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THE IMPACT OF A CO_2 REDUCTION TARGET ON THE PRIVATE CAR FLEET IN THE NETHERLANDS

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ABSTRACT

Climate change mitigation calls for a massive reduction in CO_2-emissions from human sources. A primary human source is combustion of fossil fuels. Transport by road is one of the major and growing users of fossil fuels worldwide. Private cars with internal combustion engines dominate our roads. This paper discusses the feasibility of aligning CO_2-emissions of private cars with the Paris Climate Agreement for 2030. It starts in 2010. Country of study is The Netherlands. The relation between climate change and air pollution is taken aboard. The following research questions will be addressed: How many private cars were there in The Netherlands, how many kilometres were driven and what were their CO_2, NO_x and PM_{10} emissions in 2010? What would these values be in the year 2030 assuming continuation of current trends in technology and policy? What could these values be if there were only full electric vehicles (FEV) on the road by 2030? Would behavioural change be necessary to reach the national CO_2-reduction target for 2030? In the simulation model assumptions were used about car ownership and volume, electric cars, fuel efficiency and electricity mix. Car production could be limited to the most fuel-efficient and lowest emission electric cars. Buyers' choice would become restricted. Fulfilling the Dutch CO_2-emission reduction target for 2030 is only possible by using state-of-the-art technology in a fleet of 100% full electric cars (FEV) and a major reduction in yearly car kilometres (either per car or via fewer cars). This assumes a revolution in car production and sales and an active mobility reduction and modal shift policy. The first has just started, while the second and third are unlikely after decades of liberal policy-making, which has stimulated car mobility by expanding the road network, increasing maximum speeds and cutting public transport budgets.
Keywords: climate change, transport, technology, behaviour, car use, simulation, 2030.

1 INTRODUCTION

Climate change is due to emissions of greenhouse gases by interacting natural processes and human activities [1]. The focus will be on the latter, more in particular from combustion of fossil fuels in private cars. The rationale is that road transport dominates mobility on land. It has a share of well over 25% in the final energy consumption in OECD countries [2]. Car use dominates road transport in terms of vehicles and kilometres. Most cars are privately owned and used (Table 1). Nearly all have engines in which fossil fuels are combusted. They use energy in a very inefficient way; only 12–30% of the energy input is available as effective kinetic energy [3]. The rest is wasted as heat and emissions, in particular of CO_2, NO_x and PM_{10}. CO_2-emissions are directly linked to climate change [4]. NO_x and PM_{10} are key air pollutants and detrimental for human health [5], [6] and nature [7].

The relation between climate change and air pollution is important [8], which explains why regulators oblige car manufacturers to reduce both [9].

Climate change mitigation means reducing CO_2 and other greenhouse gases by [10]:

1. Avoidance (activity reduction); less frequent or shorter trips reduce the total number kilometres driven by all cars in a year, or in case of growth in total car kilometres, mitigate this growth;
2. A modal shift from car to public transport or active modes (walking, cycling);

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Table 1: Estimated car use in The Netherlands in 2010. *(Source: [13].)*

Ownership	Yearly car (driver) use in million kilometres				
	Petrol	Diesel	Gas	Electric	All
Private	55143	18404	3251	0	76798
Business	8367	12075	429	0	20871
Total	63510	30479	3680	0	97669

3. Energy intensity reduction, i.e. a higher fuel efficiency of cars;
4. Use of low carbon fuels, which means considering electric or hybrid-electric cars as (full) replacement of cars with internal combustion engines.

A choice was made to focus on car-only options, which excludes option 2.

The paper investigates the impact of a national CO_2-emission reduction policy with variable targets on the car fleet in a country, in this case The Netherlands. Technical and behavioural changes are seen as policy variables. Base and reference years are 2010 respectively 2030. The following questions were addressed:

1. How many private cars were there in The Netherlands, how many kilometres were driven and what were their CO_2, NO_x and PM_{10} emissions in 2010?
2. What would these values be in the year 2030 assuming continuation of current trends in technology and policy?
3. What could these values be if there were only full electric vehicles (FEV) on the road by 2030?
4. Would behavioural change be necessary to reach the national CO_2-reduction target for 2030?

Tools used were desk research, scenarios, a simulation model, and (quantitative) evaluation.

2 THE SYSTEM AND THE PROBLEM

2.1 Introduction

The Netherlands is a densely populated small country with 16.6 million inhabitants in 2010. Population density is in the top-3 of the world with about 412 people/km^2. Car (driver only) mobility approached 98 billion kilometres with 7.6 million cars in 2010 (Table 1). There were 17.13 million inhabitants and 8.2 million cars by 2017 [11], [12].

2.2 Car use related emissions in The Netherlands (2010)

To estimate the corresponding tail pipe emissions, the car kilometers in Table 1 were multiplied by the average fuel consumption and emission factors per fuel type (Table 2).

Table 2: Car emissions in The Netherlands in 2010. *(Source: Own estimations.)*

Metric	Yearly emissions of all cars		
	CO_2	NO_x	PM_{10}
Tons	12257031	20224	9150

2.3 EV fleet by 2016

There were no electric vehicles (EV) in The Netherlands in 2010. This changed after a new national tax regime in favour of cleaner cars and a growing charging network. By 2016 86.200 EV were on the road. Their average purchase price was (is) way above the price of a similar conventional car. For private owners this is too expensive, while the tax regime favours business owners. As a result, they own 99% of all EV. Business users tend to drive (much) more kilometres than private users. The driving range of an FEV is very limited. All this explains the high number of PHEV (Table 3). PHEV emissions of CO_2 are less, but those of NO_x and PM_{10} are worse than those of fuel-efficient petrol cars, however [14].

2.4 Car use and emissions in The Netherlands (2030)

The following assumptions were used to estimate car kilometers in the year 2030. First, the economic recession (2008–2014) and recovery after 2014 balance each other out. This gives a stabilization of car use for the period 2010–2020. Second, an annual growth in car kilometers of 2% is expected for 2020–2030. Third, the division of engine types stays the same. Fourth, cars with internal combustion engines still dominate in 2030. Tables 4 and 5 provide the kilometers and emissions on a tank-to-wheel (TTW) basis.

2.5 Growth of the car fleet compensates technical progress

Decoupling of economic activity growth and emissions is a way to mitigate climate change. In the earlier data, a linear relation between the two is assumed; both may grow by 21.9%. So, there is no decoupling. This could be regarded as conservative, given the latest statistics, which indicate that due to technical progress average CO_2-emissions of new cars

Table 3:

Table 3: EV cars and ownership, NL 1-1-2016. *(Source: [15].)*

Ownership	PHEV	FEV	Total
Business	75.270	9.347	84.617
Private	980	603	1583
Total	76.250	9.950	86.200

Table 4: Car use in The Netherlands in 2030. *(Source: Own estimations.)*

Ownership	Yearly car use in million kilometres by fuel type				
	Petrol	Diesel	Gas	Electric	All
Private	67219	22434	3963	-	93616
Business	10199	14719	523	-	25441
Total	77418	37153	4486	-	119057

Table 5: Car emissions in The Netherlands in 2030. *(Source: Own estimations.)*

All combined (year)	Yearly emissions of all cars		
	CO_2	NO_x	PM_{10}
Tons	14941321	24653	11154

has been reduced from 181 to 106 grams/kilometre between 1998 and 2016 [16], while EU regulators aim to reduce these even further.

Yet, conservatism seems warranted. First, fuel efficiency is a trade-off between costs; drive quality and safety [17]. Cars are increasingly sold with advanced systems for protection (airbags, ABS, ESP), entertainment, navigation and climate control. These systems add weight (e.g. 30% between 1993 and 2004) to a car and also use energy themselves [18]. Official test cycles are manipulated by favourable conditions, such as a warm engine start, switching off these systems and temporary modifications of engines, tyres etc. With diesel passenger engines, there is the "Dieselgate" fraud with (at least) one manufacturer manipulating its engine management software [19]. Experts also regard pre-2017 road test cycles as "tame" [16] considering the available horsepower [17]. There is an increasing and unfavourable gap (now 35%) between test cycles and real driving [16].

Other factors that limit the potential of new technology to reduce CO_2-emissions are an extended technical life of cars with reduced maintenance requirements plus economic uncertainty. These factors explain why an average private car is scrapped after 18 years [20]. Only 12% of all cars sold each year are new, the remainder are used cars [21].

The growth of the car fleet largely compensated for the achieved reduction of CO_2-emissions per car. As a result, CO_2-emissions of cars were fairly stable in the period considered. Technical progress may allow a substantial increase in fuel efficiency and reduction in emissions by the year 2030, but there is no guarantee.

Questions 1 and 2 are answered with the data in Tables 1–4 and the explanation above. All emissions will rise without more stringent policies and effective technical development.

2.6 The root problem: Politics, policy-making and the environment

2.6.1 Urgency and scope

The urgency of CO_2-reduction was discussed at subsequent UN conferences. The most recent was the one in Paris in 2016. The Paris Agreement, which was signed by 195 countries, deals with national CO_2-reductions. They should prevent the threat of a prolonged rise of the global average yearly temperature of 2% above pre-industrial levels; an out-of-control scenario. A reduction to 1.5% is advised to prevent islands from being swallowed by the oceans [22]. The world is now approaching the (short term) 1% average growth [23]. It may reach 2.7% in a business as usual scenario [24].

2.6.2 Multiple pollution sources

CO_2 is a prime target, but it is not the only greenhouse gas. Methane (CH_4) is another, with a 25 times higher global warming potential (GWP). Hence, it is much more damaging.

The Netherlands is the second largest agricultural exporter of the world, just after the USA. Among the many negative externalities of agriculture is the emission of methane (and N_2O). The country is also a major producer and consumer of natural gas. Its main seaports Rotterdam and Amsterdam are among the world's main importers and exporters of fossil fuels. Table 6 provides more insight in the national sources of CO_2-emissions.

Large sources of CO_2 are thus a major source of income and a major economic and political force in the country. This puts the environment in a rather difficult spot.

2.6.3 Laissez faire

During three decades, neoliberal "business first" policy-makers have deregulated the economy and cut spending on nature and environment, including research and protection [26]. Ministers of Transport (and Environment called officially) expanded the highway

Table 6: CO_2-emissions 1990–2016[1)] in Mton CO_2-equivalents. *(Source: [25].)*

Activity/sector	Years			
	1990	2000	2010	2016
Industry and energy	94	98	101	101
Agriculture	8	7	10	7
Traffic and transport	32	37	39	35
Built environment	29	29	33	24
Total	163	172	183	167

[1]Preliminary data for 2016.

network and increased maximum speed from 100 to 120–130 kilometres on many road sections. The ministry even tried to remove environmental zones and 80-kilometre speed limits on main roads crossing cities, arguing that these zones were limiting business and that the speed reduction led to more congestion and air pollution. Simulations indicated an increase in congestion due to a more complex driver task, but also a reduction in total emissions measured over a whole day and of noise [27], however.

Air quality in The Netherlands has improved in the past decades due to de-industrialisation and cleaner technology in many sectors. Yet, the country still scores average in Europe regarding air quality. It is true that air pollution also originates in other countries, while the sea and sea shipping are also major sources of air pollution. This so-called background level cannot explain the rather poor air quality along many streets in major cities, however [28].

2.6.4 The Paris Agreement and The Netherlands

In a 2% scenario, The Netherlands has to reduce CO_2-emissions by 50% by the year 2030 and even 85–95% by 2050. A 1.5% limit would demand a 100% cut [29]; all values compared to the 1990 data. CO_2 targets cover all economic activities, but the implications per activity may vary, depending on the actual share in the emissions and the way public and private decision-makers respond to the Agreement. Politicians and lobbyists were prominently present, but whom do they actually represent?

The drastic CO_2-targets strongly deviate from the trend in Table 6. Awareness is rising, however. As a result, many decision makers are busy to reduce their energy consumption and emissions. The achievements per unit (car or other product) are still (largely) compensated by a growth of consumption, production and trade, however.

A massive reduction in CO_2-emissions may only be achieved by a drastic decarbonisation of the Dutch economy. This demands terminating the use of natural gas for heating, different pricing for energy and electrification of road transport [30]. A transition from carbon to renewables is even more complex considering the short time-span and until now very modest and fluctuating government incentives, which limits investments [31].

3 METHODOLOGY

3.1 A simulation model

A MS© Excel© model was built to estimate the energy consumption and emissions of a fleet of private cars with different engine-fuel types.

The model consists of several modules:

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- A module to enter data and estimate fuel consumption and emissions. The model takes as input kilometres driven per year, emission factors and average fuel consumption per kilometre. It then calculates total fuel consumption and emissions;
- A solver module where policy scenarios are entered as constraints in a linear programming exercise;
- Tables with fuel consumption, emission factors (EF) and TTW-WTW conversion;
- Tables with the electricity mix to charge EV batteries (with emission factors based on the current grey-green mix of energy sources or only green energy sources);
- A module, which adds dynamics (growth of the car fleet, change in electricity mix).

3.2 Key parameters

Like in earlier studies, it was necessary to combine data from many sources, both academic as well as professional. Data from car manufacturers was too biased.

The averages in Table 7 are key to estimate emissions (Section 4). For a complete picture, from here on they will be expressed on a tank-to-wheel (TTW) basis. Well-to-wheel (WTW) values were multiplied with a "WTW-factor" [32]. No multipliers were found for NO_x and PM_{10} in literature. CO_2-multipliers were used to adapt all WTW values.

4

4 AN APPLICATION

4.1 Purpose

In Section 2 it became apparent that the total number of kilometres driven by persons as car driver has become stable over time. A growing car fleet then means that more drivers (and less passengers) drive fewer kilometres each on a yearly basis. The latter corresponds with an increasing number of second cars in households and growing number of female car drivers. Women tend to drive (substantially) fewer kilometres per day than men [34].

Table 7: Input parameters. *(Source: Own estimations.)*

[1]	Fuel use (litre/100 km)	Electricity use (kWh/100 km)	Emission factors (CO_2)
Petrol	5.6		2269
Diesel	4.7		2606
LPG	6.6		1610
Hybrid[2]	4.45		2269
PHEV[3]	1.8	11.6	2269 + 464
FEV[4]	–	15.3	464
Hydrogen[5]	N/A	N/A	N/A

Notes:
[1]All values are averages for a representative car fleet and based on the New European Driving Cycle (NEDC);
[2]Hybrid = 2 engines (diesel or petrol plus electric engine) in one car, which cannot be charged from a wall socket;
[3]PHEV = plug-in hybrid electric vehicle, a car which can be charged by the internal combustion engine or by a wall socket;
[4]FEV = full electric vehicle, a car with an electric engine, which is charged externally;
[5]Hydrogen cars will not be considered, because of the uncertainties regarding H_2 [33].

Overall CO_2-emissions are also rather stable over time. This has profound implications for the feasibility of climate change mitigation.

The remaining two research questions will be addressed next: What is the potential of (new) car technology to reduce CO_2-emissions and is behavioural change inevitable?

4.2 Five (policy) scenarios for 2030

Scenarios can be written as different sets of (policy) targets for the year 2030 in comparison to base year 2010. The following assumptions were used:

- A significant and substantial market share of FEV's in 2030;
- Phasing out of internal combustion engines by engine type in 2030;
- Phasing out of fossil fuels in 2030;
- Electricity mix in 2030. It is very difficult to comprehend this mix, both now and in future. In the simulation an actual mix corresponding with 442 g/kWh was used, but this may be too optimistic. A green grid is used as an alternative;
- No significant improvement in fuel efficiency between 2010 and 2030. There will still be a mix of older and newer cars on the road. It is impossible to predict if new technologies will be available and what their impact will be by 2030.

The model introduced in Section 3.1 was used to simulate future emissions of CO_2, NO_x and PM_{10}. The scenario assumptions act as boundary conditions in the model. It is obvious that a reduction in emissions must come from fewer kilometres by cars with internal combustion engines in favour of EV. Increasing the number of PHEV is not a solution, hence they are not considered any further in the simulation. The question is, how much change fulfills the CO_2 target for 2030 (Section 2.6.4)?

4.3 Impact on emissions

Only the fifth "all or nothing" scenario approaches the target for 2030. The following can be concluded per scenario (Tables 8 and 9).

Less convention engines (Scenario A)

In Scenario A 25% of all cars with internal combustion engines are swapped by the *less* polluting electric equivalents (FEV) charged by grey electricity.

In this scenario CO_2-emissions will not go down, but up. This can be explained by the 21.9% growth of the car fleet between 2010 and 2030, the use of grey electricity and the assumption that cars will not become more fuel-efficient.

As can be derived from Table 1, about 87% of the petrol cars are privately used. Current business-oriented tax reduction policy for the purchase of an EV will thereafter hardly impact the market for petrol cars. It might have an effect for the diesel market, because 39.6% of the diesel cars is owned by businesses.

It would be advisable to revise the current tax regime to incorporate privately owned cars as well in order to make electric cars much more affordable for the general public.

Phasing out petrol engines (Scenarios B and C)

In both scenarios, a small to moderate reduction in CO_2-emissions may be achieved, as well as a small reduction in NO_x and a major reduction in PM_{10}.

Double A (Scenario D)

Scenario D is more rigorous than scenario A, but the reduction in CO_2-emissions is limited. It is more beneficial to focus on a rapid and vast reduction of the petrol car portion of the car fleet in exchange for FEV and the grey electric infrastructure (Scenarios B and C).

Table 8: Policy targets and emissions in Scenarios A–C. *(Source: Own estimations.)*

	Scenario A	Scenario B	Scenario C
Change in kms by fuel type (compared to the 2010 values)			
Petrol E95	-25%	-75%	-100%
Diesel	-25%	-25%	-25%
LPG	-25%	-25%	-25%
FEV grey electricity[1]	> 0	> 0	> 0
Emissions in metric tons/year			
CO_2	13261415 (8%)	11090905 (-9.5%)	10005650.(-18.4%)
NO_x	20767 (2.7%)	21018 (3.9%)	21144 (4.6%)
PM_{10}	84113 (-8.1%)	51756 (-43.4%)	35577 (-61.1%)

[1]Electricity generation with fossil fuels only.

Table 9: Policy targets and emissions in Scenarios D–E. *(Source: Own estimations.)*

	Scenario D	Scenario E
Petrol E95	-50%	-100%
Diesel	-50%	-100%
LPG	-50%	-100%
FEV grey electricity	> 0	100%
CO_2	11658344 (-4.9%)	8452202 (-36.3%)
NO_x	16880 (-16.5%)	9108 (-55%)
PM_{10}	5668 (-38.1%)	182 (-98%)

Full throttle (Scenario E)

Scenario E shows that it is possible to reduce CO_2-emissions by more than 36% when only FEV are in use on Dutch roads.

4.4 Considering NO_x- and PM_{10}-emissions

The results indicate that a certain CO_2 reduction does not automatically imply a similar linear reduction in NO_x- and PM_{10}-emissions. Especially the NO_x values are hardly reduced when many internal combustion cars remain on the road and the electric ones are powered by grey electricity.

5 EVALUATION

5.1 Going (all) green?

Clearly, a higher CO_2 target can only be achieved if electric cars are powered by green electricity. For instance, to cut the 2010 CO_2 emissions of scenario A (viz. 6628122 ton/yr) by half requires an emission factor of about 366 g/kWh (TTW) or 323 g/kWh (WTW). This assumes a significantly greener electricity mix, either from large-scale wind- or solar (PV) facilities or small-scale solar PV (to directly charge car batteries).

The ambitious CO_2 mitigation target obliges to fully replace the actual car fleet on Dutch roads by FEV, because (see Table 7) hybrid and PHEV are not clean enough.

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By considering the TTW of cars, in essence the entire chain must be addressed. This indicates that a much higher effort is needed to reduce the total level of car emissions.

The newest Dutch cabinet agreement is a mix of various financial instruments without cohesion and hardly any budget for sustainable measures [35]. A desire to only sell electric cars from 2030 onwards and hence ban conventional engines raises many questions:

- Which types of engines would be precisely banned? How is this ban enforced?
- How will car buyers react to such a measure? Will they import cars and/or extend the period of ownership of their present cars? Will be there a hausse in sales of regular petrol and diesel cars just before 2030 (making the impact of the policy measure largely ineffective for about another 10 years)?
- What is the legal basis? The Netherlands does not have a car industry. Blocking imports is against EU law.

Finally, it is important to realize, that emissions of other road users such as vans, trucks, buses and coaches should also be included in the analysis to understand the full scale of the climate change mitigation challenge as far as road transport is concerned.

5.2 More detailed scenarios are welcome

The above scenarios are deliberately general. They fulfill their purpose in the presented simulation exercise. More realism can be added by incorporating details like:

- Technical progress: A status qua was assumed, largely based on the past trend concerning energy efficiency in cars;
- Battery production: There is an enormous shortage of production capacity for EV-batteries, which limits production of electric cars. Planned mass production of EV-batteries may remove that bottleneck and also lower the parts price substantially;
- Car price: Car batteries make up for half of the purchase price of an FEV. The same is true is expensive raw materials in the batteries were to be replaced by cheaper alternatives;
- Use: There are different types of car use. Currently, the limited driving range and long downtime for charging makes FEV unattractive for longer distance trips. In summer (air conditioning) and winter (heating) batteries run out very quickly;
- Acceptance: a much lower purchase price, increased driving range and faster charging increase the attractiveness of EV.

5.3 Towards an individual mobility budget

The above technology-centric scenarios were used to estimate the impact of large-scale substitution of one engine/car type for another.

The ecological footprint of man is far beyond the capabilities of the earth. The human-centric idea that nature is there only to serve humans is likely to turn against man itself. It is time for policymakers and lower level decision makers to really understand value of nature and act accordingly. Mobility has become one of the social additions [36]. If individuals would ask themselves if car use is really necessary (all the time) and act accordingly, then the number of kilometres driven per car could be reduced. The same holds for the decision to own a car or to hire/share it if necessary [37].

The idea of limiting car use to a certain yearly mobility budget is a logical consequence of the climate change mitigation initiative and a way to escape from a key tragedy of the commons, which the climate issue really is. A personal mobility budget could be freely divided over modes of transport. The more polluting ones will of course have a large penalty.

6 CONCLUSIONS

The paper has addressed the potential impact of new car technologies on the CO_2-emissions of privately used cars compared to the climate change mitigation agreement of Paris in 2016.

A rise in the number of cars and the total number of kilometres goes along with higher CO_2-emissions. If private car mobility will develop without restraints, then only a full substitution of cars with conventional internal combustion engines by full-electric equivalents will help to bring the emission target nearer. But, it is not enough. These electric cars should also run exclusively on green electricity. Even then, then the target is not in reach.

The results indicate that a certain CO_2 reduction does not automatically imply a similar linear reduction in NO_x- and PM_{10}-emissions. Especially the NO_x values are hardly reduced when many internal combustion cars remain on the road and the electric ones are powered by grey electricity.

Behavioural change is necessary. This includes having people buy electric cars. Technical progress is needed to make EV more affordable for a general public. Technical progress is also necessary to make electric cars as usable as conventional cars. The situation will of course be quite different if car manufacturers, like some already have expressed, will stop making non-EV in future. Without this technical progress, the social cost of the transition process will be excessive, which is a recipe for resistance and subsequent failure.

Another discussed behavioural change, namely to give everyone a yearly mobility budget, could be very interesting to completely bend the trends in fuel consumption and emissions and prevent the foreseeable out-of-control scenario. There will be strong resistance from the general public, as many still don't see the necessity to act in favour of the environment or have the financial means to do so.

REFERENCES

[1] IPCC, Understanding and attributing climate change. www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter9.pdf.

[2] IIASA, Energy End-Use: Transport. www.iiasa.ac.at/web/home/research/Flagship-Projects/Global-Energy-Assessment/ GEA_Chapter9.pdf.

[3] Where the energy goes: Gasoline vehicles. www.fueleconomy.gov/feg/atv.shtml.

[4] IPCC, *Climate change 2014, Mitigation of climate change, Working Group III Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press: Cambridge, USA, 2014.

[5] Chu, J., Air pollution causes 200,000 early deaths each year in the U.S., MIT News Office, 2013.

[6] Rossman, R.E., The effect of vehicular emissions on human health. teachers.yale.edu/curriculum/viewer/initiative_08.07.09_u.

[7] National Park Service, Ecological effects of air pollution. www.nature.nps.gov/air/AQBasics/ecologic.cfm.

[8] US EPA, Air quality and climate change research. www.epa.gov/air-research/air-quality-and-climate-change-research.

[9] E.g. Dieselnet, EU: Cars and light trucks. www.dieselnet.com/ standards/eu/ld.php.
[10] Sims, R. et al., Transport. *Climate Change 2014: Mitigation of Climate Change, Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press: Cambridge, UK and New York, USA, 2014.
[11] CBS, www.statista.com/statistics/263749/total-population-of-the-netherlands/ opendata.cbs.nl/#/CBS/en/dataset/82044ENG/table?ts=1517220682507.
[12] Van der Waard, J., Jorritsma, P. & Immers, B., New drivers in mobility: What moves the Dutch in 2012 and beyond. Discussion paper presented at *OECD International Transport Forum*, Oct. 2012.
[13] CBS, *StatLine: Verkeersprestaties motorvoertuigen; kilometers, voertuigsoort, grondgebied*, Den Haag: Heerlen, 2016.
[14] Vleugel, J.M. & Bal, F., Electric cars as buffers in an electricity network? *WIT Transactions on Ecology and the Environment*, vol. 203, WIT Press: Southampton and Boston, pp. 1–12, 2016.
[15] Ewalds, D. & Kampert, A., *Electrische personenauto's van particulieren*, CBS: The Hague, Heerlen, 23 Nov. 2017.
[16] CBS, PBL, RIVM & WUR, *CO_2-emissie per voertuigkilometer van nieuwe personenauto's, 1998–2016* (indicator 0134, version 14, 28 April 2017), The Hague, Bilthoven, Wageningen, 2017.
[17] Naughton, K., Why cars don't get 50 mpg. *Newsweek*, 3 Apr. 2008.
[18] De Mol, J., Allaert, G. & Vlassenroot, S., Autoconstructeurs moeten dringend op diet: Stijgend gewicht auto's nefast voor verbruik en emissies. hdl.handle.net/1854/LU-333852.
[19] Vleugel, J. & Bal, F., The impact of hybrid engines on fuel consumption and emissions of heavy-duty trucks. *WIT Transactions on Ecology and the Environment*, vol. 224, WIT Press: Southampton and Boston, pp. 203–212, 2017.
[20] NOS, Nederlands wagenpark wordt steeds bejaarder. nos.nl/artikel/2106283-nederlands-wagenpark-steeds-bejaarder.html?
[21] CBS, Verkoop nieuwe personenauto's loopt terug. www.cbs.nl/nl-nl/nieuws/2016/41/verkoop-nieuwe-personenauto-s-loopt-terug.
[22] United Nations, The Paris Agreement. unfccc.int/paris_agreement/items/ 9485.php.
[23] Rice, D., Global temperatures could pass limit set by Paris climate deal within 5 years. www.usatoday.com/story/weather/2018/02/01/global-temperatures-could-pass-limit-set-paris-climate-deal-within-5-years/1087326001.
[24] What you need to know about the Paris agreement. www.climaterealityproject.org/ sites/climaterealityproject.org/files/Paris_Agreement_Toolkit-Edit.pdf.
[25] RIVM, Nationale broeikasgassen volgens IPCC. www.emissieregistratie.nl/ erpubliek/erpub/international/broeikasgassen.aspx.
[26] CBS Statline, Kosten en financiering; natuur – en landschapsbeheer, between 2000 and 2015 gross costs (expenditures) fluctuated around 915 million Euros. This equals a nett reduction after inflation.
[27] Wilmink, I., 80 km zones and dynamic speed limits in the Netherlands, TNO. www.polisnetwork.eu/uploads/Modules/PublicDocuments/80Km.
[28] RIVM, *Luchtkwaliteit*. www.rivm.nl/Onderwerpen/F/Fijn_stof/Luchtkwaliteit.
[29] PBL, *Parijs-akkoord betekent halvering Nederlandse CO_2 uitstoot in 2030*, The Hague, 2016.
[30] Duurzaamheidsoverleg Politieke Partijen (Dopp), Duurzaam is de toekomst. legacy.gscdn.nl/archives/images/Dopp-Def170425.pdf.

[31] Editorial Board, We hebben een Minister van Klimaat en Energie nodig. www.duurzaamnieuws.nl/we-hebben-een-minister-van-klimaat-en-energie-nodig/.
[32] Verbeek, R., van Zyl, S., Van Grinsven, A. & van Essen, H., Brandstoffen voor het wegverkeer: kenmerken en perspectief v.2, TNO & CE Delft: Delft, Jun. 2014.
[33] Hench, S., Why are car manufacturers ignoring hydrogen engines? www.forbes.com/sites/quora/2017/06/27/why-are-car-manufacturers-ignoring-hydrogen-engines/#44bdb0d4027d.
[34] Regiolease, *Over auto's, kilomeers, mannen en vrouwen*. www.regiolease.nl/nieuws/autos-kilometers-mannen-en-vrouwen/.
[35] Blok, H., *Regeerakkoord van Rutte is net als doorgaan met roken.* www.duurzaamnieuws.nl/regeerakkoord-van-rutte-3-is-net-als-doorgaan-met-roken/.
[36] Costanza, R. et al., Twenty years of ecosystem services: How far have we come and how far do we still need to go? *Ecosystem Services,* **28**(A), pp. 1–16, 2017.
[37] Vleugel, J.M. & Bal, F., More space and improved living conditions in cities with autonomous vehicles. *Int. J. of Design & Nature and Ecodynamics,* **12**(4), pp. 505–515, 2017.