New Roads for Transport

Towards a sustainable solution for the 10% renewable transport energy target in 2020

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Summary

Background

Recently, the European Union issued the Renewable Energy Directive (RED) which states that 10% of the (road) transport fuels must have a renewable origin by 2020. Biofuels are currently by many considered to be the most obvious option to meet this target. However, concern is growing about the sustainability of current biofuels, especially due to the likelihood of competition with food production, deforestation and greenhouse gas effects by direct and indirect land use change. Friends of the Earth Netherlands (Milieudefensie) therefore asked CE Delft to develop an alternative scenario to meet the 10% renewable energy target for transport in the Netherlands.

Energy demand in transport

When developing a scenario to meet the 10% RED target for 2020, we first need to determine the energy demand for the sector in that year. Current prognoses predict further growth of energy demand in the next decade. The Netherlands Environmental Assessment Agency (PBL) expects that transport energy use will increase by 17% between 2010 and 2020[1]. Meeting the 10% RED target would then require about 57 PJ of renewable energy in the Netherlands. This may reduce about 4 Mton CO_2 in 2020, according to government predictions[2].

Reducing this growth has a significant effect on both CO_2 emissions and renewable energy demand. For example, if transport energy demand in 2020 would equal that of 2010, the sector would emit 7.5 Mton less CO_2, and only 49 PJ renewable energy would be required to meet the 10% RED target.

Options assessed

The study assesses a number of options to use renewable energy in the transport sector:

- electric (EV) and plug in hybrid (PHEV) vehicles;
- electric trains and trams;
- electric bicycles; and
- biofuels from waste fat.

The assessment of these options led to the following conclusions.

- If the electrification of cars is successful in the coming years, if these are powered by renewable energy and if that renewable energy is monitored and counted towards the RED target, renewable electricity could contribute to more than half of the RED target, i.e., to 5-6% of the 10%. Reducing road transport energy demand can increase this percentage.
- However, if the technological development of EVs and PHEVs is much slower, their contribution to the RED target will be negligible.
- There is also the option of biodiesel from used frying fat. Current production contributes 1.4% to the RED target, and might be further increased in the coming decade.
- Electric rail transport and electric bicycles can achieve significant CO_2 reductions, but offer little potential to contribute to the 10% RED target.

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[1] The Global Economy (GE) scenario of the Netherlands Environmental Agency.

[2] Note that the RED states that some types of biofuels count double (biofuels from waste) to promote these fuels, and renewable electricity counts 2.5 times, to take into account the higher efficiency of EVs. The actual amount of renewable energy required to fulfill the 10% target may thus be much lower.

Towards an alternative scenario

Depending on two different approaches, the assessment led to the following conclusions:

If we prioritize the fulfilment of the 10% RED target, the above options can contribute to a maximum of about 7.4% renewable energy in the sector in 2020, at current energy demand predictions. This share would be higher if energy demand in the sector would be reduced.

This assumes a very significant market introduction of EVs and/or PHEVs in 2020, and requires that these EVs and PHEVs are charged with renewable electricity. To illustrate the challenge that this poses: if this renewable electricity is to be produced by offshore wind turbines, about 650-700 turbines (3 MW each) would be required to power these EVs and PHEVs.

If we prioritize meeting a CO_2 reduction goal, rather than a renewable energy share, more options arise.

- First of all, keeping the energy demand of the sector at 2010 levels will reduce 7.5 Mton CO_2, compared to the GE scenario – almost twice as much as the RED target would achieve. Further demand reduction will lead to further reductions.
- EVs and PHEVs can also lead to CO_2 savings, if a breakthrough of EVs and PHEVs is achieved in the coming decade. The scenarios used here lead to 1-2 Mton CO_2 reduction if the average electricity mix is used, and to 2-3 Mton CO_2 reduction if the vehicles are charged with renewable energy only.
- Electric bicycles seem to have potential to reduce car use for short distances, especially in commuter travel. The calculations show that 1 Mton CO_2 is saved if e-bikes increase bicycle shares in short distance trips[3].
- The effect of the current biodiesel production from frying fat is about 0.3 Mton CO_2 reduction[4].

Policy recommendations

- The Dutch government should look at alternatives to meet the 10% target, and not focus only on the use of biofuels.
- More attention should be given to legislation, taxation and other measures that limit energy demand and thus CO_2 emissions of the transport sector.
- Governments should assess the potential impact of EVs and PHEVs, and adapt policies to harvest their potential. For example, significant gains could be achieved if the renewable energy production is increased in line with the growth of electricity demand from EVs and PHEVs.
- Policies to promote the use of electric bicycles seem to have significant CO_2 reduction potential and should therefore be implemented.
- Concerning electric road transport, there are still a number of loopholes and barriers in the current policies, and also rebound effects may significantly reduce the benefits that electric road transport could achieve. They should be addressed and solved in the coming years.
- For the next few years the Dutch biofuel consumption should be frozen at current levels. The period between now and 2014 should then focus on R&D and first market introduction of EVs and PHEVs, and on the further assessment of the true potential for sustainable biofuels that demonstrably do not pose significant land use issues and do not risk social and environmental conflicts.

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[3] Bicycle shares are assumed to increase by 10-14%, see section 3.3.2 for the assumptions used.

[4] Note that the same amount of feedstock would lead to more CO_2 reduction if it would be used to replace coal in electricity generation.

1 Introduction

1.1 Introduction

In April 2009, the European Union issued the Renewable Energy Directive (RED) which states, among other things, that the EU Member States must ensure that 10% of the (road) transport fuels is made from renewable sources, in 2020. The original aim of this target was to promote the use of biofuels, and sustainability criteria were included in the directive to ensure that not all biofuels would count towards the target. However, the concerns about the sustainability of the current biofuels are still growing, especially due to the increasing evidence that the negative impacts of direct and indirect land use change on greenhouse gas emissions, biodiversity, water use, etc. can be very significant and are difficult if not impossible to control (see, for example, the following recent reports on this issue: Bindraban, 2009; WBGU, 2009; SCOPE, 2009).

Friends of the Earth Netherlands (Milieudefensie) has now asked CE Delft to develop an alternative scenario to meet the 10% renewable energy target in transport, in 2020.

Milieudefensie has campaigned against the 10% target, which it largely expects to be fulfilled by biofuels without adequately addressing sustainability concerns. Nor CO_2 reduction, nor reduction of transport and energy consumption stands central with the volume target, while at the same time, it creates an additional demand and market for biofuel feedstocks. Milieudefensie's position is that current biofuels from food crops and other agricultural commodities should be phased out, to prevent further conversion of land such as rainforest and grasslands, and to stop violation of land and human rights of local communities. Waste and residues could be an alternative, but are more efficiently used for power generation rather than biofuels. It is unlikely that algae diesel will become sustainably available in large quantities before 2020.

The question is thus, how can the 10% target be met without these biofuels, whilst moving towards a truly sustainable transport future.

1.2 Aim and scope of this study

The main pillars of this alternative scenario will then have to be the following:

- Replacing part of the conventional road transport (that has to use fossil fuels or biofuels) with transport powered by renewable electricity. The following options exist:
  - increasing the share of electric and plug in hybrid vehicles, and (preferably) charging these vehicles with renewable electricity;
  - a modal shift from road to electric rail transport, again combined with an increase of renewable electricity production;
  - a shift from car transport to electric bicycles and scooters.
- Reducing transport energy demand, which will automatically reduce the demand for renewable energy and reduce the need for biofuels.

We will focus this study on the first pillar, but will use various transport energy growth scenarios to asses the effect of energy use reduction on the effort required to meet the 10% sustainably. We will not, however, go into detail on how these alternative growth curves can be achieved.

The study assesses renewable energy use in the Dutch transport sector, and thus focuses on developing an alternative scenario for the Netherlands. The focus is on 2020.

As explained in the introduction, the starting point regarding biofuels is the position of Friends of the Earth Netherlands on biofuels (see the text box on the previous page, or Milieudefensie, 2008). Despite the criticism of Friends of the Earth Netherlands on the 10% target for transport in the RED, that target is taken as a given in this study.

1.3 The report

In the next chapter, we will first describe the context: the most relevant EU and Dutch policies, and the expected energy demand of the road transport sector in 2020.
In chapter 3, we will assess the potential of various alternative options for renewable energy in transport: electric and plug in hybrids, electric trains, trams and bicycles, and (briefly) biofuels from waste streams.
These issues and options then come together in chapter 4, where we design an alternative scenario for energy use in the transport sector in 2020.
Policy recommendations are given in chapter 5.

2 Renewables in transport

2.1 Introduction

This chapter provides the necessary background information and context for the study.
First of all, the policy context is described, in an overview of the most relevant EU en national policies. Then, we show what the 10% RED target for the transport sector actually means for 2020, in terms of renewable energy required. As this depends on the development of energy use in the transport sector in the coming decade, a number of scenarios are presented. These clearly illustrate the potential effect of reducing energy demand in the sector on the renewable energy target set by the RED and on the CO_2 emissions of the sector.

2.2 Policy context

The following provides an overview of EU and national policies that are most relevant to this study.

2.2.1 EU policies

Renewable Energy Directive (RED) (RED, 2009):
This policy defines a target for the renewable energy share in the EU Member States, in 2020, and a separate target for use of renewable energy in the transport sector. The main (relevant) issues for this study are the following:

- 10% renewable energy in transport, in 2020[5].
- 20% renewable energy in the EU, and 14% in the Netherlands, in 2020.
- Sustainability criteria for biofuels, incl. a minimum GHG reduction requirement (and a methodology to calculate the reduction), currently excl. indirect land use change effects.
- Double counting of 2nd generation biofuels (from waste and residues), for the 10% target
- The contribution of renewable electricity is calculated from a) the total electricity use in transport, and b) the average renewable electricity share, in either the Member State or in the EU. However, the Directive also states (Art. 3(4)) that the Commission shall present by 31 December 2011, if appropriate, a proposal permitting, subject to certain conditions, the whole amount of the electricity originating from renewable sources used to power all types of electric vehicles to be considered.
- Renewable electricity in road transport is multiplied by paragraph 2.5, for the 10% target.
- NB. These double and 2.5X counting only apply to the 10% transport target, there is no double counting in the overall 20% renewable energy target.

Member States now have to implement this legislation in national policies, and define action plans to meet the targets.

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[5] The directive defines that the target is 10% of the fuel used in the road transport sector. However, renewable energy use in other modes may also be counted towards the target.

Revised Fuel Quality Directive (FQD) (FQD, 2009):

- 6% from well to wheel greenhouse gas emission reduction of transport fuels, between 2010 and 2020, compared to the EU-average level of life cycle GHG emissions, per unit of energy from fossil fuels in 2010. These reductions should, according to the directive, be obtained through the use of biofuels, alternative fuels and reductions in flaring and venting at production sites.
- An additional 4% GHG emission are voluntary, where 2% is foreseen to be obtained by the use of environmentally friendly carbon capture and storage technologies and electric vehicles, and an additional further 2% reduction can be obtained through the purchase of credits under the Clean Development Mechanism of the Kyoto Protocol. These additional reductions are currently not binding.
- The methodology to determine the GHG emissions of biofuels and electric transport is the same as in the RED, with the exception that the FQD does not allow double counting of 2nd generation biofuels.

CO_2 and cars (CO_2 and cars, 2009):

- Sets an emission target for car manufacturers: the average emissions of new passenger cars from 2015 onwards should be 130 g CO_2/km.
- Electric cars count as zero emission.
- Electric cars (and any other cars with less than 50 g CO_2/km according to the type approval tests) get supercredits until 2016: they may be counted as 3,5 cars in 2012 and 2013, 2,5 cars in 2014, 1,5 cars in 2015 and 1 car from 2016.

ETS:

- Sets a cap to the CO_2 emissions of the EU power sector and industry. Aviation will also be included in the near future. Emission allowances are allocated for free or auctioned (depending on the type industry and year), trading of allowances is allowed.
- This cap has been set until 2020. Any increase in electric power production will thus have to be carbon-free, either by additional emission reductions elsewhere in the ETS (e.g., efficiency improvements in the industry or power sector), or by more carbon-free electricity production.

2.2.2 NL policy

The Netherlands will decide on a national action plan for implementation of the RED in 2009/2010. Final plans have to be submitted to the Commission in June 2010.

The biofuels regulation obliges fuel suppliers to achieve a 4% share of biofuels in the road transport fuels, in 2010.

In addition, various policies are in place to promote electric cars: taxation, local and regional initiatives to promote charging points, ...

2.3 Transport prognoses - how much is 10%?

When deriving scenarios to meet the 10% renewable energy target for transport in 2020, we first need to know how much energy that would be.

Using the Global Economy (GE) scenario of the Netherlands Environmental Agency (Planbureau voor de Leefomgeving, PBL), we find that the energy use in the road transport sector in the Netherlands in 2020 will be around 570 PJ (about 13 million tons of fuel). Passenger cars are the main contributors, with a 64% share, light duty vans have an 11% share, and heavy duty vehicles about 25%.

As we need to replace 10% of this energy use in road transport with renewable energy, we need about 57 PJ of renewable biofuels or electricity. However, as some types of energy count double (biofuels from waste) or 2.5 times (renewable electricity), the actual amount of renewable energy required to fulfill the 10% target may be much lower[6].

Reducing the total energy demand of road transport will also reduce the amount of renewable energy needed to meet the 10% target. We have therefore also looked at two other growth scenarios: one in which the energy use in road transport in 2020 is equal to that of 2010, and one in which the energy use is reduced by 20% between 2010 and 2020. As the GE scenario expects the energy demand to grow by 17% between 2010 and 2020, the two alternative scenarios clearly have much lower renewable energy requirements.

The resulting demand for renewable energy in these three growth scenarios is shown in Table 1. This table clearly illustrates the significant role that preventing further growth of energy use or even a reduction of energy use, can have on the energy demand of the sector and thus on the GHG emissions. If the energy use of the sector would remain at 2010 level, in stead of growing according to the GE scenario, 7.5 Mton CO_2 emissions would be saved. This alone would be much higher than the GHG savings that could be achieved with the 10% renewable energy target: this will not be more than about 4 Mton CO_2 (assuming that the 10% target will be met by renewable energy with 80% CO_2 reduction well-to-wheel, and ILUC is prevented) (ECN, 2007). If energy use would be reduced by 20% between 2010 and 2020, transport CO_2 emissions would be almost 16 Mton lower in 2020 than in the GE prediction.

The table also illustrates that the 10% target can be met much easier (i.e., with much less renewable energy) if energy demand is reduced – or that a higher share of renewables can be achieved with the same amount of renewable energy.

Table 1 **Road transport energy use and CO_2 emissions, and renewable energy target for three different growth scenarios, in 2020**

	Road transport energy use (PJ)	CO_2 emissions (Mton/year)	Renewables target (PJ)
GE scenario, which assumes a 17% growth between 2010 and 2020	570	49.1	57
No-growth energy use scenario	489	41.6	49
-20% scenario	391	33.3	39

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[6] Note that the double counting of 2nd generation biofuels will lead to more fossil fuels, as the energy demand from the sector will remain the same. Electric vehicles are more energy efficient, so they will lead to a reduction of energy demand.

3 Assessment of options

3.1 Introduction

In this chapter, the various options to increase the share of renewable energy in transport are described and assessed:
- electric and plug in hybrid vehicles;
- electric trains and trams;
- electric bicycles;
- Biofuels from waste fat.

3.2 Electric and plug in hybrid vehicles

Little is known about the future development and uptake of the electric and plug in hybrid vehicles. For the present study we have created three uptake scenarios that are loosely based on literature and show a spread of the possibilities.

Two options: electric and plug in hybrid vehicles

In the current situation, car manufactures explore two different options to use electricity as an alternative to the conventional liquid fuels in transport: electric (EV) and plug in hybrid (PHEV) vehicles.

Electric vehicles drive on electricity that is stored in batteries that need to be charged before the trip, from the conventional power grid. When the batteries run out of energy, the vehicle will stop until the batteries are charged again. These vehicles only have electric motors on board.

Plug in hybrids also have batteries on board that can be charged from the national grid before the trip. Their battery capacity is such that a significant range can be driven with the electricity stored in the batteries. However, these vehicles also have an internal combustion engine (ICE) and a conventional fuel tank (gasoline or diesel) which is sometimes called a range extender. If the batteries run out of power, the ICE will take over, thereby allowing a much larger range to be driven before the vehicles need to be recharged or refuelled.

Both options have both advantages and disadvantages, in terms of cost, range, etc, and both types are expected to enter the market in the coming years. As the future technical performance and cost of batteries are still highly uncertain, it is too early to say whether one of these options will win in the long term, or whether they will both be able to develop significant market shares, probably in different segments of the market. One might expect, for example, that EVs would be the preferred options for vehicles that are used for relatively short distances (e.g., current EVs can drive up to 150 km on one battery charge), and that PHEVs would be the main option to electrify vehicles that are used to drive longer distances.

3.2.1 Three scenarios

The number of electric (EV) and plug in hybrid (PHEV) vehicles in each of the scenarios can be found in table Table 2. In all scenario gradual growth of the number of vehicles is assumed, and unchanged car transport demand[7]. Details about the assumptions used for these scenarios are provided in Table 2.

Table 2 Number of electric and hybrid vehicles in three electrification scenarios

	2010		2015		2020	
	EV	PHEV	EV	PHEV	EV	PHEV
Slow uptake scenario	0	0	5.000	20.000	16.000	50.000
Fast uptake scenario	0	0	10.000	40.000	160.000	500.000
C,MM,N scenario	0	0	100.000	25.000	800.000	200.000

All three scenarios use the following assumptions:

- Both electric cars (EV) and plug in hybrid vehicles (PHEV) will be developed and obtain a share of the transport market.
- EVs will have a lower annual mileage than PHEVs (comparable to the current difference between petrol and diesel cars).
- For light goods vehicles the distribution between EV and PHEV will be identical to that of passenger cars.

The slow uptake scenario is based on the ‘business as usual’ scenario in BERR, 2008 describing the uptake of EVs in Britain. There is, however, no EV pilot project in the Netherlands comparable to the stimulation of EVs in London. The number of EVs in 2010 is therefore lowered to 0 for the Dutch situation.

The fast uptake scenario is similar in ambition as the high-range scenario from BERR (2008) but it attributes a larger market share to the plug in hybrids.

Finally the C,MM,N scenario is based on the ambitious vision on EVs in SN&M, (2009). In this scenario the fleet contains a total of one million electrified vehicles by 2020, and EVs dominate PHEVs.

It should be noted that both the Fast uptake and the C,MM,N scenario would probably require a great deal of effort on the parts of the government and car industry, and a technological and cost breakthrough in battery technology.

For these three scenarios the total energy used by electrified vehicles was calculated[8]. To facilitate a more detailed calculation the following assumptions were made:

- Both electric cars (EV) and plug in hybrid vehicles (PHEV) will be developed and obtain a share of the transport market.
- For light goods vehicles the distribution between EV and PHEV will be identical to that of passenger cars.
- Both PHEVs using petrol and diesel will be developed. PHEVs on petrol will run on electricity for 80% of their total mileage while PHEVs on diesel will

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[7] I.e., it is assumed that the vehicle kilometers are the same for all scenarios, and equal to those in the GE scenario.

[8] Note that energy use in the production phase of the vehicles and batteries are not included. The data given here are only for the use of the vehicles.

be mainly used for long distance travel and will only use electricity for 50% of their mileage.
- PHEVs on petrol will be more common than PHEVs on diesel.
- The availability of electric vehicles does not influence the total distance (vehicle kilometres) travelled.

Other assumptions are listed in Annex A.

3.2.2 Results for the GE scenario

The results from the three scenarios are shown in Table 3 and Table 4, where CO_2 reduction results are provided in terms of

1. RED-equivalents, where the 2.5 counting of renewable electricity in road transport is taken into account. These results are given in percentages, as the RED target is not an absolute but a relative goal.
2. CO_2 reduction, compared to the reference scenario where only fossil fuels are used. These results are given in Mton CO_2 reduction per year, for 2020.

Results are shown for two different electricity assumptions: first assuming that renewable energy share is equal to the average EU target for renewable energy in 2020, which is 20% (Table 3); second for the cases that all electricity in the transport sector is produced from renewable sources (Table 4). Note that the first assumption is most in line with current policy.
The GE scenario of the WLO scenario (paragraph 2.3) was used to determine the renewable shares in this table.

Table 3 **Energy use and CO_2 emission reduction due to electrification in the GE scenario, assuming an electricity mix with 20% renewables**

	Renewable electricity	Renewable energy share	CO_2 Reduction	CO_2 Reduction
	(PJ)	RED_eq.	(%)	(Mton)
Slow uptake scenario	0.6	0.3%	0.1%	0.1
Fast uptake scenario	2.8	1.3%	1.8%	0.9
C,MM,N scenario	2.6	1.2%	4.1%	2.0

Table 4 **Energy use and CO_2 emission reduction due to electrification in the GE scenario, assuming 100% renewable energy**

	Renewable electricity	Renewable energy share	CO_2 Reduction	CO_2 Reduction
	(PJ)	RED_eq.	(%)	(Mton)
Slow uptake scenario	3	1.3%	0.6%	0.3
Fast uptake scenario	14	6.1%	3.8%	1.9
C,MM,N scenario	13	5.8%	6.0%	2.9

Clearly, in the slow uptake scenario electric cars contribute little to the overall energy use required. The fast uptake and the C,MM,N scenario result in a renewable electricity contribution of about 1-1.5% if a 20% renewable energy share is assumed, and about 6% if the renewables share is 100%. The C,MM,N scenario, however, achieves much higher CO_2 reduction than the fast uptake scenario, because of the much higher number of EVs that are considered to be more fuel efficient than PHEVs and conventional cars[9]. This leads to a greater reduction of total energy use, and thus CO_2 emissions. This also explains why the CO_2 reduction in the c’mm’n scenario increases only by 0.9 Mton if 100% renewable energy is used: the main CO_2 benefits are due to the reduction in gasoline and diesel use, which is independent of the type of electricity used.

When the (electric) energy mix required by the EU for 2020 is used in the calculations, the effects of electrified vehicles are rather small, even in the quite extreme fast uptake and C,MM,N scenarios. They will contribute about 1% to the 10% RED target. However, if a 100% sustainable energy mix were to be used for transport electrification, a far larger RED-equivalent CO_2 reduction can be obtained in the fast uptake and C,MM,N scenarios, of up to 6.1%.

3.2.3 Results for different growth scenarios

The following tables show the effects of the electrification scenarios for the different transport energy growth assumptions shown in section 2.3. We have used here the same EV and PHEV uptake scenarios as in the previous calculations (i.e., the same number of EVs and PHEVs in 2020), and have assumed that the energy reduction is achieved by reducing the total kilometers driven[10].

These results illustrate that whereas the electricity demand is the same as in the GE scenario, higher shares of renewable energy are achieved. The total CO_2 reduction in these scenarios (compared to the GE scenario) is dominated by the CO_2 reduction of the reduced energy use[11]. The CO_2 reduction due to the renewable energy is much more limited.

Note that the CO_2 reduction shown here is additional to the CO_2 reductions achieved due to lower energy demand (section 2.3).

Table 5 **Energy use and CO_2-emission reduction due to electrification in the no-growth scenario, assuming an electricity mix with 20% renewables**

	Renewable electricity	**Renewable energy share**	**CO_2 Reduction**	**Compared to no-growth scenario**	**Compared to GE scenario**
	(PJ)	RED_eq.	(%)	(Mton)	(Mton)
Slow uptake scenario	0.6	0.3%	0.2%	0.1	7.6
Fast uptake scenario	2.8	1.5%	2.1%	1.0	8.5
C,MM,N scenario	2.6	1.4%	4.8%	2.3	9.9

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[9] The difference between the C,MM,N scenario and the Fast uptake scenario is strongly dependent on assumptions made as to the difference in energy consumption between EVs and PHEVs (see annex A).

[10] This is a rather rough assumption, as energy use can also be reduced, for example, by improving the fuel efficiency of vehicles. However, a more sophisticated modeling of how these different energy growth curves could be achieved was not part of this study.

[11] See section 2.3, where is was concluded that the CO_2 emissions in the no-growth scenario were 7.5 Mton less than in the GE scenario, and in the -20% scenario even 15.8 Mton less.

Table 6 **Energy use and CO_2 emission reduction due to electrification in the no-growth scenario, assuming 100% renewable energy**

	Renewable electricity	Renewable energy share	CO_2 Reduction	Compared to no-growth scenario	Compared to GE scenario
	(PJ)	RED_eq.	(%)	(Mton)	(Mton)
Slow uptake scenario	3	1.5%	0.7%	0.3	7.8
Fast uptake scenario	14	7.1%	4.4%	1.8	9.2
C,MM,N scenario	13	6.8%	7.0%	2.9	10.4

Table 7 **Energy use and CO_2 emission reduction due to electrification in the -20% scenario, assuming an electricity mix with 20% renewables**

	Renewable electricity	Renewable energy share	CO_2 Reduction	Compared to no-growth scenario	Compared to GE scenario
	(PJ)	RED_eq.	(%)	(Mton)	(Mton)
Slow uptake scenario	0.6	0.4%	0.2%	0.1	15.9
Fast uptake scenario	2.8	1.9%	2.6%	1.3	17.1
C,MM,N scenario	2.6	1.7%	6.0%	2.9	18.8

Table 8 **Energy use and CO_2-emission reduction due to electrification in the no-growth scenario, assuming 100% renewable energy**

	Renewable electricity	Renewable energy share	CO_2 Reduction	Compared to no-growth scenario	Compared to GE scenario
	(PJ)	RED_eq.	(%)	(Mton)	(Mton)
Slow uptake scenario	3	1.9%	0.9%	0.3	16.1
Fast uptake scenario	14	8.9%	5.5%	1.8	17.7
C,MM,N scenario	13	8.5%	8.7%	2.9	18.8

3.3 Other electric transport modes

Apart from electric vehicles, there are a number of other options for green electric transport: electric trains, trams, bicycles and scooters, preferably charged with renewable energy.

3.3.1 Electric trains and trams

The oldest and most common modes that use electricity in transport are, of course, the electric tram and train. The renewable electricity used for these modes can also count towards the 10% RED target.

However, the energy use of rail transport is currently only 0.4% of that of road transport[12], despite their much larger share in passenger transport: about 8% of the kilometers travelled are by train, and 3% by bus/tram/metro (there are no separate data for tram and metro travel).

These data clearly show the limitations of these transport modes in contributing to the 10% RED target: a doubling (!) of rail transport means that 0.4% electricity is added, and only the renewable energy share of that electricity can contribute to the target[13]. This also illustrates that the RED target only provides very limited incentive for modal shift from road to (electric) rail.

Achieving modal shift from cars to trains has been a policy objective in the past, but has been very difficult to achieve in practice. Building new railway infrastructure typically leads to some shift from cars to rail, but it also attacks even more new passengers, leading to an overall increase in transport – unless car transport is discouraged at the same time, for example with increased charges (e.g., congestion or parking charges).

As rail transport is more efficient than road transport in most cases[14] (see, for example, the STREAM study of CE Delft (CE, 2008)), modal shift without additional transport can cause significant CO_2 emission reductions. According to CE Delft (CE, 2008), the average emission reductions are as follows:
- Shifting from car to Intercity train will lead to about 30-60% lower CO_2 emissions, where the 60% can be reached if short distance trips are replaced, and the 30% are more typical for the longer distances.
- Shifting from car to metro will reduce about 28% CO_2 emissions.

As concluded above, these CO_2 reductions would, however, not show in the 10% RED target.

3.3.2 Electric bicycles and scooters

In recent years, the electric bike – a bicycle that has a battery and electric motor on board, that provides power to the wheels roughly proportional to the power provided by the cyclist - has gained considerable interest and market share in the Netherlands: e-bikes sales increased from 40,000 in 2006 to 89,000 in 2007 and 134,000 in 2008 (Bovag website). As these bicycles make cycling much easier and more comfortable, they can be a more attractive means of transport than the conventional bicycles for short distances, and could also prove a good alternative for cars for trip distances that are too long for the average cyclist. This is confirmed by a study by TNO (TNO, 2008), in which the current use of electric bike is analysed, and the future potential is assessed: the e-bike is used as an alternative to all modes, but mainly for the car (39%) and conventional bike (45%). The study also confirms that the e-bike is used for trips that are on average longer than the trips made by conventional bicycles: the average distance of commuter traffic by e-bike is about 50% higher than of normal bikes (9.8 km versus 6.3 km).

Using current average CO_2 emission factors for passenger cars (for short distances: 251 g CO_2/km, www.cbs.nl), and assuming that the e-bike is charged with the current average electricity mix in the Netherlands, we can then estimate the potential CO_2-effect of increasing the use of e-bikes. The

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[12] 2.1 PJ in 2010, according to PBL data.

[13] The current renewable energy share of the Dutch railways (NS) is 10% (www.ns.nl), however, this can be expected to increase of the coming decade.

[14] Exceptions are e.g., if the utilisation of the train is low, and that of the car is high.

average emissions of the electricity mix in the Netherlands are assumed to be 569 g CO_2/kWh (ECN, 2007).

The following table provides an overview of a scenario that can illustrate the potential effects of the increased use of electric bicycles. We assume that:

- the current share of the bicycle in the trips shorter than 7.5 km is increased from 32% to 46% (the current share in the Dutch city with the highest bicycle use, Groningen);
- the bicycle share in the trips between 7.5 and 10 km increases from 17% to 28%; and
- the share in the trips 10 and 15 km increases from 12 to 22%.

These seem reasonable growth potentials, but are only intended to illustrate the potential effect. As more scientific scenarios are lacking, the assumptions used here are based on rough estimates of the authors.

The result of this shift from car to e-bike is quite impressive: a reduction of about 12 mln car kilometres per day, which amounts to almost 4% of all passenger car kilometres, and CO_2 emissions of cars reduce by 1.1 Mton CO_2 per year.

On the other hand, the e-bike will also replace part of the bicycle kilometres, leading to an increase of emissions and energy use as these use electricity rather than manpower alone. Furthermore, the car kilometres that are saved will be replaced by e-bike kilometres. Assuming that 20% of all current cycle-kilometres will be replaced by the e-bikes, and all additional cycle-kilometres are driven by e-bike, this will lead to about 90 kton CO_2 emissions per year

Clearly, the net effect of this shift to e-bikes is positive in these calculations, about 1 Mton CO_2 reduction per year.

The electricity demand for the e-bikes is limited, about 0.3 PJ per year in this scenario. This is about 0.06% of the GE scenario for fuel use for road transport in 2020, as described in section 2.2.2.

Table 9 **Illustrative scenario for increase in e-bikes, and its effect on mode choice at short distances**

		Current shares (in kms)		**Assumed shares in the scenario**	
Trip distance	Average km per person per day	Bicycle	Car (driver)	Bicycle	Car (driver)
<7.5 km	5,26	32%	32%	46%	23%
7.5-10 km	1,09	17%	47%	28%	40%
10-15 km	2,53	12%	51%	22%	44%

The e-bike will, however, not contribute much to the 10% renewable energy target for transport in 2020. First of all, because the electricity demand of these bicycles is very limited. In the example shown here, the e-bikes replace almost 4% of the car kilometres, but their energy use is only 0.06% of the total energy use in road transport. Even if this energy would be 100% renewable, and if we multiply it with 2.5 as allowed for the RED target, the e-bikes will only contribute by 0.15% to the 10% RED target. As not all of this electricity will be renewable, the actual renewable energy contribution will be even (much) smaller.

Secondly, these bicycles are typically charged at ordinary power sockets at home, and accurate monitoring of their power use (total and renewable) will be very difficult.

The interest in electric scooters is also increasing. Little is known about their effects, but they seem to be used rather as a replacement for conventional scooters and mopeds than as a replacement of bicycles or cars. They might thus contribute to local air quality and noise reduction, but their effect on CO_2 emissions of the transport sector would then be very limited. If they would also replace car kilometres, their effect might well be comparable to that of electric bikes.

We thus conclude that electric bicycles have the potential to significantly reduce CO_2 emissions of passenger cars, if a shift from cars to e-bikes can be achieved on the relatively short trips. The illustrative example here results in a reduction of 1 Mton CO_2 emissions per year. Other benefits, namely in terms of air pollution and noise reduction, can also be expected. Despite their significant CO_2 reduction potential, their potential contribution to the RED target seems negligible.

3.4 Biofuels from waste oils and fat

As explained in the introductory chapter, Friends of the Earth Netherlands would like to achieve the 10% scenario without biofuels from food crops, and with only very limited use of biofuels from waste and residue streams, if the biofuel production compares favourably to alternative uses (Milieudefensie, 2008).

One of the least debatable options might then be production of biodiesel from waste products such as frying fat or cooking oil. The current Dutch production of these types of biodiesel is at present about 125 million litres[15]. Assuming that these biofuels achieve 88% GHG reduction of the life cycle (RED, 2009), the RED equivalent and the CO_2 reduction due to the use of these biofuels were calculated. The results are shown in Table 10. The current biodiesel production from frying fat achieves about 0.3 Mton CO_2 reduction, or 0.6% of the transport fuel emissions.

Table 10 RED contribution and CO_2 reduction due to the use of biodiesel from current Dutch biodiesel production from used frying fat

		Renewable energy share	CO_2 Reduction
	Energy (PJ)	RED_eq.	(%)
Biodiesel from frying fat	4.0	1,4%	0,6%

NB. The RED-eq of this biodiesel is much higher than the actual CO_2 emission reduction because of the double counting of this type of biofuel for the RED, and the fact that the CO_2 reduction is not 100% over the life cycle.

The current biodiesel production from used frying fat is based on fat that is collected in the Netherlands, Belgium and a part of Germany. Quite a significant part of this feedstock seems to come from Belgium and Germany, as data from 2005 conclude that a total of about 60 kton of used cooking oils was collected in the Netherlands (SenterNovem, 2005), which would result in about 65 mln. liters of biodiesel. This collection might be further optimized in the future, leading to larger volumes of potential feedstock, but no specific data were found for this potential.

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[15] From: NRC, 3 april 2009, based on data from the Vereniging Nederlandse Biodieselindustry and the Euopean Biodiesel Board/.

The current biodiesel production process for these feedstocks is esterification, which leads to a FAME diesel. However, used frying fat and other types of oil or fat waste streams could also be used to produce Hydrogenated Vegetable Oil (HVO).

It should be noted, though, that this feedstock can also be used for electricity production in coal power stations. That route provides more GHG and other environmental benefits for the same amount of feedstock (CE, 2005).

4 Conclusions alternative scenario

4.1 Introduction

The various renewable energy and CO_2 reduction options that were discussed in the previous chapter can now be combined to form the alternative scenario.

This alternative scenario can be approached by two routes:

1. One can aim to meet the 10% renewable energy target set for 2020. This target is aimed at promoting the development and use of renewable energy in the sector, but does not target CO_2 reduction of the sector directly[16].
2. One can also focus on achieving the CO_2 reduction that is expected from the 10% target, about 4 Mton CO_2 in the Netherlands in 2020 (see section 2.3). This approach basically assumes that the renewable energy target is a means to meet a certain CO_2 reduction.

In the following, we will look at what the alternative options can do for both of these aims.

4.2 Focus on reduced growth, and renewable electricity in transport

4.2.1 Focus on meeting the RED target

We can see from the calculations in the previous chapters that meeting the 10% RED target without biofuels requires

a a very significant market share of electric vehicles (EVs) and/or plug in hybrid electric vehicles (PHEVs) in 2020.

b achieving that these EVs and PHEVs are charged by renewable energy that is additional to the renewable energy in the reference scenario.

If the electrification of cars is successful in the coming years, if these are powered by renewable energy and if that renewable energy is monitored and counted towards the RED target, the fast uptake and c'mm'n scenarios can contribute to about half of the RED target, i.e., to 5-6% of the 10%. Reducing road transport volume (energy demand) will increase this percentage to a level almost at par with the RED target (about 8 or 9%).However, if the technological development is much slower, the contribution of electric vehicles to the RED target will be negligible.

There is also scope for biodiesel from used frying fat. The current production contributes 1.4% to the RED target, and there might be scope to increase the production in the coming decade.

Other types of electric transport such as rail transport and electric bicycles offer very little potential to contribute significantly to the 10% target in 2020.

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[16] Note that the RED does give attention to the CO_2 reduction of the renewable energies that are used, as it sets a minimum CO_2 savings requirement for the biofuels. However, as the greenhouse gas emissions due to indirect land use change are not yet included in these calculations, the current methodology is quite unsafe (Bindraban, 2009; Gallagher, 2008; SCOPE, 2009). Furthermore, the RED does not limit the absolute emissions of the sector.

This alternative scenario can thus lead to a maximum of about 7.4% renewable energy in the sector, in 2020 without reducing road transport volume. This assumes that two conditions mentioned above are met, and that the current production volumes of biodiesel from used frying fat is kept constant. This figure includes double and 2.5 counting of biofuels from waste and renewable electricity respectively.
This percentage can be increased by further increasing the use of biofuels (biodiesel or HVO) from waste fat and oils. However, these waste streams would lead to more CO_2 reduction if they would be rather used for electricity production in coal power stations.

4.2.2 Focus on CO_2 reduction

If we focus on meeting a CO_2 reduction target that is equivalent to the RED goal (4 Mton reduction in 2020, in the Netherlands), more options arise. Reducing overall energy demand of the sector, electric vehicles and electric bicycles can all contribute to meet this target.

- First of all, keeping the energy demand of the sector at 2010 levels will lead to a reduction of 7.5 Mton CO_2, compared to the GE scenario – almost twice as much as the RED target would achieve. Further demand reduction will, of course, lead to further reductions: a 20% reduction of energy use between 2010 and 2020 would lead to almost 16 Mton less CO_2 emissions than the GE scenario.
- Creating a significant market share for EVs and PHEVs will also reduce CO_2 emissions, due to the higher fuel efficiency of these vehicles. In our calculations, this effect increases especially with increasing number of EVs, as their fuel efficiency is assumed to be higher than that of PHEVs. Increasing the share of renewable energy in the electricity used will further increase the CO_2 reduction. CO_2 savings are negligible in the slow uptake scenario, but increase to 0.9 and 1.9 in the fast uptake scenario (depending on the type of electricity used), and to 2.0 and 2.9 in the C,MM,N scenario.
- Electric bicycles seem to have a significant potential to reduce car use for short distances, especially in commuter travel. The calculations of section 3.3.2 show that 1 Mton CO_2 is saved if the e-bike manage to increase bicycle shares at distances until 15 km[17].
- The effect of the current biodiesel production from frying fat is about 0.6% CO_2 reduction, about 0.3 Mton.

We also see that the RED target can be met much easier if the growth of the road transport sector is curbed, in particular the energy use of the sector. In the no-growth scenario, the RED target requires about 8 PJ less renewable energy than the GE scenario.

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[17] See that section for an overview of the assumptions behind these calculations.

How much additional renewable electricity would be required?

In **Table 4** page 14, we conclude that we would need about 3–14 PJ additional renewable energy per year to provide 100% renewable electricity to the EVs and PHEVs in 2020. To illustrate this figure, we can calculate how many windmills would be needed to provide this amount of energy.

Windmills are made in different sizes, but a typical offshore 3 MW wind turbine is expected to produce about 6 mln kWh per year (**http://www.vrom.nl/pagina.html?id=6985#a2**). This corresponds to about 0.02 PJ. Therefore, if we want to provide the renewable energy for the slow uptake scenario by offshore wind energy, we would need about 150 of these turbines.
The energy demand of the fast uptake and c'mm'n scenario's is much higher, requiring 650 to 700 of these turbines.
For comparison, the wind park offshore Egmond consists of 36 turbines (108 MW total), the park offshore Ijmuiden has 60 turbines (120 MW total).

4.3 Main barriers and opportunities

Regarding the feasibility of actually realising the options in this alternative scenario, we can identify a number of barriers and opportunities.

First of all, curbing the growth of energy use in transport can be considered an opportunity for CO_2 reduction in the sector. As past and current trends show continued growth, however, current developments in the sector can be seen as a barrier to achieving this.

Other renewables difficult, as biofuels count for 100% carbon free, lock in.

The development of EVs and PHEVs with good performance and reasonable cost are a prerequisite for a significant use of non-biofuel types of renewable energy in the transport sector. The current attention for electric vehicles and PHEVs throughout the car manufacturing sector is clearly an opportunity, some of the electricity companies, car manufacturers and NGOs arouse high expectations. This is therefore also a potential barrier – if the sector does not succeed in developing attractive EVs and PHEVs, electric cars will not be able to achieve the market share necessary to meet the RED target. Current technology is clearly not yet mature enough, as EVs are still very rare and costly, and PHEVs have not yet been introduced in the Netherlands, only a few are operational worldwide. It therefore remains to be seen if the development of these vehicles is successful before 2020.

Another issue is that the type of electricity used to power the EVs and PHEVs is crucial to both the CO_2 reduction and the RED contribution of electric vehicles. The efficiency of EVs is higher than that of comparable conventional vehicles, but if the electricity used is produced in current coal power stations, the CO_2 emissions will be very comparable. If the electricity is produced from gas, a CO_2 benefit is achieved, renewable electricity will further reduce CO_2 emissions.
It is currently not yet clear what type of power generation will be used to produce the additional electricity for electric cars. In the current power sector situation, charging EVs and PHEVs at night or in the weekends (a likely scenario for many potential car owners) is expected to typically increase the base load of the grid, which may lead to additional coal power production. Charging during specific parts of the day may lead to additional gas power production. Renewable energy such as wind power is currently not a marginal power source, so there will be no specific incentive to invest more in those

types of energy. The EU ETS will then make sure that any additional CO_2 emissions lead to equal CO_2 reductions elsewhere (in the EU industry) – unless the cap of the EU ETS is increased in response to an upcoming electricity demand from the transport sector.
We expect that both EU and national policies could be implemented to achieve that the additional electricity for EVs and PHEVs is from renewable, low carbon energy. However, these are not yet in place.

The potential of electric bicycles to reduce CO_2 emissions of the sector seems to be significant, and harvesting that potential seems quite feasible to achieve in the medium term. Fiscal policies could promote their use (e.g., making the higher cost of e-bikes tax-deductible), promotion of the installation of charging points at companies would allow longer commuting distances, improving the quality of bicycle tracks could make cycling more attractive, etc. The technology of e-bikes is proven, and performance and cost improvements can still be expected if the market shares increase further.

It is expected that there is an opportunity to further increase the potential of biofuels from waste streams, that do not create negative impact on greenhouse gas emissions, biodiversity, social economic conditions, etc. These opportunities should be assessed, and their potential should be harvested, also in the light of potential other applications of these feedstocks, for example in electricity production.

Loopholes in current policies

It should be mentioned that there are number of loopholes in the current policy regarding electric vehicles, that could significantly reduce the positive effect of the scenario shown here. These could be solved in the coming years, mainly during the review process of EU policies, but also with national policies. The following issues came up during the course of this project:

- The current CO_2 regulation for passenger cars counts EVs as zero emission vehicles, and in the coming years (until 2016) they even get 'supercredits', as explained in section 2.2.1. As long as the energy they use is not 100% carbon neutral, the sales of EVs can lead to a net increase of passenger car emissions: as car manufacturers have to meet an average CO_2 emission target of the cars they sell (130 g/km in 2015 and further reductions are anticipated), every EV sold in 2015 means that the manufacturer can sell, for example, one 260 g/km vehicle, or ten 143 g/km vehicles. As these vehicles are likely to have higher annual mileage than the EV, and as the EVs will not be zero emission but will cause emissions due to electricity production, the net effect will be an increase of emissions.
- There is a significant risk that the total transport volumes (kms) increase due to electric cars under current policies, for two reasons:
  - The cost per kilometre is lower than with current cars, due to lower taxes on electricity than on diesel and gasoline, and due to the higher fuel efficiency. Literature clearly shows that lower km cost will cause an increase in kms driven.
  - Local and regional governments are starting to implement stimulation policies for electric vehicles, such as access to environmental zones, free parking etc. This may lead to a modal shift from public transport and bicycle to EVs in these areas, thus also increasing car kilometres.
- In the current policy regime and power structure in the Netherlands, there is a significant chance that electric vehicles will lead to additional coal power. As this type of power production causes high CO_2 emissions, the significant CO_2 reduction potential of these vehicles will then be cancelled out. In addition, this will increase the pressure on the EU ETS, potentially raising the cost of emission allowances.

- There is currently no means to monitor the actual electricity use by electric vehicles, or their renewable energy use. Especially the latter is necessary for the alternative scenario, as the renewable energy needs to be reported to the EU, to demonstrate that the RED target is met.

5 Policy recommendations

5.1 Introduction

Based on the conclusions in the previous chapter, we conclude that there are a number of non-biofuel options that can have significant potential to fulfil a significant share of the 10% RED target, and to reduce CO_2 emissions to an extent comparable to what the biofuels might achieve.

However, this alternative scenario will not be realised automatically, without policy intervention and investments. Experience in recent years shows that the Dutch government regards biofuels as the main option that will be developed to meet the RED target. Electric vehicles are being developed, but their large scale market introduction is still uncertain.

In the following, we have derived a number of policy recommendations aimed at realisation of these alternative options. These are primarily geared towards the Dutch situation analysed in this report. However, many of the issues described in this report will be also applicable to other EU countries that are designing policies to comply with the RED.

5.2 Recommendations

There are still large uncertainties regarding future renewable energy options in transport, both regarding biofuels and regarding electric transport. We therefore recommend governments to focus on the ones with largest future potential, that offer the best long term opportunities for sustainable and carbon free transport. At the moment, these options seem to be
- reduction of transport energy demand (by reducing transport volume and by increasing energy efficiency in the sector);
- electric road transport that uses renewable energy; and
- sustainable biofuels from feedstock that does not cause direct or indirect land use change, and compare favourably with use in the electricity sector.

Reducing the growth of transport energy demand (and, in the long run, reducing demand itself) should always receive sufficient attention. Any growth in energy demand will make CO_2 reduction in the future more difficult, as long as sustainable renewable energy remains limited and costly.

If the technology and cost of EVs and PHEVs is improved successfully in the coming decade, they have significant potential to reduce CO_2 emissions in the sector in the longer term. Governments should therefore assess the impact of these developments, and adapt policies to harvest their potential.

In order to realize the alternative scenario, the renewable energy production should be increased in line with the growth of electricity demand from EVs and PHEVs. This should be additional to the increase of renewable energy production required to meet the Dutch 14% RED target for 2020. In addition, the RED policy should be adapted to allow governments to include this renewable electricity to count towards the 10% RED target in transport[18].

There are still a number of loopholes and barriers in the current policies, and also potential rebound effects may significantly reduce the benefits that electric road transport could achieve. These are briefly discussed in section 4.3. They should be addressed and solved in the coming years.

Replacing car transport with cycling in short distance trips can significantly reduce CO_2 emissions. The electric bicycle now provides an opportunity to achieve this modal shift, and to increase bicycle shares of trips shorter than 10 or 15 kilometres. Policies to promote this, especially targeted at commuters, seem to have significant CO_2 reduction potential and should therefore be implemented.

In view of the current uncertainties surrounding a large part of current biofuel production, and the uncertainty of a potential breakthrough of electric vehicles, a robust policy strategy should be developed for the coming decade. For example, the period between now and 2014 (the RED review date) could be used to focus on R&D and first market introduction of EVs and PHEVs, and on the further assessment of the true potential for sustainable biofuels that do not cause land use change. At that point in time, it should have become clear which options are successful, and which options are technically too complex, too costly or not sufficiently sustainable. More detailed policies can then be implemented. Until then, the biofuels consumption could remain at the current level, to avoid further increase of feedstock cultivation (and associated land use change), and further investments in biofuel production capacity that may prove unnecessary or even counterproductive for longer term sustainable transport developments[19].

Governments will need to find a balance in the short term: setting ambitious targets for specific technologies now seems to be too early and may result in wrong investments, but a potential market must be created for new technologies in order to convince industry to invest. Technology-neutral policies such as the CO_2 standards of new cars can prove useful to encourage R&D in various different technologies – if they are stringent and ambitious enough.

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[18] The current directive only allows to use the average renewable energy share of the electricity mix.

[19] See, for example, PBL 2009.

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Annex A Electric and plug in car scenarios

As the uptake of EVs and PHEVs is still highly uncertain, as outlined in section 3.2, we have designed a number of market introduction scenarios for the purpose of this study. In these scenarios, the number of EVs and PHEVs sold yearly was varied, leading to a different market share of these vehicles in the various years.

The growth of the number of EVs and PHEVs in the Dutch car park is shown in Figure 1, Figure 2 and Figure 3, for the three scenarios. Note that the first two scenarios, the slow and fast uptake scenarios assume that the PHEVs gain the largest share in the coming decade, whereas we assume in the C,MM,N scenario that most of the 1 million electric cars in 2020 are EVs.

Figure 1 Uptake of EVs and PHEVs in the Dutch passenger car park, in the Slow uptake scenario

Figure 2 Uptake of EVs and PHEVs in the Dutch passenger car park, in the Fast uptake scenario

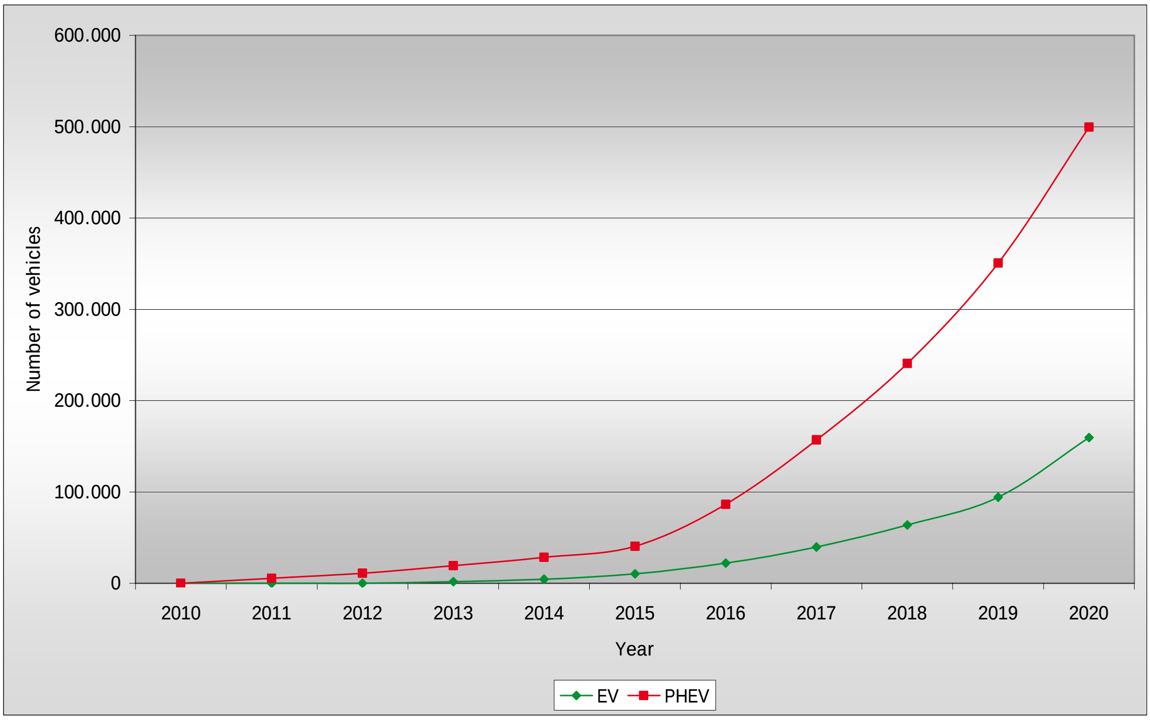
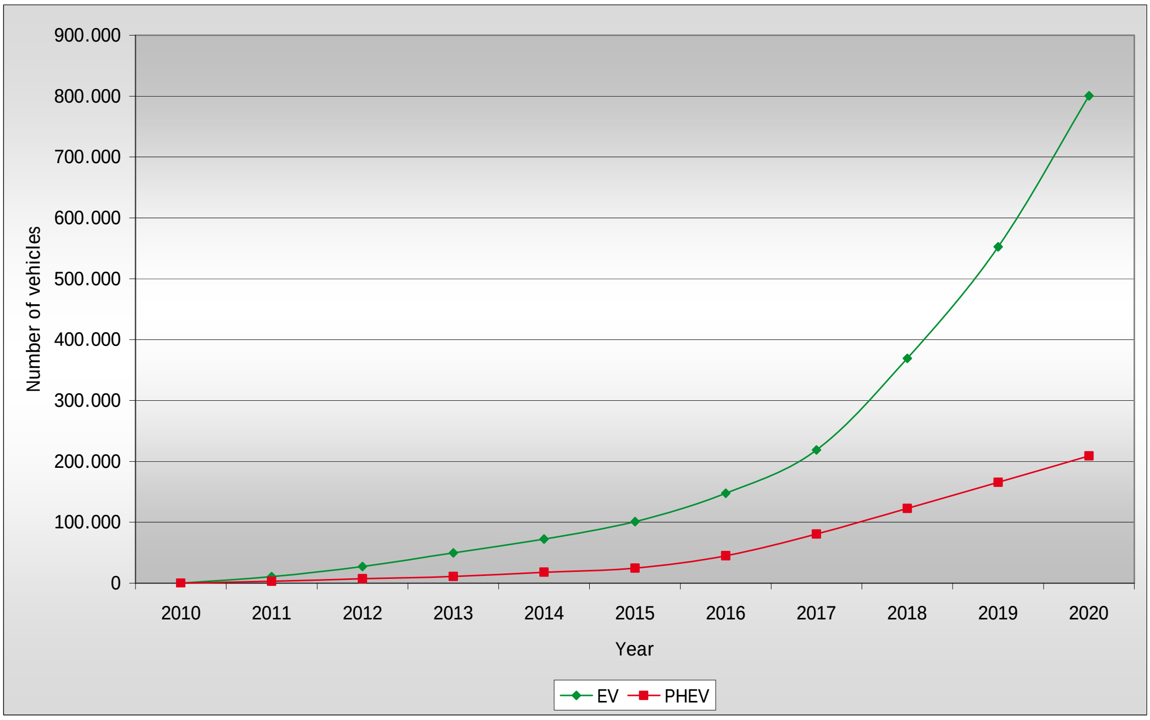


Figure 3 Uptake of EVs and PHEVs in the Dutch passenger car park, in the C,MM,N scenario



Other assumptions used for these scenarios are

- In the slow and fast uptake scenarios, the average kilometers driven per year by EVs is 0.8X that of gasoline cars. In the C,MM,N scenario, it is assumed that the performance of EVs improves significantly in the coming decade, and the average kilometers/year will be equal to that of gasoline cars.
- The average kilometers driven by PHEVs on gasoline is assumed to be equal to that of conventional gasoline cars, and PHEVs on diesel have equal annual mileage to that of conventional diesel cars.
- PHEVs on gasoline drive 80% of their annual mileage on electricity, whereas diesel PHEVs drive 50% on electricity.
- Electric cars are assumed to consume 0.72 MJ/km (based on data in CE, 2008), the PHEVs are assumed to be 20% more efficient than their conventional counter parts.