Figure 3, assuming no negative emissions.

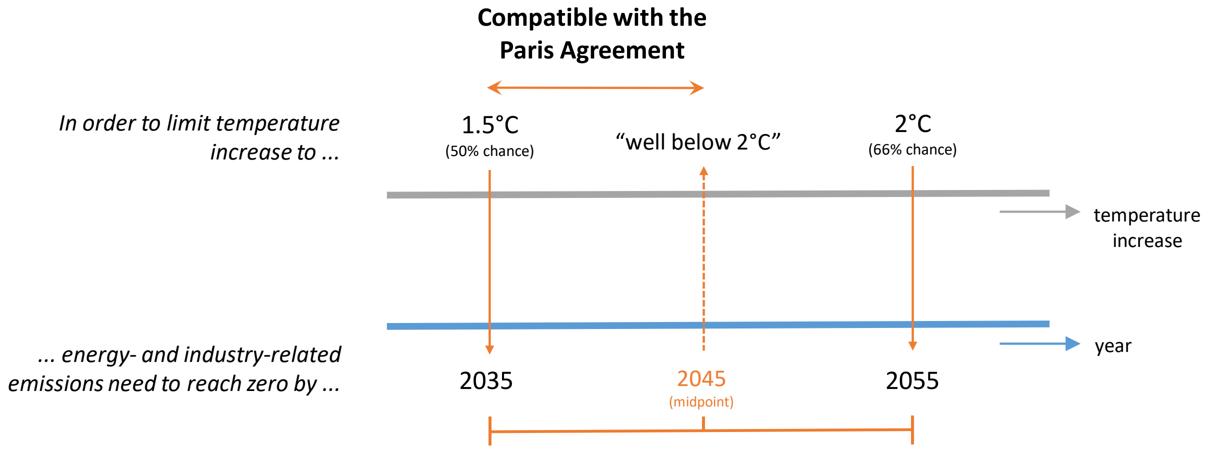

Figure 3: Schematic diagram showing the interpretation of the Paris Agreement's long-term goals as being between what is required for 1.5°C compatibility and "well below 2°C" compatibility (without negative emissions). The result is that global energy- and industry-related emissions need to reach zero between roughly 2035 and 2045.

Box 1: Negative emission technologies and BECCS

Negative emission technologies, or Carbon Dioxide Removal (CDR) as referred to in the 5th Assessment Report (AR5) of the IPCC, remove CO_2 from the atmosphere and store the carbon in land, ocean or geological reservoirs. Various methods can be considered as negative emission technologies. Examples include reforestation and afforestation, soil carbon management, ocean carbon sequestration, bioenergy combined with carbon capture and storage (BECCS), and direct air capture.

Among these methods, BECCS is considered by many modelling studies to play a crucial role in keeping the global temperature increase within 2°C or 1.5°C because it is considered to be more cost-effective than other negative emission technologies. The concept of BECCS is that vegetation growth removes CO_2 from the atmosphere, and store that carbon contained in bioenergy products underground (CCS). Examples of BECCS include not only biomass-fed power plants but also industrial plants such as bio refineries or biochar-fed blast furnaces. In this way, CO_2 emissions that would lead to a temperature increase of well over 2°C, if they stay in the atmosphere long enough, could theoretically be removed from the atmosphere and stored back underground in the future, thus lowering the actually occurring temperature increase.

The magnitude of BECCS in 1.5°C-compatible emission scenarios can be quite large, i.e. in the order of a few $GtCO_2$ to tens of $GtCO_2$ in the second half of the century. Emissions as much as those of the US or China would have to be buried underground every year. However, this is a very strong assumption as CCS is currently neither technologically nor economically feasible for deployment on the scales needed to be in line with these scenarios. Large-scale deployment of BECCS requires large-scale bioenergy production, and thus requires large land area. The bioenergy needed for BECCS could be roughly equivalent to 20% of today's global total energy consumption (Rose et al. 2014) plus additional bioenergy used for other purposes.

This would require enormous amount of land to produce bioenergy, leading to risks of deforestation and competition with food production for the nine to ten billion people who will be alive by then. To keep temperature increase *well below* 2°C, as agreed upon in Paris, even more bioenergy would be needed if that goal were to be met by BECCS.

Thus, relying on scenarios that reserve a role for BECCS is equivalent to betting on the fact that carbon-capturing will be technologically and economically feasible and a widely accepted practice by then.

Box 2: The logic of the carbon budget

For the phase out dates without negative emissions, we assume that global emissions decline linearly to zero until the budget is depleted (Figure 4). Considering that the leftover carbon budget is depleted linearly is, of course, a very simplified assumption. It is not meant to claim how actual emission pathways will go, but rather to give an idea of the timeline corresponding to phasing out emissions in line with different temperature goals. The graph below shows the timelines for keeping warming to <1.5°C with 50% (medium) chance and <2°C with 66% (likely) chance, where the surface area below the graph corresponds to the overall carbon budget left. The numbers are based on (Höhne et al. 2016), and the further analysis in this report is based on these.

These timelines can be extended by deviating from the linear carbon budget, but only if current ambition is increased massively, as the dashed line indicates. This line corresponds roughly to the same carbon budget as the grey area, i.e. for 50% (medium) chance of keeping warming to <1.5°C, but it requires emissions to be cut in half roughly by 2020, within the next five years. Extra time can thus only be bought through very deep, immediate reductions in emissions, in areas where solutions already exist – such as by removing coal from the power mix immediately and switching to renewable energy. This will buy extra time in the future to phase out emissions that are more difficult to reduce, for instance process emissions from industry.

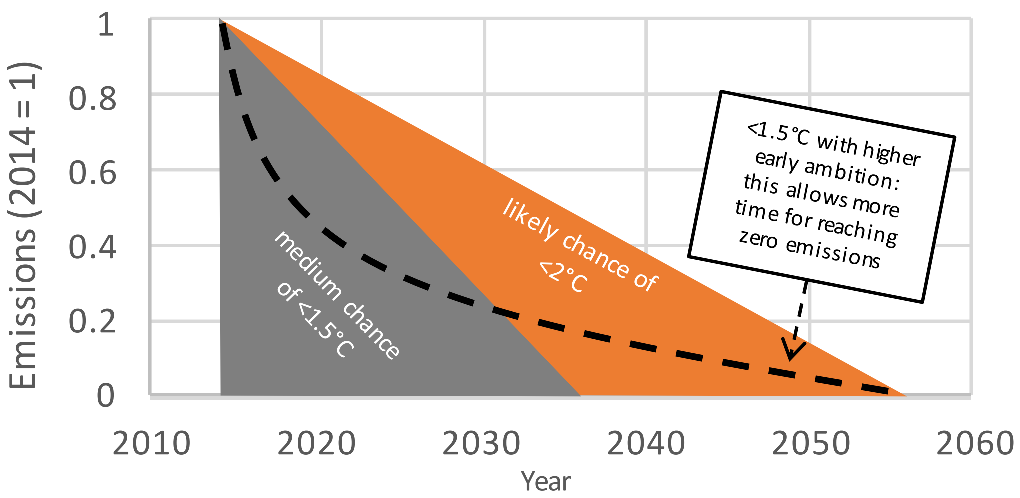

Figure 4: Illustration of the remaining carbon budget

2.2 What do global emission scenarios mean for the Netherlands?

2.2.1 Responsibility as developed country

Global emission scenarios do not show how efforts in reducing emissions should be divided between developed and developing countries. The Netherlands, as a developed country, have a large responsibility for reducing emissions fast, in order to give developing regions more "breathing space" as they continue to grow. There are a number of reasons for this:

- The Netherlands has a historical debt to pay by taking on a larger burden in reducing emissions, as they have used up much more than their "fair share" of the carbon budget as compared to developing nations – the "polluter pays" principle;

- Emissions per capita in the Netherlands are much higher than in developing nations; thus, in order to be compatible with long-term temperature goals, a much higher responsibility for reducing present emission levels falls on its citizens;
- Developed economies are overall growing at much slower rates than developing nations, and it is thus more cost-effective to start reducing emissions in the former.

A simplified calculation based on least-cost scenarios shows that a developed country such as the Netherlands should bring its CO_2-emissions to zero at least about 10 years ahead of the world as a whole. We estimate here the range by which the Netherlands should be ahead of the global timeline by looking at the IEA World Energy Outlook's 450 (ppm) scenario (IEA 2015b), which is a proxy 2°C pathway based on least-cost scenarios for emissions from fuel combustion. A least-cost approach sees developed countries reducing emissions earlier than developing countries because their growth is assumed to be much smaller; thus, this "opens space" to developing countries to continue to grow. We compare the pathways of emissions globally with that of the OECD countries and see that the latter would need to reach a 40% reduction of emissions by 2030, whereas the global number only reaches this reduction by 2040, i.e. roughly **10 years later**. This is shown in Figure 5(a).

If we assume that the global pathway continues until it reaches zero in 2065, following the "likely below" 2°C pathway in (Rogelj et al. 2015), this difference of 10 years still applies a decade later as well, with OECD emissions being reduced by 60% by 2040 and global emissions reaching this level roughly in 2050. Thus, in this report, we take 10 years to be the rough timeframe by which the Netherlands (and other developed countries) should be ahead of global emission reductions required for pathways consistent with the Paris Agreement.

2.2.2 Faster action in the power sector

If overall energy- and industry-related CO_2-emissions have to be reduced to zero by a certain year, then an even higher ambition is needed in those areas where solutions for reducing emissions readily exist. For instance, the obvious solution for reducing emissions from power generation is by shifting to renewable energy, and some countries (i.e. Denmark) already source large amounts of power from renewables (The Guardian 2015c). Reducing all emissions from energy and industry to zero will require extra efforts, however, the knowledge on possibilities for reducing process emissions from heavy industries, for instance, is less advanced. We can compare the trajectory of overall emissions with that of emissions from electricity production, and more specifically from coal, from the same IEA scenario referenced above. As shown in Figure 5(b), emissions from power generation in OECD countries should be **roughly 10 years ahead** in terms of the extent of reduced emissions as compared to all fuel combustion-related emissions by 2040; and those from coal combustion for power even by **roughly 5 years more**.

Table 1 illustrates the timelines that have been employed in the following sections of the report to denote "compatibility with the Paris Agreement". Here, we have distinguished between scenarios in which negative emissions (i.e. through BECCS) are allowed and a scenario where they are not, both of which are explained in Section 2.1. This results in two time ranges, respectively one with and one without negative emissions as a possibility.

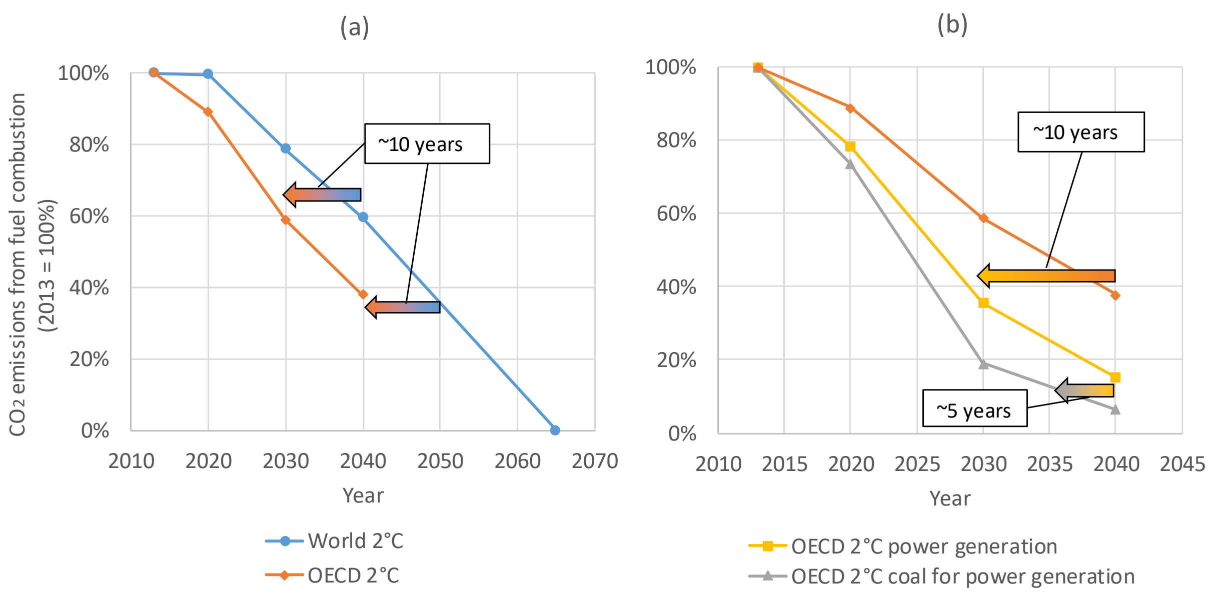

Figure 5: (a) According to the IEA WEO's 450 scenario, emissions worldwide from fuel combustion should be reduced by 40% from current levels in 2040, but those from OECD countries already by 2030. The same holds when extending the pathway up to the (median) point where global emissions would have to reach zero according to the scenario in (Rogelj et al. 2015). (b) The same scenario shows that emission reductions from power generation should also be ahead by roughly 10 years of overall energy-related emission reductions, and emission reductions from coal for power generation by another 5 years.

2.2.3 Current ambition in context

The historical GHG emissions in the Netherlands between 1990 and 2012 are presented in Figure 6. While total GHG emissions had decreased by 10% in 2012 from 1990 levels, this was mostly due to a reduction in non-CO_2 emissions; energy- and industry-related CO_2 emissions increased by 4% between 1990 and 2012. Therefore, it is of particular importance for the Netherlands to reduce its energy-related CO_2 emissions to achieve the long-term goals of the Paris Agreement. However, under current policies (ECN 2015), these emissions are not expected to decrease substantially by 2030, as indicated in Figure 6: only by about 13% below current levels.

A landmark climate liability suit in 2015, started by civil society organization *Urgenda*, resulted in the court ruling that the Dutch national GHG emission reduction plans of 14%-17% by 2020 compared to 1990 levels were unlawful (The Guardian 2015a). The court ordered the government to increase this to at least **25% by 2020** compared to 1990 levels. The emission chart in Figure 6 shows the reductions that would be needed to achieve this.

Since options for reducing non-CO_2 emissions are currently limited and emission reductions in this area have stagnated in recent years (see also Section 3.5), most of the action to meet the Urgenda verdict would have to come from reducing CO_2 emissions from energy and industry. As these emissions have hardly changed since 1990 up to now (Rijksoverheid 2015), the Urgenda verdict is basically equivalent to a reduction of CO_2 emissions from *current levels* by 2020, i.e. within 5 years, such that overall GHG emissions will be 25% lower as compared to 1990. This translates roughly to a 15% reduction of energy- and industry-related emissions between 2015 and 2020 if no further reductions in non-CO_2 emissions are assumed. This is schematically indicated in Figure 6.

The most ambitious interpretation of the Paris Agreement (warming below 1.5°C) means zero emissions have to be achieved by 2025 (Table 1); this would mean that, if the Urgenda verdict would be met, ambition would have to be ramped up substantially post-2020 to meet the objectives of the Paris Agreement. Thus, **the Paris Agreement clearly exceeds the Urgenda verdict in ambition.**

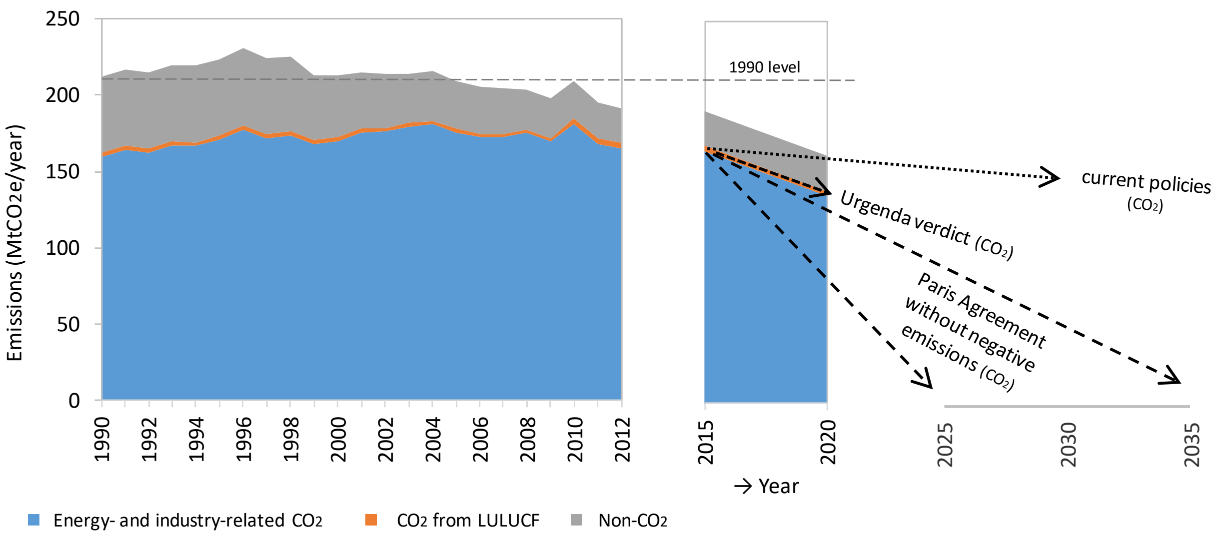

Figure 6: *Left*: GHG emissions in the Netherlands between 1990 and 2012 (UNFCCC 2015a). *Middle*: Linear emission trajectory from current values (ECN 2015, assuming constant LULUCF emissions) to the reduction pledge according to the Urgenda verdict, assuming all necessary reductions happen in energy- and industry-related CO_2. *Right*: Current policy projections do not foresee a marked change in emissions (ECN 2015). The ambition to decrease these CO_2 emissions would have to increase substantially post-2020, even if the Urgenda verdict would be met, to be in line with the Paris Agreement without negative emissions.

Table 1: An overview of the **median** years (rounded to nearest five) by which emissions of various types would have to reach zero, worldwide as well as in the Netherlands, to be compatible with proxies for the 1.5°C and 2°C temperature goals, plus the intermediate years used to define the timeframe for compatibility with keeping warming "well below 2°C" as per the Paris Agreement; see also Figure 2 and Figure 3.

Region	Emissions type	With negative emission technologies[2]			Without negative emission technologies			Notes and references
		< 1.5°C (50% chance)	"well below 2°C"	< 2°C (66% chance)	< 1.5°C (50% chance)	"well below 2°C"	<2°C (66% chance)	
		Compatible with the Paris Agreement			Compatible with the Paris Agreement			
Worldwide	Energy- and industry-related CO_2 emissions	**2055**	**2060**	2065	**2035**	**2045**	2055	With negative emissions: Rogelj et al. (2015); Without negative emissions: linear depletion of the carbon budget as in (Höhne et al. 2016).
Worldwide	All Kyoto gases	**2080**	**2085**	2090	Not estimated			Rogelj et al. (2015)
Netherlands	Energy- and industry-related CO_2 emissions	**2045**	**2050**	2055	**2025**	**2035**	2045	The Netherlands as a developed economy has a responsibility to reduce emissions faster than developing countries. Assumed 10 years ahead of the world average.
Netherlands	Electricity-related CO_2 emissions	**2035**	**2040**	2045	**2015**	**2025**	2035	CO_2 emissions from all energy use have to be zero by 2050-2060. Thus, electricity-related emissions should become zero even earlier, to allow extra time for phasing out other energy-related emissions.
Netherlands	CO_2 emissions from coal	**2030**	**2035**	2040	**2010**	**2020**	2030	Similar reason as above: coal should be phased out earlier than other fossil fuels.

[2] Negative emissions of a few to tens of $GtCO_2$ per year would be required in 2100, equivalent to the current annual emissions of the USA or China.

3 Actions for emission reduction by sector

3.1 Renewable energy

The official target for renewable energy in the Netherlands is 14% of final energy demand by 2020, and 16% by 2023, to eventually reach 100% in 2050 (Rijksoverheid 2016). The Netherlands are currently among the laggards in the European Union when it comes to deployment of renewable energy sources: only roughly 10% of electricity, and 6% of final energy use, is estimated to come from renewable sources. In fact, out of all EU countries, only two countries (Malta and Luxembourg) obtained a smaller percentage of final energy use from renewable sources than the Netherlands, and only five countries have targets for the share of renewable energy in 2020 less ambitious than the Netherlands (CBS 2014).

As shown in Figure 7, however, current policy projections foresee a marked increase in renewable sources of electricity – specifically from wind energy (mostly offshore) and solar PV – in the coming decades, which could lead to the share of renewables in electricity generation reaching close to 50% by 2030, and close to 20% in final energy demand, thus reaching the 2023 target. However, this is by far not enough to meet the demands of the Paris Agreement. In order to keep temperature increase to “well below 2°C” above pre-industrial temperatures, emissions from electricity would have to reach zero at the latest in 2025, and emissions from energy at the latest in 2035. The current policy development is seen to be not even in line yet with a 2.5°C – 3°C compatible scenario.

Total electricity generation from coal in the Netherlands has risen in the last years, mainly due to the operationalization of three new coal power plants since 2013 with a total capacity of 3,500 MW, and a combination of low coal prices and high gas prices. However, five coal power plants are slated to be shut down again by 2017, representing a capacity close to 2,700 MW (ECN 2015). This development is likely to have led to a peaking of electricity generation from coal in 2015, as can be seen in Figure 8.

In order to be compatible with the Paris Agreement goals, coal has to be phased out fastest of all fossil fuels. The Greenpeace Energy [R]evolution scenario for the Netherlands, for instance, includes a phase-out of coal already by 2020 (and of all fossil fuels except natural gas by 2050)[3]. This is precisely in line with the Paris Agreement, which requires that all coal power be phased out at the latest by 2020 if negative emissions are no option. **An immediate initiation of shutting down power production from coal** is needed.

However, current policy projections show that there is still a long way to go, with a 20% share of coal in electricity production forecast for 2030, not much different from what it was in 2000.

As shown in Figure 9, emissions from electricity and heat generation have to decrease substantially in the coming years in order to be compatible with the Paris Agreement. Looking at the graphs before, higher ambition in current policies is clearly needed in order to achieve progress towards what is required by the Paris Agreement. This highlights again the need to phase out coal as fast as possible, followed by other fossil fuels, and a simultaneous transition to renewable power.

[3] We note here that the Greenpeace Energy [R]evolution scenario for the Netherlands is based on the Global Energy [R]evolution scenario 2012 (Greenpeace International; EREC & GWEC 2012). The 2015 version of the latter is even more ambitious, but a version for the Netherlands has not been made yet.

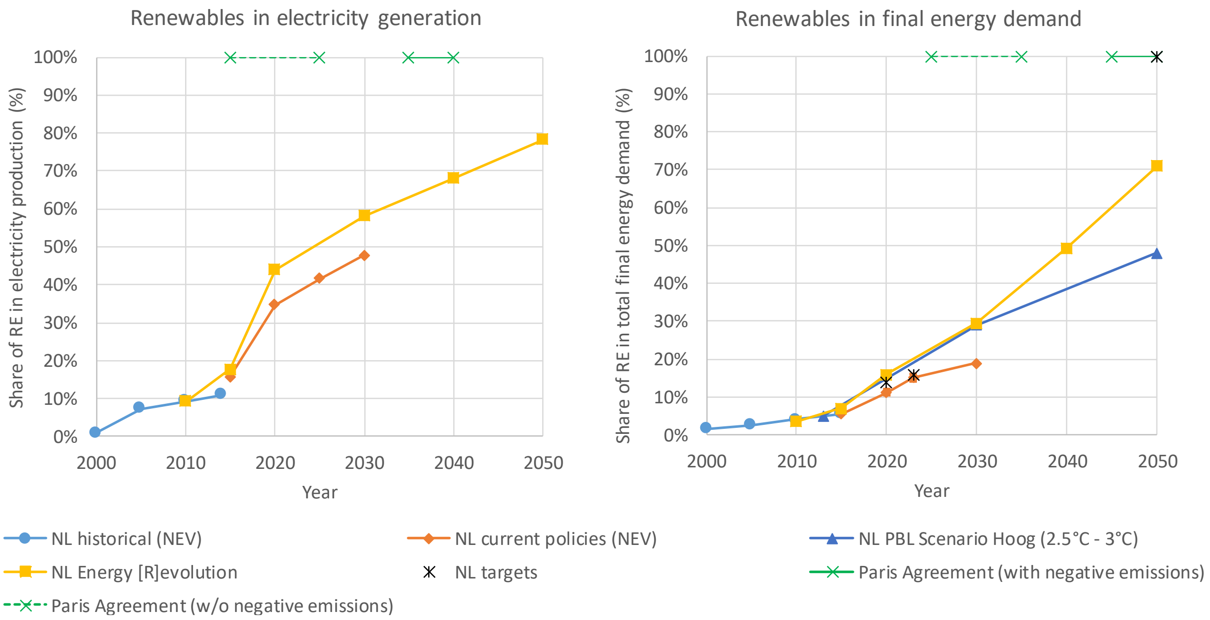

Figure 7: Historical (ECN 2015) and projected (ECN 2015; Greenpeace International & EREC 2013; CPB & PBL 2015) share of renewables in electricity generation (left) and in final energy demand (right) in the Netherlands. (NEV = Nationale Energieverkenning, see also Appendix).

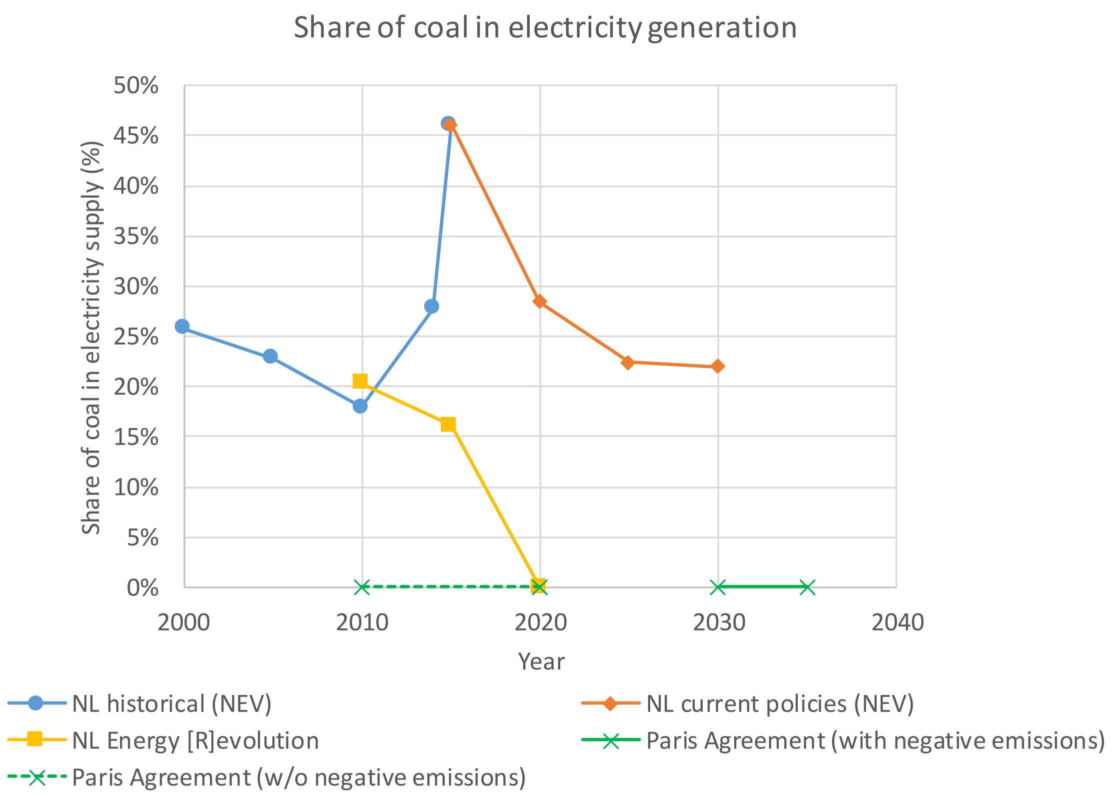

Figure 8: Historical (ECN 2015) and projected (ECN 2015; Greenpeace International & EREC 2013) share of coal in different scenarios for electricity generation in the Netherlands.

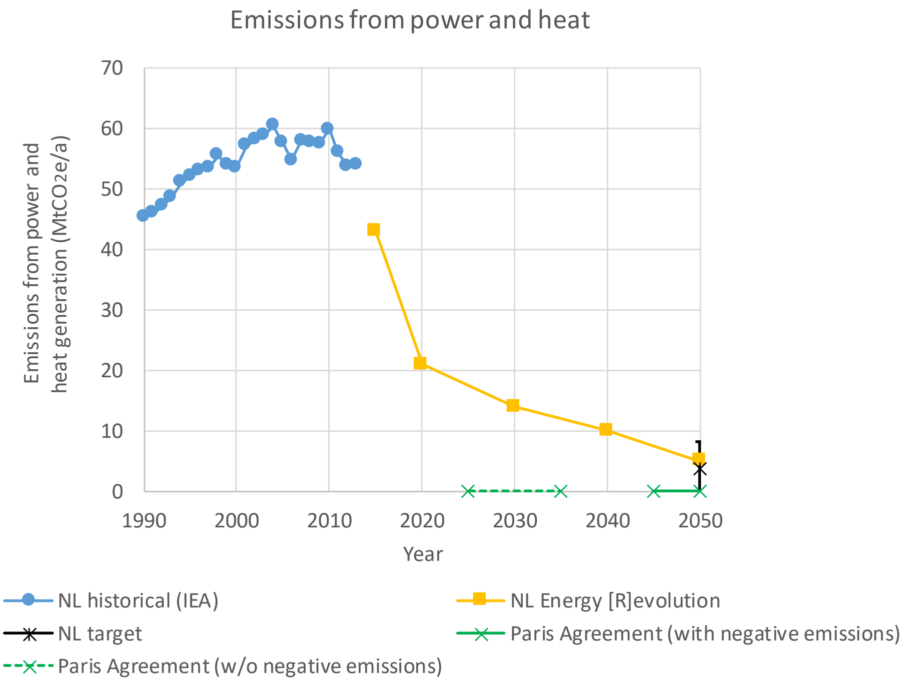

Figure 9: Historical (IEA 2015a) and projected (Greenpeace International & EREC 2013) emissions from power and heat generation in the Netherlands.

The results presented here also indicate the possible need for a large scale deployment of CCS. The Netherlands has 'theoretical CO_2 storage potential'[4] of total 1300 $MtCO_2$ by 2050 for North and West Netherlands with an annual storage capacity of about 30 $MtCO_2$/yr in 2030 and over 70 $MtCO_2$/yr in 2050 under the "Basis scenario" (EBN & Gasunie 2010). This theoretical potential is roughly 8-9 years equivalent of current annual energy-related and industry CO_2 emissions; this is not enough to serve as the backbone of the country's climate policy. Moreover, after taking into account technical, economic and legal constraints as well as the sink-source matching and public acceptance, the actual deployable potential will likely be significantly smaller and much of the deployable potential will not be available until after 2030. Furthermore, the CCS technology itself is highly contested in the Netherlands (e.g., van Egmond 2016), such that the feasibility of large-scale CCS deployment is unlikely.

One of the priority energy policy areas for the Dutch government may be to strengthen the comprehensive policy package to support renewables, in particular offshore wind power and decentralised renewable sources (International Energy Agency 2014).

3.2 Transport

The transport sector accounts for about 20% of the Netherlands' total energy-related CO_2 emissions (IEA 2015a). Transport activity is likely to increase substantially in the coming decades, with the size of the total passenger vehicle fleet being projected to rise by 10%-34% by 2050 compared to 2010 levels, and the number of vehicle-kilometres of passenger cars rising by 23%-58% in the same period. Use of public transport is also projected to increase correspondingly with higher demand for transport, with the modal split (share of personal traffic in total traffic excl. aviation and maritime transport) thus not likely to change significantly, at close to 80% of person-kilometres (CPB & PBL 2015).

[4] "Theoretical potential" equals "the total amount of CO_2 that can theoretically be stored in all the depleted gas fields based on a depth dependent CO_2 replacement volume of the ultimately recovered volume of natural gas" (Global CCS Institute 2014).

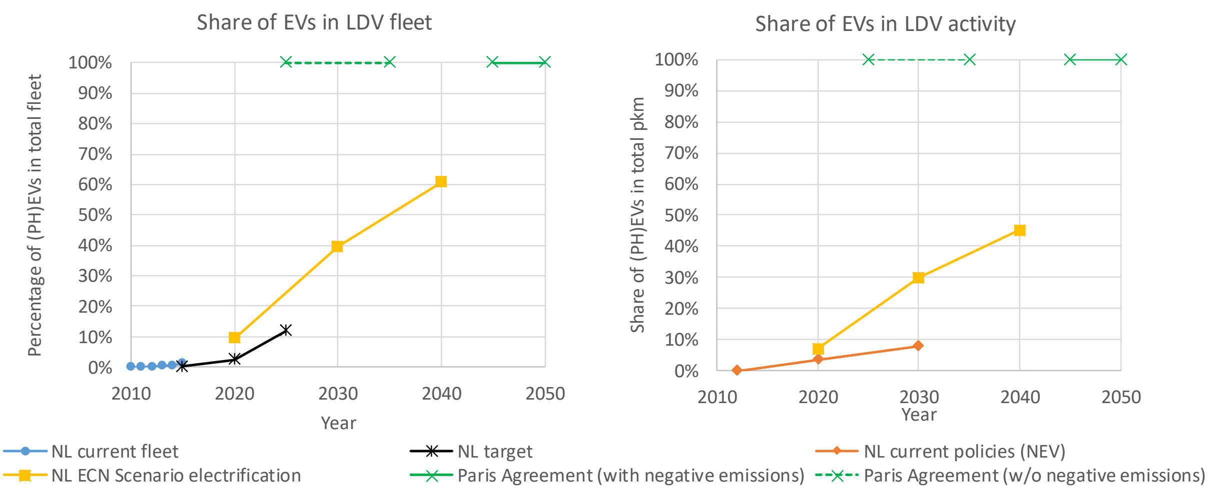

Figure 10: (left) The historical share of EVs (including plug-in hybrids) in the total LDV fleet in the Netherlands, plus the official target up to 2025 (RVO 2016), the ECN electrification scenario (ECN 2009), and the requirement for „well below 2°C“. (right) EV share in LDV activity according to current policy projections (ECN 2015), the ECN electrification scenario (ECN 2009), and the requirement for „well below 2°C“.

Thus, unless other options are found to greatly increase the attractiveness of public transport, the chief way of lowering emissions from the transport sector lies in decarbonizing the actual modes of transport. The Dutch government has in the past undertaken efforts in this direction, targeting 20,000 electric vehicles (full-electric vehicles as well as plug-in hybrids) on the road by 2015, 200,000 by 2020, and one million by 2025. The target for 2015 has been clearly surpassed, with more than 90,000 electric vehicles currently registered (RVO 2016), up from nearly zero in 2010. Nevertheless, this is still only roughly 1% of the total light-duty vehicle (LDV) fleet of the Netherlands (CBS 2015; RVO 2016).

Using projections for total fleet size in the period 2010-2050 (CPB & PBL 2015; CBS 2015), we estimated that the targets for electric vehicles translate to roughly 12% of the total passenger car fleet by 2025. This is indicated in Figure 10. An electrification scenario from ECN (ECN 2009), consistent with reducing total emissions from transport by 30% between 2010 and 2040, suggests that electric vehicles would have to constitute more than 60% of the fleet by 2040. In order to have zero emissions by 2025-2035, as required at the latest for compatibility with the Paris Agreement, the fleet would have to be 100% electric by that time.

Due to the generally short distances, flat terrain, and high population density, it is said that the Netherlands are an extremely favourable environment for EVs (Rijksoverheid 2011) as the impact of challenges facing EV traffic, such as range anxiety, would be limited. The Netherlands are a worldwide frontrunner in EV sales (Yang 2016), and the share of electric vehicles in the total road traffic activity, measured in person-kilometres, is projected to increase to about 10% by 2020 according to current policies. However, this is still far away from the ECN electrification scenario, and even further from a fully decarbonized road traffic between 2025 and 2035, as needed for the transport sector to be compatible with “well below 2°C” without negative emissions.

The Dutch parliament recently passed a motion calling on the government to aim for a target of selling only EVs by 2025 (NRC 2016). **While this has been criticized as being unrealistic, it is in line with what is required by the Paris Agreement**: assuming that the average car could be on the road for roughly 10 years (Henry 2014), the “Paris Agreement” pathway for the sale of new EVs is moved 10 years forward compared to that of Figure 10. This is shown in Figure 11, where it can be seen that the aspirational target of the Dutch parliament is roughly in line with keeping warming to “well below 2°C” as required by the Paris Agreement.

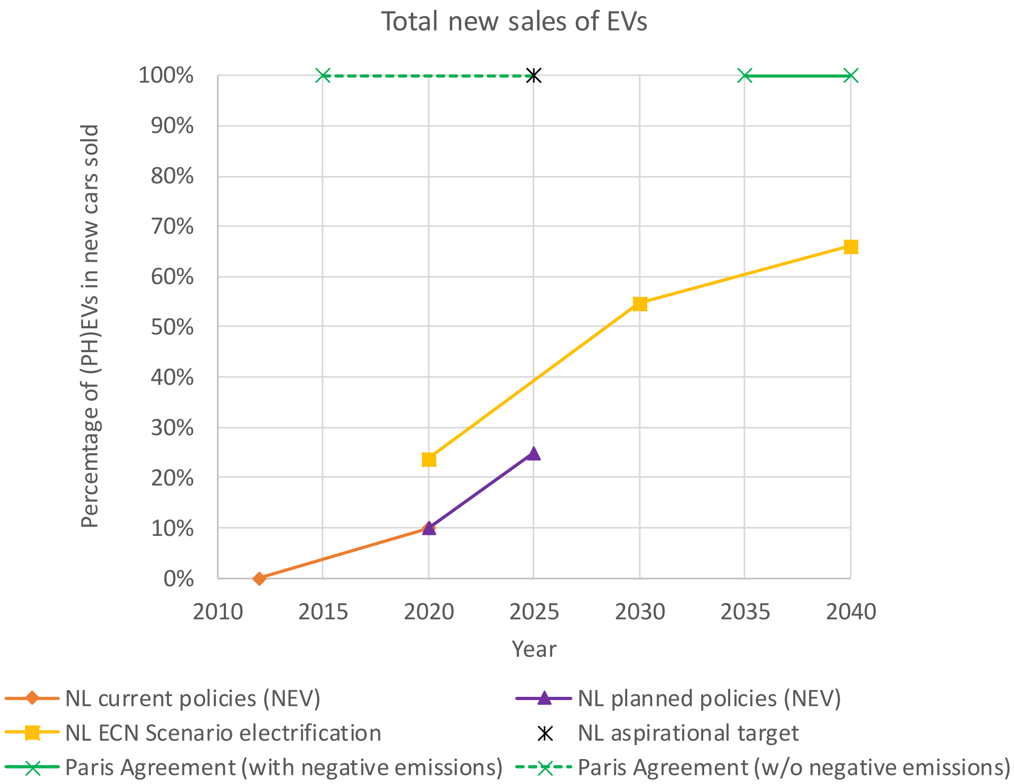

Figure 11: The total new sales of electric vehicles according to current and planned policies (ECN 2015), the ECN electrification scenario (ECN 2009), and the requirement for consistency with the Paris Agreement, assuming an average LDV lifetime of 10 years. The aspirational target according to the motion passed by parliament in 2016 of 100% electric vehicles in new car sales by 2025 is also indicated.

3.3 Buildings

The buildings sector is a source of emissions mainly because of the use of energy-intensive household appliances and the need for heating. Together, emissions from electricity and gas use in buildings account for 40% of national total energy-related CO_2 emissions (IEA 2015a; Ecofys 2016). For electricity-related emissions, the route towards reduction lies in decarbonizing the electricity supply sector, moving towards higher rates of domestic electricity generation (i.e. through solar PV on rooftops), and improving the energy efficiency of appliances. Current policy projections estimate that by 2030, 29% of electricity demand for residential housing will come from rooftop solar PV, a figure rising to 34% under planned policy projections (ECN 2015).

Energy-saving options include more efficient lighting and better insulation of houses, which requires renovation efforts for better roof-, floor-, wall- and window insulation. This means stringent renovation standards are necessary and should become obligatory. Ambitious scenarios for the built environment, such as by (PBL 2014) and (Ecofys 2016) typically assume a renovation rate between 2% and 3%, which means that the residential built environment would be renewed once every 30-50 years.

The bulk of other emissions is attributable to heating. In the Netherlands, roughly 93% of residential housing currently uses gas as the main heat source (RVO 2015), and current and planned policy projections do not foresee a strong decrease in gas use in the next 15 years (Figure 12). However, heating also needs to be (nearly) fully electrified in combination with low-carbon electricity to decarbonise the building sector. In the Ecofys' high-ambition scenario (in line with the long-term goals of the EU), a much stronger shift from boilers to air heat pumps (and to a smaller degree to district heating) is necessary, with only 7% of houses still using gas as main heating source by 2050.

District heating is often supplied by nearby industrial plants or power plants that have excess usable heat. In order to achieve the Paris Agreement's goals, however, fossil fuel-fed industrial plants or power plants need to be gradually phased out; the potential for district heating thus inevitably becomes smaller.

For commercial buildings, the required developments are very similar to those for residential buildings (Ecofys 2016). However, for compatibility with the Paris Agreement without negative emissions, gas would already have to be phased out of the heating demand between 2025 and 2035. **Essentially, this means the Dutch building stock must be gas-free by roughly 2030.**

Figure 13 shows the emissions associated with the use of gas for heating in the buildings sector. The Ministry of Economic Affairs has stated the goal of ensuring that heating in buildings is free of CO_2 emissions by 2050 (Ministerie van Economische Zaken 2016). Current policy projections are clearly a long way removed from this. The government may need to strengthen the support for or regulations on existing building stock to adopt full electrification, besides the increased efforts to lower energy demand in the built environment through obligatory insulation of houses and office buildings.

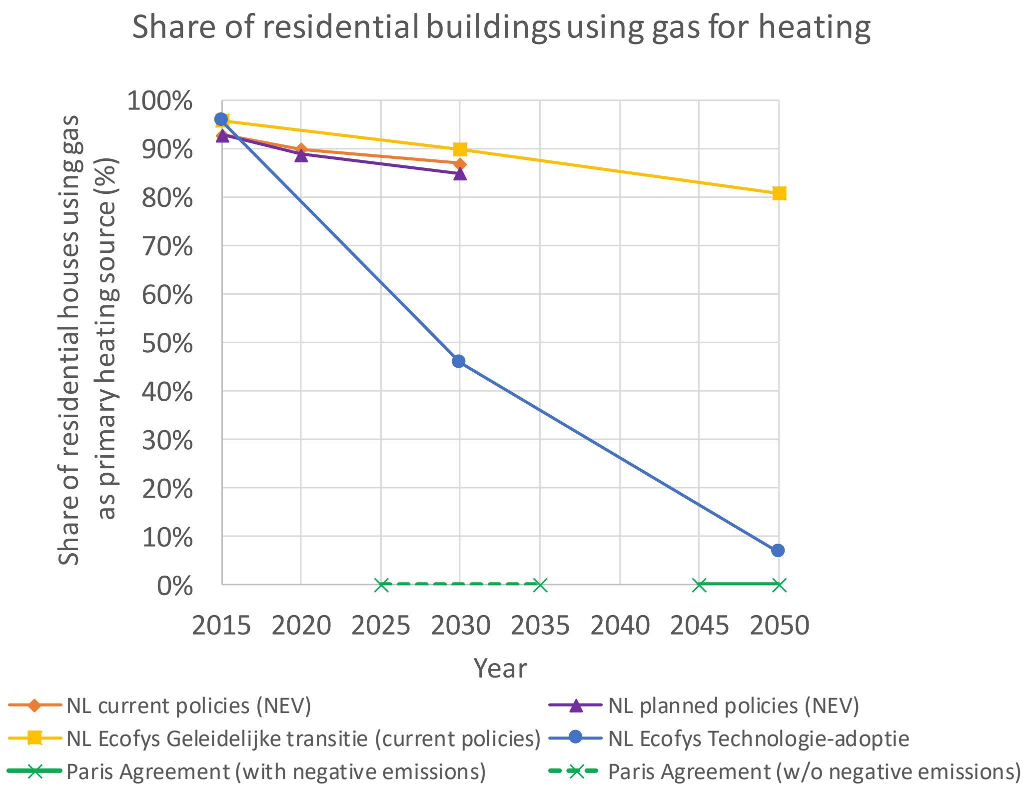

Figure 12: The share of residential buildings using gas for heating according to two current-policy scenarios and one planned-policy scenario (ECN 2015; Ecofys 2016), and a high-ambition scenario consistent with the long-term emission reduction goals of the EU (Ecofys 2016).

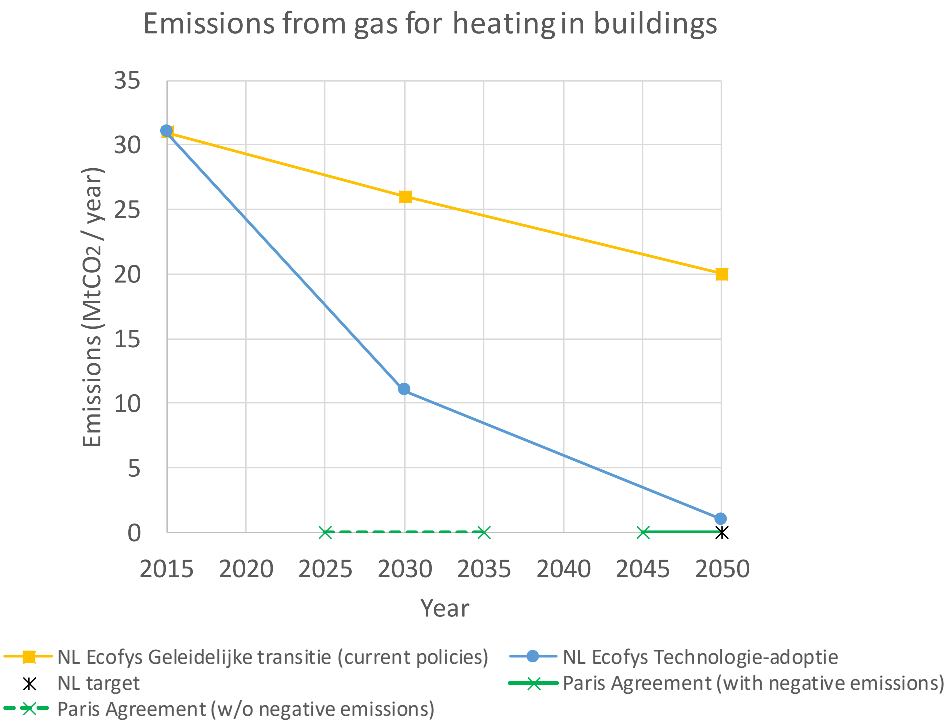

Figure 13: The emissions associated with gas for heating in all buildings, residential and commercial (Ecofys 2016), would have to decrease significantly to be in line with the 2050 aim of CO_2-neutrality (Ministerie van Economische Zaken 2016).

3.4 Industry

Direct GHG emissions from the industrial sector alone account for 18%-19% of total emissions in the Netherlands (UNFCCC 2015a). Petrochemicals and iron & steel are key emitting sectors in Dutch industry. GHG emissions from industry, as from all other sectors, would have to be reduced to zero in order to be compatible with the Paris Agreement. As “industry” comprises a large number of very different activities (chemicals, steel, cement, etc.), scenarios that go down to such a level of granularity are very rare and are thus not shown here. However, we note here that recent projections foresee almost no change in energy consumption, whether in the form of electricity or heat, until 2030 from current levels (ECN 2015).

Emissions from electricity consumption can be reduced by shifting to renewable energy, as explained above. Emissions from other energy use could be reduced by either electrification (along with a shift to decarbonised power generation) or by improvements in energy efficiency, which are, however, often constrained by the physical limits of production processes.

Moreover, CO_2 emissions resulting from non-energy use of fossil fuels in industrial processes (e.g. coal and coke as ire ore reductants in the iron & steel industry, and oil as feedstock in petrochemicals) cannot easily be reduced, as this is only possible through innovative products and processes based on different feedstocks, or through CCS. Although the Netherlands may not be able to deploy large-scale CCS toward 2050 due to storage capacity constraints among other limitations, allocating the limited CO_2 storage capacity to industrial process emissions may be a strategy to be considered seriously.

In addition, an accelerated development and deployment of innovative low-carbon industrial technologies, such as primary ironmaking by hydrogen reduction or electrolysis, would be crucial for the Netherlands to stay on a 1.5°C/2°C track. Substantial governmental support will be needed to achieve this.

3.5 Agriculture

When considering energy use in the agriculture sector in the Netherlands, one can generally separate between the greenhouse sector on the one hand (*glastuinbouw*), and crop farming and animal husbandry on the other. Most of the energy used for agriculture is attributable to the greenhouse sector, where it is used for heating and lighting. Thus, most of the CO_2 emissions from the agricultural sector, which account for about 8% of national total GHG emissions, come from greenhouse practices; most of the non-CO_2 emissions – methane (CH_4) and nitrous oxide (N_2O) – are attributable to crop and animal farming (ECN 2015).

The total CO_2 emissions from the agricultural sector under current and planned policies are plotted in Figure 14, which is nearly all from greenhouses. These are projected to keep decreasing in absolute terms under current as well as planned policies, although not by a substantial amount up to 2030. The implementation of planned policies is projected to result in higher emissions than under current policies, which is chiefly due to an expected increase in cogeneration in the greenhouse sector under planned policies (ECN 2015).

Agreements between the Dutch greenhouse sector and the government have set the CO_2 emission reduction target of 3.3 $MtCO_2$/year reduction by 2020 compared to 1990 levels, which translates roughly to an absolute emission target 6.2 $MtCO_2$/year by 2020. As can be seen in Figure 14, it is likely that this target will be met, as CO_2 emissions from the entire agricultural sector under current policies are projected to be roughly at this value by 2020 (ECN 2015; LNV 2008). The greenhouse sector also has a target of sourcing 20% of its energy from renewable sources by 2020 (LNV 2008).

However, this is so far removed from the Paris Agreement's requirement (zero energy-related CO_2 emissions in the Netherlands latest by 2035) that **one has to question the future of the Dutch greenhouse sector in its current state.** This sector either has to significantly contract in the next decades to reduce energy demand, or manage to switch completely to renewable sources of energy. In their current scope, greenhouse practices in the Netherlands cannot continue as they are, if the goals of the Paris Agreement are to be reached.

On a side note, to create the optimal condition for growing crops in a greenhouse, elevated levels of CO_2-concentration (as well as temperature and lighting) are necessary, creating a demand for CO_2 in this sector. A large part, roughly 60% of the CO_2 demand, is estimated to be met by the greenhouses' cogeneration installations; the rest has to be externally obtained. Most of this currently comes from commercial sources that obtain the CO_2 from, among others, a hydrogen production plant and a bioenergy plant, of which CO_2 is a by-product (TNO 2015). Thus, if efforts are made towards reaching the 20% renewables target by 2020, and even more in the longer term (in keeping with the overall objectives of the Paris Agreement), the direct supply of CO_2 (from cogeneration) would reduce, and the greenhouse sector would have to increasingly rely on other clean sources of CO_2, i.e. from biomass. Unless such options can be found and deployed quickly, this casts more doubt over the future of the greenhouse sector in the Netherlands in its current state.

Non-CO_2 emissions from agriculture are expected to stabilize near 19 $MtCO_2e$/year until 2030 under current and planned policies (ECN 2015), most likely missing the target of 16 $MtCO_2e$ by 2020 (Ministerie van Infrastructuur en Milieu 2011), as also shown in Figure 15. CH_4 emissions are projected to rise under current policies, among other things due to an expected increase in milk production, by up to 25% in the near term, following the cancellation of the European Union's dairy produce quota in 2015. Emissions of N_2O, on the other hand, have dropped since the 1990s in part due to decreasing levels of synthetic fertilizer usage (ECN 2015).

Technological options for limiting non-CO_2 emissions in the Netherlands are limited, although certain measures can be taken i.e. in improvement of fertilizer practices (with a shift towards animal manure instead of synthetic fertilizers) and efficiency improvements in milk production and production of livestock fodder, which could drive emissions down to 11-15 $MtCO_2e$/year in 2050. To further reduce emissions substantially, shifts in consumer behaviour would be required in order to limit demand for animal products such as meat and dairy (PBL & ECN 2011). This is not likely to happen in the near future under current policies, with the cow-, pig,- and poultry stocks in the Netherlands not projected to change significantly in the coming years (ECN 2015).

Thus, in order to meet the requirements of the Paris Agreement, strong policy shifts are needed to influence consumer behaviour and reduce demand. In practice, this means that the total cattle stocks should decrease drastically and diets would need to change accordingly. The government could take an active stance by, for instance, increasing taxes on meat consumption, or higher up the supply chain by taxing meat production, applying the “polluter pays” principle (The Guardian 2015b), to discourage meat-intensive diets.

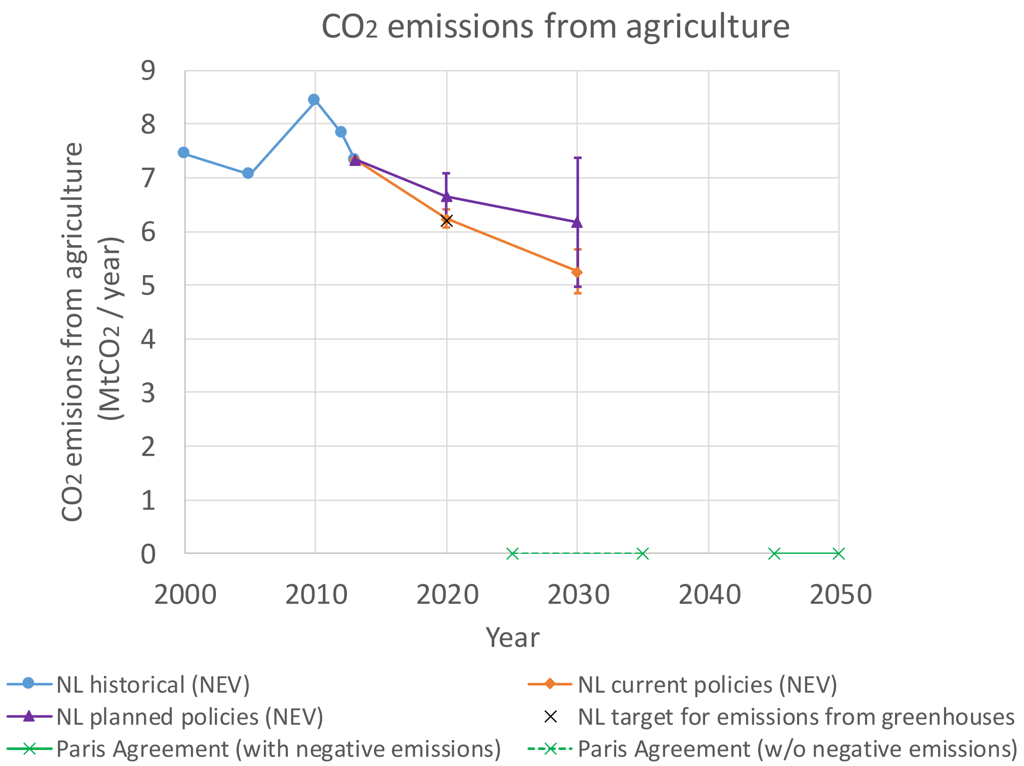

Figure 14: Total CO_2 emissions from the agricultural sector. Data series shown are historical values up to 2013 and projections under current and planned policies up to 2030 (ECN 2015); the 2020 target (LNV 2008); and what is needed long-term to be in line with the Paris Agreement.

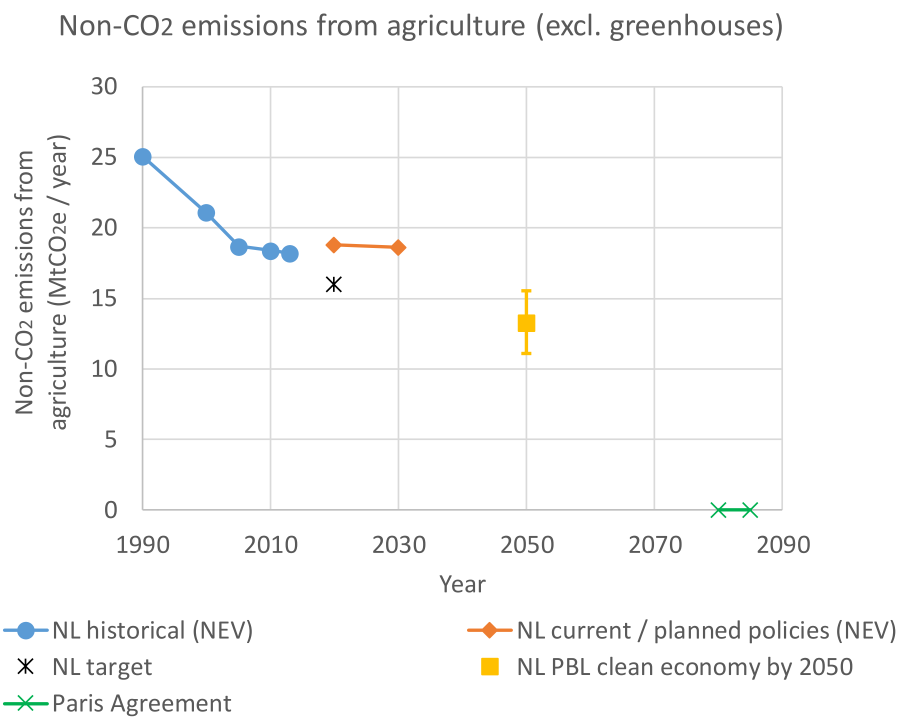

Figure 15: Non-CO_2 emissions (methane and nitrous oxide) from the agriculture sector. Data shown are historical emissions and emissions under current/planned policies (ECN 2015); the target for the agricultural sector (Ministerie van Infrastructuur en Milieu 2011); and a projection for 2050 consistent with an 80% reduction by 2050 compared to 1990 levels of economy-wide emissions (PBL & ECN 2011).

4 Conclusion

In this short analysis, we have translated the global ambition of the Paris Agreement into concrete sectoral targets applicable to the Netherlands. This has been done by comparing projected pathways of climate-relevant indicators from various authoritative literature sources to what would be needed in order to be compatible with the Paris Agreement's long-term goals.

The most important findings of this study are summarized in Table 2, where we show the main indicators that have been considered on a sectoral level, the current values of those indicators, the targets (if applicable) of the Dutch government, and the necessary timeline for compatibility with the long-term goals of the Paris Agreement.

The Netherlands faces a steep road ahead if the economy is to develop in a way that is compatible with the Paris Agreement. While promising developments have taken place in certain sectors - i.e. in transport, where the country is a worldwide frontrunner in EV sales - other sectors are lagging behind their counterparts in Europe and worldwide, such as in energy supply, where the share of renewables is still extremely low. Ambition on all fronts must be increased in order to ensure the Paris Agreement's goals can be reached, and the Netherlands, as a highly developed country, must be a frontrunner worldwide. The first step is to initiate the shutdown of all its coal power plants.

Table 2: Overview of the most important indicators investigated in this report, with their current levels, targets if applicable, and numbers compatible with the Paris Agreement's long-term goals without allowing negative emissions.

Sector	Indicator	Current / recent level	Target	Compatible with the Paris Agreement (w/o negative emissions)
Energy supply	Share of renewables in electricity supply	**11%** in 2013 (ECN 2015)	n.a.	**100%** latest in 2025
	Share of coal in electricity supply	**20-40%** in 2010-2015 (ECN 2015)	n.a.	**Zero** latest in 2020
	Share of renewables in total final energy demand	**6%** in 2015 (ECN 2015)	**14%** in 2020; **16%** in 2023; **100%** in 2050 (Rijksoverheid 2016)	**100%** by 2025-2035
Transport	Share of EVs in LDV fleet	**1.1%** in 2015 (CBS 2015; RVO 2016)	Approximately: **0.3%** by 2015 (20k vehicles) **2.4%** by 2020 (200k vehicles) **11.8%** by 2030 (1M vehicles) (RVO 2016)	**100%** by 2025-2035
	Share of EVs in new LDV sales	**<10%** in 2015 (ECN 2015)	No target, but **100% in 2025** under discussion (NRC 2016)	**100%** latest in 2025
Buildings	Share of households using gas as main heating source	**93%** in 2015 (ECN 2015)	n.a.	**Zero** by 2025-2035
	CO_2 emissions from gas for heating in buildings	**31 $MtCO_2$/year** in 2015 (Ecofys 2016)	**Zero** by 2050 (Ministerie van Economische Zaken 2016)	**Zero** by 2025-2035
Industry	Process emissions from industry	n.a.	n.a.	**Zero** by 2025-2035
Agriculture	CO_2 emissions from greenhouses	Close to **7.3 $MtCO_2$/year** in 2013 (ECN 2015)	**6.2 $MtCO_2$/year** in 2020 (ECN 2015)	**Zero** by 2025-2035
	Non-CO_2 emissions from agriculture	**18.2 $MtCO_2e$/year** in 2013 (ECN 2015)	**16 $MtCO_2e$/year** in 2020 (ECN 2015)	**Zero** by 2080-2090

5 Bibliography

CBS, 2014. *Hernieuwbare energie in Nederland 2014*, Den Haag: Centraal Bureau voor de Statistiek. Available at: https://www.cbs.nl/nl-nl/publicatie/2015/40/hernieuwbare-energie-in-nederland-2014.

CBS, 2015. *Transport en mobiliteit*, Den Haag: Centraal Bureau voor de Statistiek. Available at: http://download.cbs.nl/pdf/2015-transport-en-mobiliteit-2015.pdf.

CPB & PBL, 2015. *Nederland in 2030 en 2050: Twee referentiescenario's*, Den Haag: Centraal Planbureau, Planbureau voor de Leefomgeving. Available at: https://www.ris.uu.nl/ws/files/19342106/cpb_pbl_boek_19_wlo_2015_nederland_2030_en_2050.pdf.

EBN & Gasunie, 2010. *CO2 transport- en opslagstrategie*, EBN, Gasunie. Available at: https://www.rijksoverheid.nl/binaries/rijksoverheid/documenten/kamerstukken/2010/06/24/co2-transporten-opslagstrategie/10066211-bijlage1.pdf.

ECN, 2009. *Duurzame innovatie in het wegverkeer - Een evaluatie van vier transitiepaden voor het thema Duurzame Mobiliteit*, Energy research Centre of the Netherlands. Available at: http://www.ecn.nl/docs/library/report/2008/e08076.pdf.

ECN, 2015. *Nationale Energieverkenning 2015*, Energy research Centre of the Netherlands. Available at: http://www.cbs.nl/NR/rdonlyres/C0F1D74C-1EB1-4E3B-9A46-ECA28ABFED7E/0/2015nationaleenergieverkenning.pdf.

Ecofys, 2016. *Kwantificering van toekomstscenario's voor de gebouwde omgeving*, Ecofys. Available at: http://www.ecofys.com/files/files/rapport_kwantificering-van-toekomstscenarios-voor-de-gebouwde-omgeving_final.pdf.

van Egmond, S., 2016. *Unravelling the Contested Nature of Carbon Capture and Storage. PhD thesis*. Utrecht, the Netherlands: Utrecht University.

den Elzen, M.G.J. & Höhne, N., 2008. Reductions of greenhouse gas emissions in Annex I and non-Annex I countries for meeting concentration stabilisation targets. An editorial comment. *Climatic Change*, 91(91), pp.249–274.

Global CCS Institute, 2014. *Comparing different approaches to managing CO2 storage resources in mature CCS futures*, Available at: http://hub.globalccsinstitute.com/sites/default/files/publications/162748/comparing-different-approaches-managing-co2-storage-resources-mature-ccs-futures.pdf [Accessed September 28, 2016].

Greenpeace International; EREC & GWEC, 2012. *Energy [R]evolution - A Sustainable World Energy Outlook*, Available at: http://www.greenpeace.org/international/Global/international/publications/climate/2012/Energy Revolution 2012/ER2012.pdf.

Greenpeace International & EREC, 2013. *Energy [R]evolution - A Sustainable Netherlands Energy Outlook*, Available at: http://www.energyblueprint.info/fileadmin/media/documents/national/2013/0113_gpi_E_R__nl_08_mr-with_Jobs.pdf.

Henry, J., 2014. Average Car On The Road Still Getting Older, But For The Right Reasons. Available at: http://www.forbes.com/sites/jimhenry/2014/06/30/average-car-on-the-road-still-getting-older-but-for-the-right-reasons/#50993c7e28be [Accessed September 2, 2016].

Höhne, N. et al., 2016. *Was bedeutet das Pariser Abkommen für den Klimaschutz in Deutschland ?*, Cologne, Germany. Available at: https://newclimateinstitute.files.wordpress.com/2016/02/160222_klimaschutz_paris_studie_02_2016_fin_neu1.pdf.

Hulme, M. et al., 2000. *Using a climate scenario generator for vulnerability and adaptation assessments: MAGICC and SCENGEN version 2.4 workbook*, Norwich, UK: Climatic Research Unit, University of East Anglia. Available at: http://www.start.org/Projects/AIACC_Project/resources/ele_lib_docs/magicc_scengen_workbook.pdf.

IEA, 2015a. *CO2 Emissions from Fuel Combustion (2015 edition)*, Paris, France: International Energy Agency.

IEA, 2015b. *World Energy Outlook 2015*, Paris, France: International Energy Agency.

International Energy Agency, 2014. *Energy policies of IEA countries: The Netherlands: 2014 review*, International Energy Agency.

Jeffery, L. et al., 2015. *2.7°C is not enough – we can get lower - Climate Action Tracker update 8 December 2015*, Berlin, Germany: Climate Actiom Tracker. Available at: http://climateactiontracker.org/assets/publications/briefing_papers/CAT_Temp_Update_COP21.pdf.

KNMI, 2015. *Klimaatscenario's voor Nederland*, KNMI. Available at: http://www.klimaatscenarios.nl/images/Brochure_KNMI14_NL.pdf.

LNV, 2008. *Convenant Schone en zuinige Agrosectoren*, Den Haag: Ministerie van Landbouw, Natuur en Voedselkwaliteit. Available at: https://www.rvo.nl/sites/default/files/bijlagen/Convenant Schone en Zuinige Agrosectoren Agroconvenant.pdf.

Meinshausen, M., Raper, S.C.B. & Wigley, T.M.L., 2011. Emulating coupled atmosphere-ocean and carbon cycle models with a simpler model, MAGICC6--Part 1: Model description and calibration. *Atmospheric Chemistry and Physics*, 11(4), pp.1417–1456.

Meinshausen, M., Wigley, T.M.L. & Raper, S.C.B., 2011. Emulating atmosphere-ocean and carbon cycle models with a simpler model, MAGICC6--Part 2: Applications. *Atmospheric Chemistry and Physics*, 11(4), pp.1457–1471.

Ministerie van Economische Zaken, 2016. *Energierapport*, Den Haag: Ministerie van Economische Zaken. Available at: https://www.rijksoverheid.nl/documenten/rapporten/2016/01/18/energierapport-transitie-naar-duurzaam.

Ministerie van Infrastructuur en Milieu, 2011. *Kabinetsaanpak Klimaatbeleid op weg naar 2020*, Den Haag: Ministerie van Infrastructuur en Milieu. Available at: https://www.rijksoverheid.nl/documenten/kamerstukken/2011/06/08/kabinetsaanpak-klimaatbeleid-op-weg-naar-2020.

NRC, 2016. Omstreden motie over elektrische auto's aangenomen. 29 March, 2016. Available at: https://www.nrc.nl/nieuws/2016/03/29/tweede-kamer-neemt-omstreden-motie-over-elektrische-autos-aan-a1408296 [Accessed August 23, 2016].

PBL, 2014. *Op weg naar een klimaatneutrale woningvoorraad in 2050*, Planbureau voor de Leefomgeving. Available at: http://www.ce.nl/?go=home.downloadPub&id=1638&file=CE_Delft_3A31_Klimaatneutrale_gebouwde_omgeving_2050_DEF.pdf.

PBL & ECN, 2011. *Exploration of pathways towards a clean economy by 2050*, PBL Netherlands Environmental Assessment Agency, Energy research Centre of the Netherlands. Available at: http://www.pbl.nl/sites/default/files/cms/publicaties/pbl-2011-exploration-of-pathways-towards-a-clean-economy-by-2050.pdf.

Rijksoverheid, 2011. *Elektrisch Rijden in de versnelling Plan van Aanpak 2011-2015*, Den Haag. Available at: http://www.rijksoverheid.nl/documenten-en-publicaties/kamerstukken/2011/10/03/aanbiedingsbrief-green-deal.html.

Rijksoverheid, 2015. Emissies broeikasgassen, 1990-2014. Available at: http://www.clo.nl/indicatoren/nl0165-broeikasgasemissies-in-nederland [Accessed September 1, 2016].

Rijksoverheid, 2016. Meer duurzame energie in de toekomst. Available at: https://www.rijksoverheid.nl/onderwerpen/duurzame-energie/inhoud/meer-duurzame-energie-in-de-toekomst [Accessed August 23, 2016].

Rogelj, J. et al., 2016. Paris Agreement climate proposals need a boost to keep warming well below 2 °C. *Nature*, 534(7609), pp.631–639. Available at: http://www.nature.com/doifinder/10.1038/nature18307.

Rogelj, J. et al., 2015. Zero emission targets as long-term global goals for climate protection. *Environ. Res. Lett.*, 10, pp.1–11. Available at: http://iopscience.iop.org/1748-9326/10/10/105007.

Rose, S.K. et al., 2014. Bioenergy in energy transformation and climate management. *Climatic Change*, 123(3–4), pp.477–493.

RVO, 2016. Cijfers elektrisch vervoer. Available at: http://www.rvo.nl/onderwerpen/duurzaam-ondernemen/energie-en-milieu-innovaties/elektrisch-rijden/stand-van-zaken/cijfers [Accessed August 10, 2016].

RVO, 2015. *Monitor Energiebesparing Gebouwde Omgeving 2014*, Rijksdienst voor Ondernemend Nederland. Available at: http://www.rvo.nl/sites/default/files/2015/12/monitor energiebesparing gebouwde omgeving 2014 definitief.pdf.

Sociaal-Economische Raad, 2013. *Energieakkoord voor duurzame groei*, Den Haag: Sociaal-Economische Raad. Available at: http://www.ser.nl/~/media/files/internet/publicaties/overige/2010_2019/2013/energieakkoord-duurzame-groei/energieakkoord-duurzame-groei.ashx.

The Guardian, 2015a. Dutch government ordered to cut carbon emissions in landmark ruling. 24 June, 2015. Available at: https://www.theguardian.com/environment/2015/jun/24/dutch-government-ordered-cut-carbon-emissions-landmark-ruling [Accessed September 1, 2016].

The Guardian, 2015b. UN expert calls for tax on meat production. 25 May, 2016. Available at: https://www.theguardian.com/environment/2016/may/25/un-expert-calls-for-tax-on-meat-production [Accessed September 2, 2016].

The Guardian, 2015c. Wind power generates 140% of Denmark's electricity demand. 10 July, 2015. Available at: https://www.theguardian.com/environment/2015/jul/10/denmark-wind-windfarm-power-exceed-electricity-demand [Accessed August 23, 2016].

TNO, 2015. *A secure and affordable CO2 supply for the Dutch greenhouse sector*, TNO. Available at: http://www.tuinbouw.nl/sites/default/files/15051.03 CO2 voor de Nederlandse glastuinbouw.pdf.

UNEP, 2015. The Emissions Gap Report 2015: A UNEP Synthesis Report. In Nairobi, Kenya: United Nations Environment Programme (UNEP). Available at: http://uneplive.unep.org/media/docs/theme/13/EGR_2015_301115_lores.pdf.

UNFCCC, 2015a. *Greenhouse Gas Inventory Data*, Bonn,Germany: United Nations Framework Convention on Climate Change. Available at: http://unfccc.int/ghg_data/ghg_data_unfccc/items/4146.php.

UNFCCC, 2015b. *Paris Agreement - Decision 1/CP.21 - Report of the Conference of the Parties on its twenty-first session, held in Paris from 30 November to 13 December 2015 Addendum Part two: Action taken by the Conference of the Parties at its twenty-first session*, Bonn, Germany: United Nations Framework Convention on Climate Change. Available at: http://unfccc.int/resource/docs/2015/cop21/eng/10a01.pdf.

Yang, Z., 2016. 2015 Global electric vehicle trends: Which markets are up (the most). Available at: http://www.theicct.org/blogs/staff/2015-global-electric-vehicle-trends [Accessed August 23, 2016].

Appendix: Literature overview

In this section, we discuss the literature from which projection scenarios for the various indicators presented in this report have been taken. Table 3 presents an overview of the used reports by sector, after which we provide a short discussion of each of the scenarios, discussing which assumptions have been employed in the scenarios and which developments towards emissions reductions have been considered.

Table 3: An overview by sector of the studies and scenarios employed in this report.

Report	Policy scenario	Type of policy scenario	Sectors covered				
			Energy	Transport	Buildings	Industry	Agricul-ture
Nationale Energieverkenning [NEV] **(ECN 2015)**		Current and planned policy pathways	X	X	X	X	X
Nederland in 2030 en 2050 **(CPB & PBL 2015)**	Scenario "*Laag*" and "*Hoog*"	Reference scenarios consistent with 3.5°C – 4°C warming (*Laag*) and 2.5°C – 3°C warming (*Hoog*)	X	X			
Energy [R]evolution **(Greenpeace International & EREC 2013)**		Consistent with long-term EU goals (80-95% reduction in emissions by 2050 compared to 1990)	X	X			
Duurzame innovatie in het wegverkeer **(ECN 2009)**	Scenario 3	Consistent with reduction of transport emissions by 30% between 2010 and 2040		X			
Op weg naar een klimaatneutrale woningvoorraad **(PBL 2014)**	Scenario "*Beperkt*" and "*Diep*"	*Beperkt* is consistent with reducing emissions from heat demand by 55% by 2050 compared to 2010; *Diep* results in reducing emissions from heat demand by 94% by 2050 compared to 2010.			X		
Kwantificering van toekomstscenario's voor de gebouwde omgeving **(Ecofys 2016)**	Scenario "*Geleidelijke transitie*" and "*Technologie-adoptie*"	The *Geleidelijke transitie* scenario is consistent with current policies. The *Technologie-adoptie* scenario comes closest to the EU-wide goal of 80-95% emission reduction by 2050 compared to 1990 levels, and is consistent with 80% reduction of buildings emissions by 2050 compared to 2015 levels.			X		
Exploration of pathways towards a clean economy by 2050 **(PBL & ECN 2011)**		Consistent with a reduction of greenhouse gas emissions of 80% by 2050 compared to 1990 levels					X

Renewable energy

Nationale Energieverkenning (NEV)

The recent developments and current policy pathways of electricity production in the *Nationale Energieverkenning* (National Energy Exploration) reflect a number of factors. Firstly, production from coal has risen in the recent past due to relatively low prices for coal and high prices for gas; secondly, a number of new coal-fired power plants have recently commenced operation. The share of coal in electricity production is set to drop again in the near future, though, as power plants are phased out as necessitated for compliance with the long-term climate goals of the EU and the *Energieakkoord* (Energy Agreement), according to which the Dutch government and a set of companies and other organizations have committed to a number of broad targets in energy and climate policy (Sociaal-Economische Raad 2013). Renewable energy use will increase up to 2030, as further stimulating measures are taken and intentions in the *Energieakkoord* are converted into policies. Especially offshore wind energy and solar PV home systems will gradually become cost-effective without any financial support. However, it is also assumed that total electricity production will rise in the decade 2020-2030 by 20-30% due to export of electricity to neighbouring countries, due to which the share of renewable energy in the total electricity mix will be somewhat curtailed. As many measures from the *Energieakkoord* are assumed to have a strong effect in the period 2020-2023, the goal of 16% renewables by 2023 is expected to be reached in the current policy scenario.

Nederland in 2030 en 2050

This study provides two reference scenarios (*Laag* and *Hoog*, or “low” and “high”) for development in various social, economic and technical indicators in the Netherlands up to 2050. Overall, the “high” scenario is consistent with a 65% reduction of emissions in the Netherlands by 2050 compared to 1990, and thus a 2.5°C to 3°C average increase in global temperature compared to pre-industrial levels, while the “low” scenario is consistent with a rise of 3.5°C to 4°C. In the “high” scenario, it is assumed that international climate policy remains relatively ambitious and technological developments will keep decreasing the costs of renewable energy; in the “low” scenario, the climate policy of the Netherlands (and the EU) is slow, and the EU loses its ambition to be a leader in this field post-2030. Carbon pricing by 2050 is four times as high in the “high” scenario as in “low”.

Energy [R]evolution

Energy [R]evolution scenarios have been published before in the context of the EU and the world. This 2012 study is the first *Energy [R]evolution* scenario applied to the Netherlands. The scenario presents a possible development towards a sustainable energy supply and a decarbonisation of the economy on a sectoral basis. As far as energy generation is concerned, in the *Energy [R]evolution* scenario, nuclear energy should have already been phased out by 2015 and coal power should be phased out completely by 2020. This would set the stage for a surge in renewable energy generation, in which wind power generation is more than 20 times as high in 2050 than in 2020, and solar PV generation about 300 times, and all fossil fuels are phased out by 2050 with the exception of natural gas. Similarly, the use of renewables in heat supply would surge from just 2.4% in 2010 to 65% in 2050, and heating demand would be reduced considerably.

Transport

Nationale Energieverkenning (NEV)

For the transport sector, the current policy pathway of the *Nationale Energieverkenning* assumes that, even though traffic activity will rise in the period up to 2020, final energy consumption in the transport sector will roughly stabilize due to the fact that the car fleet becomes ever more fuel-efficient owing to increasingly strict fuel economy standards. In this pathway, emissions from the transport sector are even projected to decrease slightly in this period, due to the rising usage of biofuels. It is assumed that due to fiscal and other stimulating measures, the recent surge in take-up of electric and plug-in hybrid vehicles will continue, with PHEVs and EVs reaching respectively 7% and 3% of new LDV sales by 2020 under the influence of an increasing amount of EV types on offer and the benefits of fiscal measures for EV users. In the “planned policy” pathway, it has been assumed that CO_2 emission standards will be further strengthened in 2025, leading to a stronger increase of (semi)-electric vehicles post-2020. Planned policies as per the 2015 *Autobrief II*, proposing amendments to the existing fiscal policies for PHEVs and “ultra-clean vehicles” (<50 gCO_2/vkm), have not been taken along in the analysis, although the study presents a short overview of what their likely effects could be (marginally higher emissions in 2020, fewer sales of PHEVs, and increased sales of “ultra-clean vehicles”).

Nederland in 2030 en 2050

The reference scenarios for the transport sector in this study provide an outlook of transport activity. Both “low” and “high” variants of the scenarios foresee an increase in total traffic activity up to 2050, for cargo as well as for passenger transport. The high variant foresees a development in which international climate policy leads to a much more efficient, but also more expensive car fleet. This reduces the sale of new cars, but also leads to much lower expenses on fuel, and as a result vehicle activity will still rise markedly. Neither scenario foresees a large change in modal share of traffic. Overall, due to cleaner vehicles and an increase in electric car deployment, overall emissions from transport are projected in these scenarios to drop by 31%-37% by 2050 compared to 2010 levels. In our analysis, we have used the reference scenario to obtain numbers on the size of the Dutch LDV fleet up to 2050 and for estimations of the modal shift under reference scenarios.

Duurzame innovatie in het wegverkeer

This 2009 study covers a number of future scenarios for the transport sector in the Netherlands, each of which has a different focus (i.e. hydrogen fuel cells, electric vehicles, increased use of biofuels). We have used data from this study’s Scenario 3, which concentrates on the possibilities of expansion of electric transport, and would result roughly in a 30% reduction of Dutch road transport emissions by 30% in 2040 compared to 2010 levels. This scenario proposes that, due to pressure on car manufacturers to produce cleaner vehicles, hybrid vehicles (including plug-ins) become a serious technological option in the 2010s and could surge in popularity to up to 85% of new LDV sales in 2020. Owing to improving infrastructure of charging points, decreasing costs, and improving reputation of PHEVs, the share of plug-in hybrids in the total amount of hybrid cars sold could rise to 40% by 2030. Meanwhile, the commercial deployment of full-electric vehicles starts around 2015, at first mostly in regions where the limited driving radius presents no barrier to customers. Post-2020, again owing to improving infrastructure of charging points and decreasing costs, more and more drivers will then perform the switch from plug-in hybrid cars to full-electric cars as this starts to become financially attractive; meanwhile, users of non-plug-in hybrid cars will switch to plug-in vehicles, thus stabilizing the share of PHEVs post-2030. However, full-electric vehicles will not present a viable option to drivers of i.e. 4WDs and camping cars, who will choose stick with PHEVs at best.

Energy [R]evolution

The scenario presents a possible development towards a sustainable energy supply and a decarbonisation of the economy on a sectoral basis. In the transport sector, it is assumed that (plug-in) hybrid and full-electric vehicles have to bring large efficiency gains in the coming decades, and that a shift to higher usage levels of public transport as well as to smaller and more efficient cars will be necessary to drive down overall energy demand in the transport sector. Electricity and biofuels should constitute a majority of fuels (roughly 30% each) used in the Dutch transport sector by 2050.

Buildings

Nationale Energieverkenning (NEV)

For the current policy pathways in the buildings sector, the Nationale Energieverkenning considers the current requirements on the *Energie Prestatie Coëfficient* (EPC, Energy Performance Coefficient) of new buildings, a measure for energy efficiency, as well as a number of agreements from the *Energieakkoord* and current requirements for energy efficiency of appliances and lighting as per the EU-Ecodesign guidelines. The planned policies include a tightening of EPC requirements to nearly energy-neutral by 2020, increased energy standards for appliances, and a continued roll-out post-2015 of “nul-op-de-meter” houses (i.e. houses self-sufficient in energy) under the *Stroomversnelling* initiative (an initiative of housing corporations, municipalities and other stakeholders; see i.e. http://stroomversnelling.nl/over-stroomversnelling/wat-is-nul-op-de-meter).

Op weg naar een klimaatneutrale woningvoorraad

This PBL study presents a number of investment pathways towards reaching a “climate-neutral” (interpreted as being in line with the EU’s long-term goal of 80-95% reduction by 2050 compared to 1990 levels) built environment in the Netherlands by 2050. The study looks at the potential of technological options such as increased energy-saving measures (insulation, heat pumps), switch to district heating, use of “green gas”, and using solar PV on rooftops for electricity generation. As in the Ecofys study (see below), four pathways are presented with varying degrees of potential for climate-neutrality by reducing emissions from energy-saving measures related to heating. The scenarios with weaker potential in these measures are then assumed to need a greater amount of solar PV electricity generation in order to be compatible with climate neutrality. We have considered the two scenarios with minimum and maximum potential for reduction related to heating, named respectively “Beperkt” (limited) and “Diep” (deep). The scenario *Beperkt* is consistent with reducing emissions from heat demand by 55% by 2050 compared to 2010; the scenario *Diep* results in reducing emissions from heat demand by 94% by 2050 compared to 2010. The two other scenarios considered in the report - *Breed* (broad) and *Gefaseerd diep* (phased deep) – result in emission reductions somewhere in between these two extremes.

Kwantificering van toekomstscenario’s voor de gebouwde omgeving

This Ecofys report presents four different scenarios for the built environment in the Netherlands up to 2050, based on varying assumptions of technology, policy and energy costs development and with different outcomes for overall emissions. The *Geleidelijke transitie* scenario (“gradual transition”) is consistent with a 50% reduction of emissions in 2050 compared to 2010 and represents the continuation of current developments and pledges already made, i.e. from the *Energieakkoord*. It is the closest to “current policies” out of the four scenarios presented. The *Technologie-adoptie* scenario represents a scenario in which sustainable solutions in the buildings sector become increasingly attractive to consumers, resulting in a surge in adoption of measures such as an increased connection of households and commercial buildings to district heating or air/ground heat pumps; a high rate of deployment of solar PV on rooftops; better insulation measures and electrification of heating supply; as well as decarbonization of electricity supply which is assumed to happen as in the *Nationale Energieverkenning* under planned policies until 2030. This scenario is roughly consistent with reducing emissions from the buildings sector by 80% by 2050 compared to 2015 levels. The other two scenarios discussed in the report (*Urgentie* and *Schaarste*, or “Urgency” and “Shortage”) result in emission levels somewhere in between the *Geleidelijke transitie* scenario and the *Technologie-adoptie* scenario.

Agriculture

Nationale Energieverkenning (NEV)

Under current policies, CO_2 emissions from agriculture (mainly from greenhouses) are projected to keep decreasing in absolute terms under current as well as planned policies, although not by a substantial amount, up to 2030. The implementation of planned policies is projected to result in higher emissions than under current policies, due to an expected increase in cogeneration in the greenhouse sector under planned policies. It is assumed that energy demand for heating from the greenhouse sector will roughly stabilize in the period 2015-2030 as continuing improvements in energy efficiency compensate the increase in greenhouse activity levels. Of chief importance are projected improvements in energy efficiency and their diffusion as part of *Het Nieuwe Telen* “New Cultivation”, a program for the greenhouse sector implemented in order to make progress towards the greenhouse sector targets), for instance in insulation and more efficient lighting.

Methane emissions from agriculture, mainly dairy cows, are projected to rise under current policies, among other things due to an expected increase in milk production, driven by the cancellation of the European Union’s dairy produce quota in 2015. The production increase is expected to be mainly due to an increase in productivity per cow and to a lesser extent an increase in the number of dairy cows. The increase in methane emissions is projected to flatten off towards 2030, as the number of young cattle will eventually decline while the average age of dairy cows increases (resulting in a higher milk production per cow) and co-fermentation of manure (which prevents methane emissions as the demand for manure storage is reduced) will increase after 2020. Furthermore, nitrous oxide emissions have been on the decline recently, but are projected in the *Nationale Energieverkenning* to stabilize until 2020 and afterwards decrease slightly due to reduced grazing levels of dairy cows.

Exploration of pathways towards a clean economy by 2050

This study, which shows a pathway consistent with an 80% reduction of emissions by 2050 compared to 1990 levels (the low-ambition level of the EU’s long-term pledges), considers that technological opportunities for reducing non-CO_2 emissions from agricultural sources are limited. The study estimates that improvements in milk production, production of cattle fodder, and fertilizer usage, plus increased co-fermentation of animal manure, could reduce emissions by roughly 5 $MtCO_2e$ by 2050 compared to 2010 levels. Under the scenario, agricultural sources of non-CO_2 gases would constitute the bulk (25%) of all emissions by 2050.

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