The future of transport in the European Commission’s 2050 Strategy

Identifying the limitations in PRIMES transport modelling and its implications for policy makers, citizens, and the climate

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Authors: Thomas Earl, Lucien Mathieu, Carlos Calvo Ambel
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For more information, contact:

Thomas Earl
Data Analyst
Transport & Environment
Thomas.earl@transportenvironment.org
Tel: +32(0)2 851 02 09

Executive Summary

The 2050 Strategy being developed by the European Commission for COP25 is of key importance to the future of European climate policy. The 2050 strategy central aim is to guide European climate policy to adhere to the Paris Agreement: how to reduce greenhouse gas emissions from all sectors of the economy to limit global temperature rises to well below 2ºC. To do this, the Commission relies on the PRIMES econometric model to determine the most cost-effective pathways. In this paper, we describe the model and report on some of its technical limitations when it comes to transport; the consultation process of the Strategy itself, and; we propose measures to ensure robust, trustworthy modelling, the consequences of which are crucial for environmental policy for the next decade. This paper has a particular focus on the transport sector, both the largest source of GHG emissions in the EU and the only sector to have increased since 1990.

The model is a comprehensive suite that can compute the European economy and its associated emissions. Based on historical and anticipated costs of technologies to reduce emissions, such as the cost of an electric vehicle compared to a more efficient petrol or diesel powered car, the model helps determine the cheapest pathway forward. The most recent modelling work, namely the 2016 Reference Scenario, along with the EUCO scenarios designed to achieve the EU's 2030 target, raise some fundamental flaws that we highlight. The general criticisms of the model include:

Transparency. From the consultation process to the final results, we highlight in the report numerous occasions where assumptions and modelling inputs are intransparent. This restricts critical review from relevant stakeholders, and reduces confidence in the results.

The inability to model disruptive changes. One such example is that in the heavy-duty vehicle CO2 emission standard proposal, there was no ingress of battery electric trucks by 2030, despite several models already on the market or announced in the next two years. This is due to, in one part, the lack of transparency of the assumptions used for these trucks, and also due to the structure of the model itself.

The effort allocated across sectors. Road transport has clear decarbonisation pathways that are becoming compelling in terms of cost, range, and charging infrastructure. Despite this, the 2030 car and truck CO2 regulation had a less ambitious target than the building sector, which appears to be based on out of date cost assumptions that were implemented in the EUCO scenarios. This does not appear to reflect the affordable and clear decarbonisation pathways available in transport.

International shipping and aviation. The Commission's previous modelling of aviation showed very optimistic efficiency gains, resulting in stagnating emissions growth despite a 125% increase in passenger numbers. Shipping shows a switch to LNG, which many studies have shown do not reduce GHG emissions. The model does not appear to be equipped to adequately model these sectors.

No societal cost of GHG emissions. Despite being designed to develop pathways for the European economy to reduce its greenhouse gas intensity, PRIMES does not account for a societal cost for carbon nor explicit mechanisms to limit damage to the environment. This means there is no cost penalty for inaction, although climate change would have significant direct costs related to infrastructure and biomass availability. This can distort policy decisions that only see the investment costs for new technologies, rather than money saved from climate change mitigation and other co-benefits.

The paper analyses in closer detail specific transport issues that have been identified from publicly available documents. In particular, the post 2020 car, vans, and heavy duty vehicle CO2 standards are analysed. In the case of cars, atypical behaviour such as increasing fleet sizes with new technology occur; this suggests that if a person replaces a petrol or diesel car with a battery electric vehicle, they expect to drive it less, when in reality evidence suggests the contrary is true. The implication of this is that more vehicles are needed to undertake the anticipated transport activity. More vehicles implies more cost, and more costs implies a bias against electric vehicles as being a cost effective solution. This may also be true for vans, and is certainly true for the analysis of trucks.

An important element of the PRIMES modelling pertains to biofuel and biomass availability, and the land use, land use change, and forestry sectors. In reality, these sectors are intimately linked, but how they interact within PRIMES-TREMOVE is not clear. Forests play an important role in acting as a CO2 sink, where CO2 from the atmosphere is absorbed by trees so that they can grow. However, if there is a large demand for biofuels, the model may find that felling forests to make space for energy crops is a cost effective solution to decarbonisation. This may lead to a situation where one sector may rely on forests to absorb its emissions (to reach net zero) while another sector may be relying on the biomass from forests as a fuel.

Finally, we comment on the consultation process of the 2050 Strategy, and the limitations within it. No response was given to feedback provided to the one-time-only stakeholder meeting, and this appears to be the case across many sectors. Despite being the largest source of emissions in Europe, there has been little to know detail on the mobility inputs. In the case of cars, this is despite the Commission providing over 500 pages worth of research. There appears to be no way to determine what inputs have been used, and if they haven't been, why not.

The recommendations from the analysis are summarised here, where Transport & Environment request that the European Commission:

- Implement a transparent process with more active stakeholder involvement.
- Give a stronger focus on the potential of zero-emissions technologies to achieve full decarbonization in an efficient and timely manner in the transport sector.
- Detailed inclusion of all transport emissions (namely, the fast growing aviation and maritime sectors), and justify and correctly capture the share of the effort that the transport sector must fulfil.
- Include a sensitivity analysis on the economic climate impact of non-action by assuming a societal cost of greenhouse gas emissions. The EU should adopt an approach of minimising environmental damage and biodiversity loss; although impossible to quantify, this approach is in line with its founding precautionary principle.

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1. Objectives of this report

The European Commission is in the process of developing a 2050 energy and climate strategy. A key input will be a large scale modelling exercise that will look at policy pathways to decarbonise the economy by 2050 that will update the 2011 white paper, and explore Paris Agreement compliant policies. The 2050 strategy is the cornerstone of developing transport policy in the EU over the next decades. This paper details some key concerns of the current modelling approach by the Commission, and suggestions how to manage them. One of the key issues we raise is about a lack of transparency in the whole process. To maximise trustworthiness, the 2050 Strategy requires thorough stakeholder participation and consultation. Transport is the largest sector of emissions, but the underlying modelling assumptions or inputs are not published for external review. Thus, the modelling done for transport raises many questions and some methodological criticisms - these are outlined herein.

Transport & Environment uses its in-house model, the European Transportation Roadmap Model (EUTRM) to analyse the effect of different policies on GHG emissions. Although different from the Commission's transport sub-module PRIMES-TREMOVE, this model has allowed us to increase in-house capacity and develop good expertise for modelling the European transport sectors and computing GHG emissions in various scenarios.

In this context, the main objectives of this report are:

a) To offer a critique on previous modelling work with a focus on transport
b) To propose recommendations for 2050 Strategy scenarios
c) To highlight shortcomings of the 2050 strategy process
d) Make suggestions for the Commission, policy makers, and stakeholders

2. Background

2.1. Setting EU NDCs to be Paris compliant for 2050

The Paris Agreement on climate change has committed its signatories to peaking of greenhouse gas (GHG) emissions as soon as possible and translates into "holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C" [i] [ii]. The following year, at the COP 23 UN Climate Change Conference in Bonn, the European Parliament urged the European Commission 'to prepare by COP24 [2018] a mid-century zero emissions strategy for the EU, providing a cost-efficient pathway towards reaching the net zero emissions goal adopted in the Paris Agreement with a view to keeping the global average temperature rise well below 2 °C and pursuing efforts to limit it to 1.5 °C[iii]. More recently, in June 2018, 14 Member States know as as the 'Green Growth Group' have also urged the Commissions for stronger EU climate action through a signed statement asking for several pathways for reducing GHG to be developed, including a '1.5°C scenario and at least one pathway towards net zero GHG emissions in the EU by 2050' [iv].

According the European Parliament, the process of preparing such a strategy 'should be initiated as early as possible in order to enable a comprehensive debate, in which the European Parliament should play a crucial role, in partnership with representatives of national, regional and local authorities, as well as civil society and the business sector' [v]. This new mid-century zero-emissions strategy would replace the *2011 White Paper* [vi] on Transport, the 2012 *Energy Roadmap 2050* [vii], and *2050 Low-Carbon Economy* [viii] that together aims at an 80% reduction of EU domestic emissions by 2050. Finally, the European Commission has been asked by the European Council in March 2018, to present by the first quarter of 2019 a proposal for a strategy for long-term EU GHG emissions reductions that are in accordance with the Paris Agreement[ix].

In this context some further international developments are underway to serve as a basis to the European Commission for developing long-term strategies. These include a scientific report on the 2°C and 1.5°C pathways by the Intergovernmental Panel on Climate Change (IPCC) due in the second half of 2018, as well as the UNFCCC Facilitative Dialogue at the end of 2018, which will show how countries are implementing the Paris Agreement and what more is needed.

The EU is the first major power to show how it intends to reach the Paris Agreement, which will send an important signal to the rest of the world. Other major powers like China will be looking very closely at the EU's roadmap and are expected to produce their own decarbonization strategy in the next years.

The outcome of the mid-century low carbon emissions strategy and thus the PRIMES model used for **scenario analysis is of paramount importance as it will guide EU and the world's current a**nd future climate policies for decades.

2.2. PRIMES energy system model

The European Commission relies on model-based scenario impact assessments of policy options to evaluate the different technology decarbonisation pathways. This will contribute to a better understanding of the cost effectiveness of decarbonisation options of the EU economy. The policy scenario results provide information to support the analysis of environmental, economic, and social impacts.

A systems and sectors approach is conducted to assess how they interact, which is modelled through the numerical PRIMES model[x]. PRIMES has been the linchpin of European climate policy for almost 20 years. It simulates energy consumption and the energy supply system though the resolution of an energy market equilibrium and is operated by Energy Economy Environment Modelling Lab - E3M.

The PRIMES model is designed to simulate long-term transitions and policy impact assessment for market, energy and emissions. The temporal resolution is up to 2070 with 5-year steps while the geographic resolution is the EU 28 and 10 European non-EU countries. The core model is composed of a set of sub-modules (Figure 1) that include the PRIMES-TREMOVE transportation module, described below. Each sub-module corresponds to a different sector and models the behaviour of associated agents. The sub-module coupling enables to model market interactions through an iterative process with feedback loops for equilibrium results, as a result of this coupling, one sector transformation is heavily dependent on the other (e.g. transport decarbonisation if to be achieved requires decarbonisation of electricity generation). We welcome the modular and system approach of this model as well as the Member State level granularity which is a good approach to assess the impact of different policy measures which can be defined differently for each Member State, and

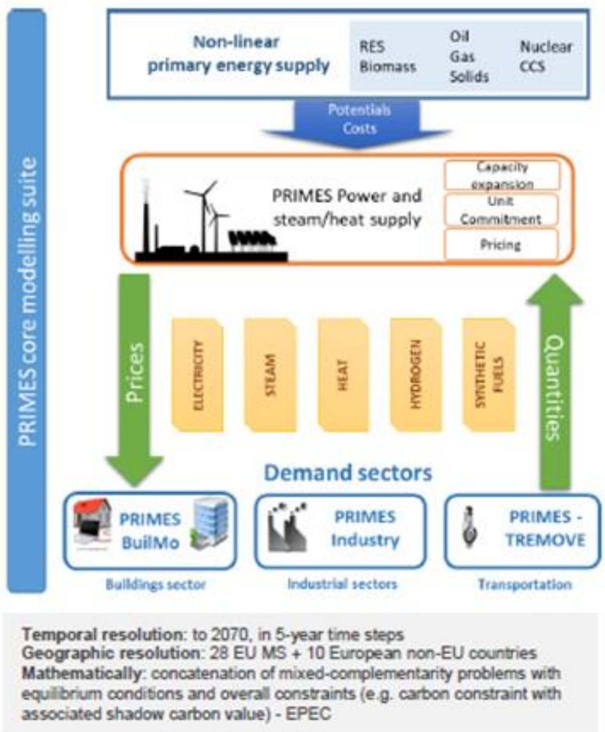

Figure 1: **The European Commission's PRIMES modelling suite**

the specific country characteristics can be accounted for.

2.3. PRIMES-TREMOVE transport model

The PRIMES-TREMOVE[xi] Transport model consists of two main modules which interact with each other and are solved simultaneously: the transport demand module projecting demand for transportation services for passenger and freight mobility and a supply module deriving ways of meeting the demand. The supply module projects the optimum technology and fuel mix to produce transportation services which meet demand. The model can be used as a stand-alone tool or with the rest of the PRIMES energy system model (in which case the interaction of the different energy sectors is taken into account in an iterative way).

Thus, the model is a detailed partial equilibrium simulation tool with a 5-year temporal resolution that meets passenger and freight transport demand based on projected wealth and population and then computes the mode [xii] (vehicle type) and drivetrain to perform the transport [xiii]. The projections are determined based on economic (for example operation and investment costs), utility (cost of time, comfort, range), policies (taxes, subsidies), and technology choices of transportation consumers. From the resulting fleet of vehicles and their activity, fuel consumption and emissions of pollutants (NOx, PM, CO, SO2) are derived. When used as a module which contributes to a broader PRIMES scenario, it can show how policies and trends in the field of transport contribute to economy-wide trends in energy use and emissions.

Regarding the purchasing and eventual uptake of new vehicles, a set of different technology options is considered. The purchase choice takes into consideration three factors; all costs elements over the lifetime of the vehicle, the market-acceptance perceived costs (simulates risk aversion and reluctance to adopt new technologies in early stages), and infrastructure availability. In short, the model predicts what vehicles consumers will buy based on what is cheap and 'not risky'. These choices are made based on what is considered rational decisions in the model.

2.4. The EU Reference scenario and 2030 target adaptations

The PRIMES model along with its sub-modules are able to capture policy changes across the whole European economy. This is no small feat; there has been a significant amount of model development and research that has been built up for over a decade. The amount of data and information that the model contains and that must be kept up to date across all sectors is significant. It is important to note therefore that we support the Commission's approach in pursuing this project and for financing its development and improvement. Although the main aim of this paper is to offer a critique of the model, there are strengths and weaknesses of all models. The all-encompassing nature of PRIMES is one of its key strengths.

The last major modelling exercises undertaken by the PRIMES model was the 2016 Reference Scenario and the EUCO scenarios. The EUCO scenarios [xiv] looked at several pathways to meet and exceed European wide 2030 targets, and the most cost effective way to get there. These were crucial results that guided European climate policy to 2030. Consider road transport as an example: the model takes inputs of battery prices, cost curves that show the incremental price for fuel efficiency improvements for vehicle manufacturers, among a vast range of other inputs (that are discussed in this paper), and from these results, the most cost effective policies can be found. These policies are then proposed to the European Parliament and Council, and they make their way to eventually become European law. On the surface of it, this is an appropriate way to find a balance between meeting climate targets with the lowest cost. However, if the industry or civil society aren't able to judge the critical inputs into the model, how can we be so sure that the model has given us the optimum pathway?

What follows in this report are general and specific criticisms of the PRIMES-TREMOVE model. In this discussion, we provide recommendations on how to improve the transparency, clarity, and trustworthiness of the process. Needless to say, an open, collaborative modelling exercise for the 2050 Strategy will lead to the most effective and trustworthy policy outcomes.

3. General criticisms of PRIMES-TREMOVE

3.1. Transparency

A general and fundamental limitation of the model and of the reports that present its findings is that there is very poor transparency with respect to many important inputs and assumptions (see costs sections for more details), and on exactly how the model derives its outputs. At the heart of a lot of the criticisms of PRIMES-TREMOVE that we discuss in this report is the lack of transparency.

Some of these general limitations are a result of the complexity of the model, however there could be significantly better transparency on key inputs and outputs (which are currently not available from standard data output files). This would be a great help in gaining confidence in the model and would give the possibility to stakeholders to suggest improvements. More information should be provided on the origins and justifications of the different data. Data that should be made available to all stakeholders include:

1. Calibrated final input datasets of vehicle stock, activity, and energy consumption data. Although these data may be obtained from the various sources cited, the final calibrated datasets are not publicly available, and only some of these data are directly available from standard model output files.
2. LDV Cost curves and EV battery costs: It is unclear to what extent the Commission will base its cost assumptions on the studies that were commissioned for the post-2020 LDV CO2 emission reduction[xv].
3. Cost curves used for heavy duty vehicles. The study used by the Commission for the heavy-duty CO2 emission proposal's impact assessment has not been published yet even though the Commission will use it for 2050 transport modelling.
4. The scope of the studies behind the LDV and HDV impact assessments is limited to 2030. The implications here are that there are no cost curves for LDVs after 2030. No information has been provided on the interpolation of these assumptions and cost curves until 2050.
5. More complete data on annual fixed costs (annual taxes, maintenance, insurance) and variable costs, and how these vary by vintage.
6. Detailed data on age-dependent annual mileage by powertrain type.
7. Calculated specific emissions of air quality pollutants by segment, mode and powertrain type – the lack of information prevents independent benchmarking to national inventory results. Only aggregated emissions data is available.
8. Information on the baseline capital costs of new vehicles by powertrain type as well as the final average price seen by the consumer.
9. Information on how potential electricity network upgrade costs are captured and how the whole system benefits could benefit from the interaction between stationary storage from batteries and renewable energy uptake in order to limit curtailment and improve grid stabilization.
10. Many technology cost assumptions which are presented in the next section.

3.2. Inability to model disruptive changes

The model is limited to running only in 5-year intervals. As a consequence, it is not possible to accurately model the impacts of changes that happen in intervening years and that it is unlikely to be able to model disruptive changes. For example, it is not clear how the car EU CO2 target is set for 2021 and the model fails to assess the uptake of zero emission trucks (see section on the detailed criticisms of trucks). The Commission mentions that "technologies that are expected to have little penetration of the market or on which literature has only scarce information are often omitted for simplification reasons." Similarly, it is difficult to obtain outputs for new vehicle shares by powertrain type and age/time dependent effects (such as vehicle age profiles, annual mileage and fuel prices) that must be averaged over relevant periods.

3.3. Effort shared between sectors

There are some doubts with regards to the ability of PRIMES to correctly capture the potential of the transport sector. In the 2030 strategies (for example EUCO27, EUCO30) that were undertaken to guide Europe to achieve its 30% reduction target on 2005 emissions in the EUCO30 scenario, the transport emissions reduction was set to 19%, whereas the building sector's emission reduce by 40% [xvi]. The EUCO scenarios show how much each sector should contribute but it is unclear how these targets were first defined and to what extent they were then used to guide/influence the appropriate ambition of the car and truck CO2 proposals for 2030. Additionally, it is unclear on how much reliance will be given to carbon capture and sequestration (CCS).

There is strong reason to believe that vehicles should be able to technically and economically take a larger share of the reductions for the following reasons:

1. Fuel efficient technologies for road vehicles will become more cost effective (learning curves) with increased deployment and with increased research and development.
2. Electric vehicles are becoming increasingly cost competitive and socially acceptable compared to ICEs. Battery costs have come down by 80% between 2010 and 2017 from about $1,000/kWh in 2010 to $209/kWh in 2017)[xvii]. These are projected to decrease further[xviii].
3. The annual turnover of buildings is reportedly below 1% [xix] despite a target of 3%, whereas for vehicles it is closer to 7%.

The car and truck CO2 proposals' impact assessment documentation indicates that the PRIMES-TREMOVE model was since updated with the new cost-curves; this then begs the question: what would the transport ambition level have been with the updated cost curves? The EUCO scenarios directly influenced the ambition of the 2030 vehicle standards. Unfortunately, this seems to be the only update of the cost curves and they appear to have been only used for the LDV post-2020 impact assessment. These cost curve updates will presumably continue to be used in future modelling. Therefore EUCO work has likely used older, possibly much higher, cost curves which would suggest that the cost-effective transport share in meeting targets could have been higher using the new cost-curves. Earlier EUCO scenario has set low expectations on what transport might need to do to contribute to meeting economy-wide targets, which in turn has influenced conservative ambition levels for modelling scenarios. New modelling work is the right opportunity to dramatically correct -if not contradict- previous modelling work on the cost-effective contribution of transport and be transparent about the data used.

The sensitivity analysis and the various decarbonisation scenarios should capture the high potential from road transport to rapidly reduce GHG emission and reach zero net emission in a cost effective way. The 2050 strategy should consider the cost effectiveness of solutions across sectors and report on these targets in a transparent way to show how these targets were met and how cost effective they are across sectors.

3.4. International Shipping and Aviation

It is important that all transport modes are included in the 2050 strategy, including international shipping and aviation. As the figures in Figure 2 show, aviation has seen the fastest growth in emissions (as measured from UNFCCC domestic and international kerosene consumption); according to the 2016 Reference Scenario, passenger activity is projected to increase by 125% from 2010[xx]. Domestic and international shipping (in Figure 2 listed as *navigation*) has risen by approximately 20% since 1990 and is projected to increase by 38% by 2050[xxi].

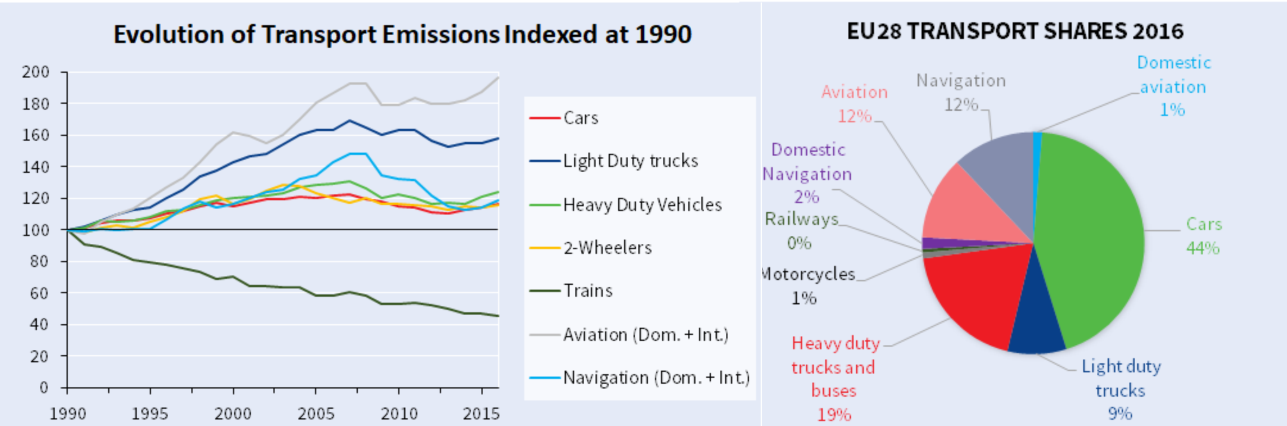

Figure 2: Evolution of transport emissions and their share in 2016

International aviation and shipping were included in the 2011 White Paper to the extent that low carbon fuels for these modes should be 50% by 2050. In the 2016 Reference Scenario, aviation is treated very optimistically and it does not appear that a thorough analysis of the price effects of zero-carbon fuels on demand has been considered. Additionally, the Reference Scenario takes the IATA aspiration of carbon neutral growth from 2020 (i.e. capping GHG emissions at 2020 levels) as a technical and economic certainty, and has an assumption that the energy intensity of aviation (toe/Mpkm) improves by 41% from 2010. It has come to light that CORSIA, the ICAO mechanism for preventing aviation GHG emissions increasing from 2020, relies on offsets; offsets essentially means to pay for other sectors to reduce their emissions. This will clearly not be an efficient mechanism for improving new aircraft efficiency, nor for capping emissions.

It is not clear in the Commission's modelling how the non-CO2 effects (or radiative forcing, RF) of aviation are calculated or whether they are considered at all. The contribution of aviation emissions from contrails and NO_x (leading to methane and ozone production) is highly dependent on local conditions and a single factor cannot be accurately prescribed[xxii]. However, by beginning to consider these important effects, fuel efficiency measures will not be the only way that aviation can reduce its climate impact, for example technology that can reduce NO_x production or re-routing to reduce contrail production could be incentivised[xxiii].

The Reference Scenario also assumes an important improvement in fuel efficiency for international shipping. The uptake of liquefied natural gas (LNG) is reported to result in a much lower growth of emissions compared to international shipping activity which should increase by slightly over than 70% for 2010-2050. However, not only is LNG not a zero-carbon fuel, there is an increasing body of research that shows that depending on methane slip, there may be negligible improvement compared to heavy fuel oil[xxiv]. The Commission should look at zero-carbon fuels for shipping and the most economical ways to accelerate their uptake in European and, as a knock-on effect, in global shipping[xxv].

It is imperative that the shipping and aviation sectors are also shown realistic and real pathways to reduce emissions until decarbonisation in the 2050 strategy. It appears that PRIMES-TREMOVE is not capable in correctly modelling these sectors, which are more complex than other transport modes. In the case of aviation, demand elasticities are reliant on journey length, alternative options to undertaking the journey, ticket prices, and season. For shipping, cost elasticities are dependent on journey length, the value of the commodities being transported, and the trade agreements between the third countries. However, owing to the proportion of emissions that these modes are in Europe, it is essential that they be captured by the modelling and in the 2050 strategy fully; to continue to ignore them will render the 2050 strategy inconsistent with the Paris Agreement.

3.5. Reference scenario

Some assumptions seem out-of-line in the absence of regulatory measures for the business-as-usual scenario (details below). As a result, it may be necessary to 'calibrate' the reference scenario outcome for more realistic scenarios. Some assumptions from the reference scenario are questionable in a business-as-usual scenario and should not be taken for granted. Most of these assumptions are reasonable when taken individually but collectively, they could cause an optimistic bias to the reference scenario.

1. Price of fossil fuels: The Reference Scenario takes as exogenous assumptions the evolution of global fossil fuel prices from a model that endogenously derives consistent price trajectories for oil, natural gas and coal based on the evolution of global energy demand, resources and reserves, extraction costs and bilateral trade between regions. The 2050 strategy will compare itself against a future with essentially unlimited supplies of stably-priced fossil fuels as detailed in the 2016 Reference Scenario. Making an economic comparison with relatively low and stable fossil fuel costs will distort the cost benefits of any scenario in which investment is required to decarbonise.
2. Vehicle efficiency improvement. In the absence of regulatory constraints (such as CO_2 targets) the model assumes that there will still be significant improvement in vehicle efficiency. In reality, though, this has been proven not to happen, either because technical improvements are not made, or these are instead utilised to offset increase performance or other metrics valued more highly by customers like vehicle size. The level of autonomous improvement in vehicle efficiency seen in the most recent reference scenario may still be slightly optimistic in the post-2020 period for light-duty vehicles in the absence of targets. This is mainly explained by the exogenous fuel prices which increases and drives fuel efficiency. There is no change in price in a scenario where demand falls significantly; this should be analysed carefully.
3. Battery costs: The 2016 Reference Scenario uses the following EV battery prices: 320- 360 $/kWh by 2030 and 270-295 $/kWh by 2050, which are already above the market average today but below the ones used for the 2013 scenario. Prices in the reference scenario assume continuation of current trends only, hence, a projected low production of battery does not yield economies of scale in the Reference Scenario but such assumptions change in a decarbonisation scenario context.
4. Share of full hybrid electric vehicles. In the reference scenario, the model predicts a high share for full hybrid electric vehicles compared to what is seen in the marketplace currently, or might be expected without further targets. This is due purely to the decision-making process within the model which takes into account vehicle-utility advantages as the fact that these types of vehicles are not constrained by range or availability of alternative refuelling infrastructure like other options.
5. Modal share of passenger cars has been assumed to gradually decrease from 73% in 2010 to 70% in 2030 and 73% in 2050, however, according to the most recent EEA indicators, the passenger car modal share has risen since 2012. In the absence of strong policy choices (investment, pricing) there is no reason to assume the modal share will change significantly.

Some changes in the 2016 Reference Scenario seem to have already been carried out prior to this new strategy work (as discussed in the section: *Efforts shared between sectors*) but without further information these changes can't be assessed correctly. Certainly, the cost-optimal solution approach isn't able to fully account for non-rational behaviours and more complex decision-making by consumers, but, collectively the above assumptions would introduce a bias that would favour a more conservative approach and limit the potential of emerging powertrain technologies as electro-mobility. It is essential for a robust modelling exercise for the results of the Reference Scenario reflect a reasonable future.

3.6. Factoring the costs of climate change

Despite the monetisation of impacts like air pollution, noise and congestion being included, the Commission's modelling does not integrate the consequences of climate change and this can have huge consequence on the outcome of the modelling exercise. The calculations balance the socio-economic benefits with the investment requirements corresponding to the associated ambition level. The preferred scenario tends to be the cheaper option. However, and rather surprisingly, PRIMES does not give a cost to climate change.

Several studies show that climate change costs can be significant with respect to GDP and would increase exponentially with higher global temperature increase: according to the JRC PESETA II Project[xxvi], limiting global warming to 2°C would save €70 billion a year in the EU by the end of the century (compared to a 3°C scenario) with particularly high costs in southern European regions and without taking potential impact on biodiversity and ecosystems into account. Furthermore Nature[xxvii] estimates an additional $20 trillion cumulative loss in the global economy from a scenario of 2°C compared to 1.5°C warming scenario. Excluding the costs of inaction in the modelling can cause the high ambition scenarios to be discredited for several reasons: first, policy makers would only see the higher investment costs and not the hidden costs in the low ambition scenarios and second, they would compare scenarios with a reference scenario were the EU would continue emitting GHG on a pathway well above 2°C without suffering economic consequences.

The cost estimates of climate change listed above take into account the direct costs, for example the cost of infrastructure improvements to deal with increasing flooding events. In a purely economic sense, these are important considerations to provide context to the significant investments necessary to decarbonise the economy. It is important to note that there are consequences to climate change that might not have direct economic consequences, such as the loss of natural habitats and biological diversity. Although this is not easily quantifiable in monetary value, the Commission should also base its decarbonisation pathways on minimising environmental damage, whether on European soil or abroad, following the precautionary principle.

The Commission acknowledged in 2011 during the previous 2050 roadmap that "Future modelling improvements could consider better representation of the impacts of climate change itself"[xxviii]. Up until now, no publications have shown that any action has been taken here. To estimate the benefits of reducing GHG emissions and to value the climate impacts of policies, many stakeholders and governments have used the approach to estimate the cost of carbon:

The Environmental Protection Agency (EPA), and other US federal agencies use the social cost of carbon. The social cost of carbon is the measure of the long term damage done by a ton of CO2 in a given year. Even though the social cost of carbon is not able to estimate various impacts (because of a lack of precise information and scientific and modelling difficulties) it does includes changes in "'net agricultural productivity, human health, property damages from increased flood risk, and changes in energy system costs, such as reduced costs for heating and increased costs for air conditioning". Four estimates of the social cost of carbon were modelled by the EPA (with different discount rates: 5%, 3% and 2.5% average and the 95th percentile social cost at 3%): from $11 to $105 in 2015 to $26 to $212 in 2050. As a consequence, the present net value of CO_2 mitigation benefits over four years for a package of vehicle regulation was projected in a range from $78 billion to $1.2 trillion[xxix].

The UK use a similar approach based on *the "traded carbon values for UK public policy appraisal"*[xxx]. These carbon values are used by The Department for Business, Energy and Industrial Strategy (BEIS) to estimate the impact of emission policy in the ETS sectors. The short-term quoted value of carbon corresponds to the period up to 2030 and the long-term value for the post 2030 period. The short-term traded carbon values are produced in three scenarios (central, high and low) in order to reach BEIS's long-term carbon values while the long-term carbon values reflect the costs required to limit global temperature increases to 2 degrees Celsius above pre-industrial levels. 2017 update of short-term traded sector carbon values for 2030 are respectively £39.72 /tCO2e, £79.43/tCO2e and £119.15/tCO2e in the three scenarios[xxxi].
The European Commission commissioned Ricardo to compute the external costs of Transport and the final report of the *Update of the Handbook on External Costs of Transport*[xxxii] was published in 2014 with base year values for climate change in the EU with the unit cost estimation for different transport modes and fuel types. For example the climate change cost for gasoline is 21.1 €ct/L (2010) which translates into about €90/tCO2e. Carbon price should be the main instrument for future global climate policy, a realistic evaluation of long term emission policies can not be done without the crucial measure. The Commission uses a price for CO_2 under the ETS legislation but this mechanism is not sufficient to take into account the damages of climate change. CO_2 ETS prices are fully endogenous and result from the interaction of all sectors and simply follow the required ETS legislation. The cost of climate damage should be an internalisation of external costs more than a partial legislative framework.

Climate change, by definition, is a global effect. If the rest of the world does not decarbonise, the EU would still face the significant costs that come with it. This should not prevent analysis that takes these costs into account that could include a sensitivity analysis under varying global ambition levels. The challenges of decarbonising the economy in the coming decades could be recast as an important opportunity for Europe to lead and innovate.

4. Detailed criticism of PRIMES-TREMOVE

4.1. Cars and vans

Annual activity and stock.

In PRIMES-TREMOVE, where there are significant changes in the market shares of different powertrain types towards powertrains with lower assumed annual/lifetime vehicle kilometres (i.e. replacing diesel vehicles for electric vehicles), the model appears to take up additional vehicle stock to compensate for the 'missing' activity that cannot be fulfilled by these 'lower' mileage vehicles. This effect can be seen in the Figure 3[xxxiii] where a significant increase in new vehicle registrations is seen between the reference (REF) and the policy scenario variants, and would imply a number of consequences as a result:

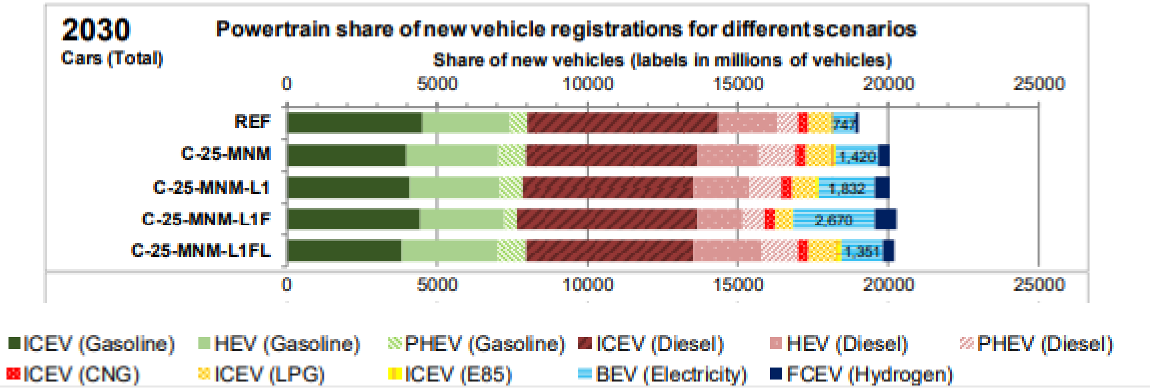

Figure 3: Extract from Ricardo Energy & Environment et al., 2018

1. Total fleet annualised capital costs would be higher than they would otherwise be due to the additional vehicles (which might be partly offset by the lower capital costs of gasoline vs diesel vehicles where there are such shifts in powertrains).
2. Total fleet fixed annual costs (that are calculated on a per vehicle basis) would be expected to be considerably higher than they would otherwise be, as there are extra annual costs for each individual vehicle added to the fleet.
3. Fuel costs should not be as significantly affected as the same overall vehicle kilometre activity constraint would be met.

In reality, if a single vehicle owner decided to change their current diesel car for a gasoline or electric vehicle, or to down-size their vehicle, this in itself would not be expected to change their annual mileage requirements (and in fact there is evidence that shows that activity tends to increase through the rebound effect of reduction in fuel costs). In addition, studies have shown that the annual mileage of an electric car increases in line with its range capacity. As the range of zero-emission vehicles increases, so will its mileage. The PRIMES-TREMOVE model does not appear to be able to adequately handle such considerations based on the current evidence.

Vans are only modelled as a single segment whereas they are used for both passenger and freight transport. This limits the accuracy of the analysis of this growing vehicle segment, especially considering that there are significant differences in costs, vehicle activity and average CO2 emissions performance between different van segments, which cannot be captured, limiting the accuracy of the analysis.

Zero-emission vehicles

Regarding adoption of zero-emission vehicles, public documentation indicates that the model assumes that cost penalties are applied to electric vehicles because of the range limitation. The model relies on the frequency distribution of trips to assess the level of penalty applied, for example certain consumers that are subject to range anxiety would observe high penalties when selecting electric vehicles. It is unclear how the model takes into account both ultra-fast charging, which is bound to become widespread in Europe by early 2020s (such charging would enable to recharge about 100 km in 10 minutes), and future expected range improvements of electric cars (announced vehicles have ranges of ca. 500 km). The two above mentioned factors should be reflected in the evolution of the penalty applied to electric cars, but unfortunately very little is known on the value and implementation of this penalty.

Similarly, little is known regarding the actual EV battery costs that will be used. The last reported update of PRIMES-TREMOVES was done under the Ricardo study for the assessment of the post-2020 LDV CO2 regulation[xxxiv]. As for the cost-curves (see Figure 4), the battery costs used are tailored to the specific scenario investigated (High, Central, Low, Very Low). The Very Low scenario was added following the earlier 2016 work done by Ricardo in 2016 based on market evidence from Bloomberg New Energy Finance. We welcome this new scenario which is much more in line with future potential of batteries from very high production capacities planned and future anticipated breakthroughs in battery technologies (lithium-air or solid state batteries). On the other hand, the High cost and Central scenario are very unlikely. Already today, battery average market costs are at the level of 2030 in the High cost scenario and 2020 in the Central scenario (see Table beneath). To give an example of the potential of battery cost reduction thanks to new industrial capacities; Tesla has announced they will reach $100/kWh by 2020[xxxv]. We regret that no information was provided on the batteries costs that would be used in scenario and ask the Commission to be transparent on this matter when selecting the scenarios.

Battery pack cost, €/kWh	2015	2020	2025	2030	2040	2050
High	375	260	228	205	180	160
Central	375	202	169	149	120	100
Low	375	174	134	102	75	65
Very Low	375	124	97	65	55	50

Sources: (Ricardo Energy & Environment et al, 2016) (SR4) for Central, High, Low cost projections. Very Low battery cost projections are new estimates for this project, based on (BNEF, 2017).

Figure 4: Extract from Ricardo Energy & Environment et al., 2018

Cost-curves

PRIMES-TREMOVE considers cost-curves that associate the potential for reducing the specific energy consumption of a vehicle option with an additional cost. They are defined by a series of only eight points for efficiency improvement and cost, relative to a 2005 “baseline” vehicle. This arguably reduces the accuracy of the saving potential. The points have to cover the whole potential up to 2050 and the intervals between the percentage improvement points used to define the cost curves vary. Since the model operates in aggregated 5-year periods, the utilised cost-curves are assumed to be the same across the whole of the 5-year period (in reality one would expect gradual change in average costs). Finally, it is not clear how/whether the cost curves have been sufficiently adjusted to account for any zero cost or non-technical improvements in regulated CO_2 targets or any improvements between 2005 and the base year for the input cost curves (2013 for the latest LDV cost-curves used in modelling for the post-2020 CO2 regulation impact assessment). The need to make such adjustments back to such an early base year reduces the accuracy of the analysis further

4.2. Trucks

The PRIMES-TREMOVE has also recently been used to model the different scenarios of CO2 standards on new heavy-duty vehicles (see Impact Assessment). During this modelling exercise, ZEVs failed to penetrate the market over the time horizon under consideration (up to 2030), which means that in the output of the model, no zero-emission trucks were sold in 2030, even in the most ambitious scenario. As a consequence, effects coming from ZEV had to be calculated externally to PRIMES-TREMOVE. This is a serious consequence of the inability of the PRIMES-TREMOVE to model disruptive changes (see *disruptive changes* section in general criticisms above). We can affirm with confidence that the model has a bias since virtually all major truck makers have announced series production of electric trucks in the next couple of years[xxxvi].

On the other hand, PRIMES-TREMOVE was able to model high LNG penetration. According to the impact assessment, this alternative fuel is even is the most relevant lorry technology option in the period until 2030 thanks to sufficient availability of refuelling stations and LNG fuel. However, as is the case for shipping, LNG is not a decarbonisation pathway with only small improvements to GHG reductions in optimistic scenarios of reduction in methane leakage and slip, and this should be accounted for in the 2050 Strategy.

4.3. Biofuels and biomass availability

PRIMES uses inputs for biomass feedstock production and availability from the PRIMES-Biomass model[xxxvii]. The model works by essentially meeting exogenous demand of biofuels based on EU policy, both domestic and imported. The main criticisms of the PRIMES-Biomass approach are that indirect land use change (ILUC)[xxxviii] emissions are not treated directly; a crop based cap of 7% was implemented to limit ILUC effects, but the significant emissions linked to ILUC go unaccounted for. With climate change, it is important that crop yields are correctly modified, as if yields reduce owing to insufficient water due to drought or damage from flooding, this will place more competition for food stocks for human consumption.

Another key criticism of the approach is that it is not clear how much of the biomass is converted to biofuels, and what is the decisive factor on how the biomass potential is used. Whether these feedstocks are sustainable, their extraction economical, and how other sectors cope with reduced biomass from increased transport use is unclear. One of the key underlying studies that is used in PRIMES-Biomass[xxxix] assumes significant uptake of unproven feedstocks such as algae[xl]. How the existing uses of biomass (for energy or materials) is treated in the model is unclear. Finally, a high amount of imports is foreseen, which means that land management will be left to third countries.

4.4. Land use, land use change, and forestry (LULUCF)

There has been no modelling of GHG emissions from the LULUCF sector in PRIMES in the past. The practice has been to take bioenergy demand and to plug them into a separate model by IIASA called GLOBIOM-G4M[xli], which is not part of the PRIMES modelling suite, which then calculates the developments for GHG in the LULUCF sector. However, this appears to have not carried for all previous policy scenarios. According to the most recent Impact Assessment on the Sustainability of Bioenergy[xlii]:
"All bioenergy demand projections are exogenously defined … GLOBIOM uses these bioenergy demand projections as exogenous inputs, they always have to be fulfilled, even if it reduces the availability of biomass resources for other purposes."
"There is no feedback from price signals of feedstocks upon total bioenergy demand i.e. increases in bioenergy use may well push up prices for feedstocks, however, this will not feedback to reduce demand for bioenergy (over other energy technologies). The demand of food and feed commodities is on the other hand price elastic and therefore changes depending on consumers' willingness to pay…"
"During the modelling, change in GHG emissions and removals due to increased or reduced biomass demand linked to land use and land use change (LULUCF) is not accounted for in the efforts needed for reaching an overall EU GHG emission reduction target for each scenario. Therefore, there is no feedback loop from increasing or decreasing forest carbon stocks in relation to the forest management levels to bioenergy demand."

To summarise, this modelling approach fulfils a biomass demand from transport, and regardless of the cost of the fuels from forest biomass (which has the biggest feedstock potential), will meet that demand, regardless of the price. Thus, the higher price does not have a self-levelling reduction in demand. It is crucial that the 2050 strategy applies appropriate feedback loops (at least once) so as to avoid a reliance on forestry feedstocks that doesn't stack up from both an economic perspective and from a forest carbon stock (soil and tree biomass) perspective. For the latter point, it is likely that forests will be used as carbon sinks for negative emissions, to achieve net zero scenario. This may well be a time consuming exercise, but a document of this importance and the importance in LULUCF as a source of biomass and as a carbon sink should not miss this.

4.5. Discount rates

The assumptions for the discount rates used in the annualised cost calculations in PRIMES-TREMOVE for passenger cars (11%) is on the high side compared to the 8% used in other previous and recent analysis for the Commission, such as (CE Delft et al., 2017). Other recent analysis has suggested the range of rates is typically between 8-12% (Ricardo Energy & Environment, 2016). Although within the suggested range, higher discount rates will mean that overall calculated annualised costs to the consumer are higher – increasing the cost seen by the consumer for capital expenditures (and/or reducing the value placed on future fuel or other operational savings). Powertrain options with higher capex but better operational savings (e.g. EVs) will therefore also be disfavoured by higher discount rates – i.e. the solution reached for technology performance and mix will be impacted as well as an increase to the overall costs for the solution.

To illustrate the importance of the discount rate, we will use the example of energy efficiency[xliii]. During the negotiations on the 2030 energy target, the Commission used a 10% discount rate, which was much higher than the average rate used by Member States (5.7%). According to a blog post from the European Council for an Energy Efficient Economy, the consequence for the modelling means that were considerable as a 40% efficiency reduction target with a 5.7% discount rate requires less investment than a 30% target with 10% rate. The discount rates used in PRIMES across the economy are almost twice as much as the EU average of Member States, which is 5.7%[xliv].

The choice of discount rates will directly affect the recommended level of EU climate action but in the end, it is not possible to rely only on numbers for discount rates. Not only should varying the discount rate play an important part of a sensitivity analysis; social and ethical value judgments are necessary and should be carried-out in a transparent, fair and open way, not hidden behind a black box. To bear the poor ability of the tool to model the uptake of new technologies, we believe these technologies should be addressed with a fairly low discount rate.

5. Stakeholder consultation and technology costs assumptions

In the modelling of decarbonisation pathways, cost assumptions for the various technologies considered is of utmost importance as it is crucial in the assessment of the optimum and the preferred decarbonisation technological pathway. The European Commission held a stakeholder consultation to assist in the review of these technological costs to be used in the PRIMES energy modelling in order to ensure robustness and representativeness of the technology assumptions. Close to a hundred stakeholders (relevant experts and industry representatives) were contacted to provide feedback on four categories of technology: industry, energy efficiency, novel technologies and power and heat. The European Commission published the final report on the technology assumptions on 20 July 2018[xlv]. This report provides feedback on the consultation and adjustment of the assumptions that have been compiled by E3M.

The next five sections detail our main concerns regarding the consultation from a transport perspective. These concerns were reported to the Commission and the consultants during the stakeholder consultation process but none of them have been addressed or taken on board in the updated final report. Only a very limited amount of cost changes were made for the new technologies as a consequence of the consultation process (introducing a learning rate for charging infrastructure,CO2 capture, underground hydrogen storage and electrolysis from high temperature).

5.1. Lack of clarity of transport assumptions in the process

The Commission made the decision to exclude transport assumptions from the technological revision project since stakeholders have been consulted for the mobility packages. The final report notes that more assumptions on transport can however be found in a Ricardo report[xlvi]. This study focuses on developing cost curves for LDV vehicles for 2015, 2020, 2025, and 2030. It is unclear to what extent the cost curves from the Ricardo report were used in the impact assessments of the mobility packages. Regarding the 2050 strategy, how these cost curves will be extrapolated over the 2030-2050 period is unknown.

The final set of cost-curve equations are provided in the depths of the DG Clima website in the Appendix of a Ricardo study[xlvii]. On the one hand, there is an impressive amount of analysis and more than five hundred pages of reports that have been used to determine the cost effective reduction potential of cars. However, the information provided does not mean greater transparency - on the contrary, there is no summarising document that indicates what conclusions or results from these studies were considered. As a consequence, very little insight can be gain from the Ricardo report regarding the potential of technologies and the cost curves used in the mobility packages and the 2050 Strategy.

5.2. Lack of transparency of underlying cost assumptions

In addition to the exclusion of the transport assumptions from this consultation, greater clarity and transparency is needed for full cost assessment of the technologies considered. There is a lack of transparency on many of the underlying hypotheses used, such as: storage/conversion efficiency, technology lifetime, utilization factor, underlying policy measures, learning curves, transport infrastructure, CO2 costs and electricity prices. As a consequence of this lack of transparency, full cost evaluation can't be thoroughly made by the numerous experts consulted in the process. It was however still possible to benchmark some of the costs with existing literature (see next section). These assumptions are highly important for calculating the costs of technologies (e.g. for PtX technologies which are very sensitive to electricity price variations). Even though electricity costs are calculated endogenously in PRIMES (thus different in every scenario), we regret that more transparency was not given on that level.

There is also a lack of transparency on what the input and final specific vehicle costs (by vehicle and powertrain type) are in the model; what the costs are before mark-up/taxes, and what the prices seen by the customer are in the model. This makes it difficult to sense-check outputs on what the total annualised costs are.

5.3. High level of aggregation

The number of technologies presented to stakeholders for review that are related to the transport sector is very limited due to the decision of the Commission to exclude transport from this consultation. The only transport-focused technology open for review was recharging and refuelling infrastructure while there was much greater detail on energy-focused technologies (e.g. very detailed classification for PtX and electrolysis). The battery costs reported in the assumption file circulated referred to stationary uses only. Below are critiques on the classification and representation of these two technology options.

1. Charging Technology: The charging technology provided in the consultation presents a high level of aggregation with only 2 categories: semi-fast charging and fast charging. The granularity doesn't take into account correctly the different charging technologies costs for slow charging (home and

work, usually 3 or 7 kW), regular charging (usually 11 or 22 kW), fast charging (50kW) and ultrafast charging (150-350kW) neither it account for catenary charging infrastructure for heavy duty vehicles or inductive charging.

2. Storage Battery Technology: From the consultation, it became clear that the same battery technology classification is used for all battery types/chemistries. This approach is worrying since the overwhelming amount of batteries produced globally for transport and storage will be Li-ion batteries[xlviii], at least in the medium-term. Other categories can include lead-acid batteries, high-temperature sodium storage, and flow-cell batteries. As a consequence, the costs per kWh stored with Li-ion batteries will be the same as for the alternatives listed. Thanks to the current and expected uptake of electro-mobility, one would expect the costs and technological trends for lithium-ion batteries to differ from other storage technologies (McKinsey confirms the centrality of lithium-ion batteries to utility-scale energy storage and the use of non lithium-ion technologies in some specific applications[xlix]). Hence, a more detailed batteries technology classification would give the possibility to adapt the modelling scenarios rather than having a fixed and very general category for all batteries.

5.4. Conservative costs of storage batteries and ownership and maintenance (O&M) costs

We acknowledge that estimation of the full development potential for technologies that are not mature is an uncertain exercise. The technological pace of improvement is derived from the R&D investment (learning by research) and the economies of scale (learning by doing). The battery costs provided in the consultation addressed only energy storage technologies and not those of electric vehicles, which are part of the transport assumptions. While the cost curves for batteries used in EVs are adjusted according to the scales of EV battery production, battery storage prices decrease over time but will not change based on level of deployment (i.e. through differences in economies of scale). The Commission should align or index the costs for storage batteries with EV batteries. Specifically, the following two assumptions appear to be on the conservative side (on top of being highly aggregated):

1. Storage Batteries: These batteries are an important element of the transition to a renewable energy future and electro-mobility, where battery storage can both help with the intermittency of renewables and storage/power contribution at fast charging power stations. The cost of storage battery packs (€/kWh) provided are conservative. The costs provided for small-scale batteries are €270/kWh in 2015 (about $315/kWh) and €114/kWh in 2030 (about $133/kWh). As a comparison, the 2017 market average for battery packs is $209/kWh according to Bloomberg New Energy Finance and the reduction rate over the past five years was in average about 20% per year[l][li]. In addition several studies also forecast much lower prices: Bloomberg New Energy Finance predicts battery pack costs will reach 70 $/kWh (57 €/kWh) in 2030[lii], and 124 $/kWh in 2020 (Noah Kittner et al., 2017). It is unknown how the second life of batteries from electric vehicles are considered in PRIMES. A significant share of these batteries may be used for second life stationary storage, however, the extent of this level is shrouded in uncertainty, which may apply additional downward pressure on the costs for stationary batteries storage.
2. O&M costs: Assumptions on fixed annual costs (maintenance + insurance + ownership tax) for electric vehicles (BEVs, PHEVs, FCEVs) used in analysis prior to the LDV post-2020 CO2 regulation impact assessment that were in some cases substantially higher than conventional vehicles even in later periods once these technologies were more mature, for example in 2025 (see Figure 5)[liii]. It is unknown to what extent the revised cost data which still appears conservative compared to some recent evidence on EVs, will be updated/utilised in subsequent analyses using PRIMES-TREMOVE and in particular for the purpose of the 2050 strategy work.

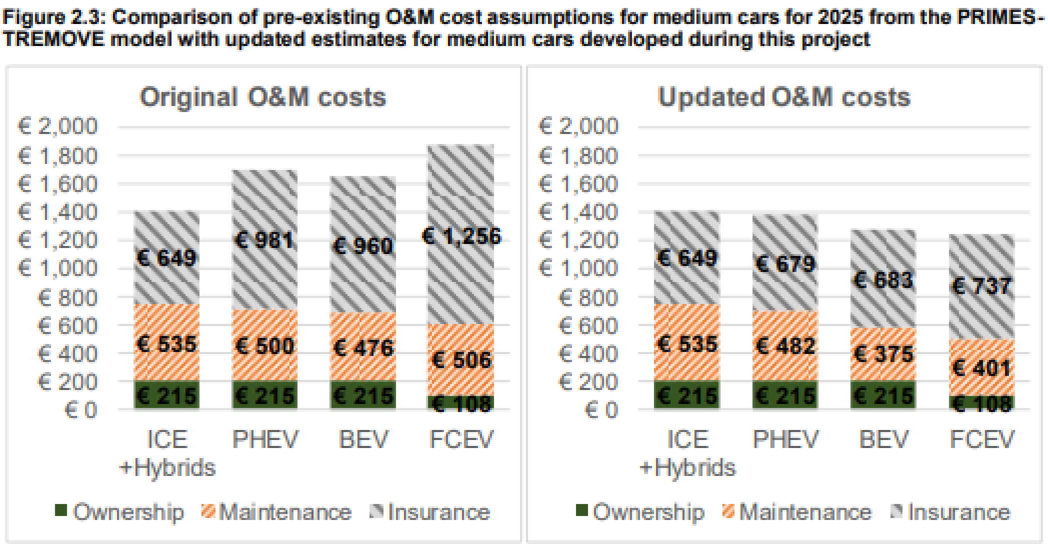

Figure 5: Extract from Ricardo Energy & Environment et al., 2018

5.5. Modelling of different modes, road transport fuel disaggregation, and modal share

A previous analysis of road transport fuel disaggregation (based on the 2013 Reference scenario) was commissioned by the European Commission and carried out by Ricardo-AEA[liv]. The analysis has shown some significant discrepancies between PRIMES-TREMOVE and historic international reporting to UNFCCC, with overly high allocation of diesel total consumption to heavy duty trucks and buses in PRIMES-TREMOVE (see Figure 6). These discrepancies are even more pronounced on the national level.

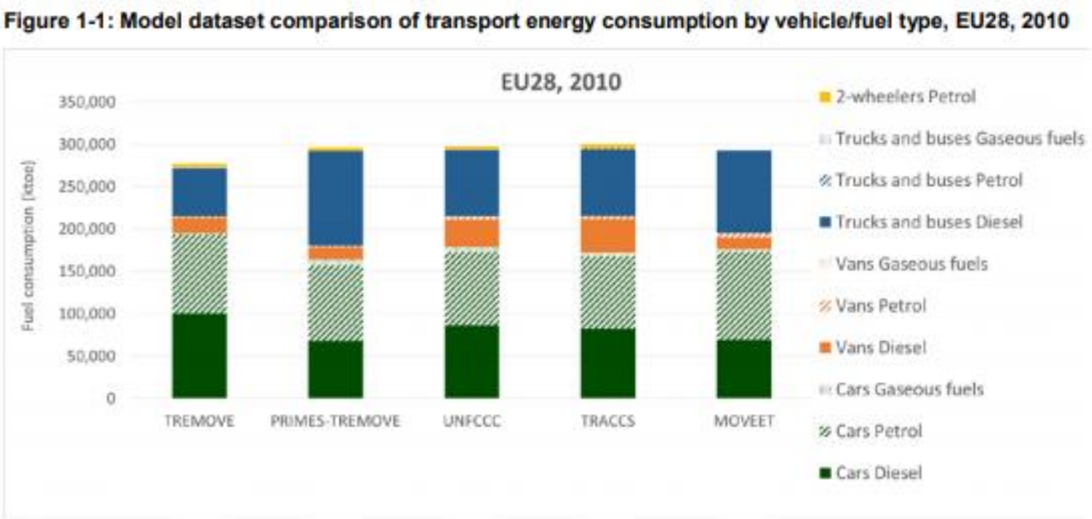

Figure 6: Extract from Ricardo Energy & Environment et al., 2016

The same report suggested that the discrepancies were likely to be reduced for the (at the time still in preparation) 2016 reference scenario update. However, we are not able assess to what extent the more recent 2016 reference scenario has been adjusted to be closer to UNFCCC reporting and accurately model the different modes, Member States and road transport model share. The crucial implication here is that we are also unsure on whether this will be corrected for the 2050 Strategy

6. Robust decarbonisation pathways

Up until this point, a range of limitations on the modelling for the 2050 strategy has been discussed in detail, along with overarching issues such as the lack of transparency. This section aims to give guidance on what the 2050 strategy scenarios should consider, how to gain the trust of key stakeholders, and as a result, the general public.

No information has been communicated on the different scenarios that will be considered in the 2050 strategy. During a stakeholder meeting, the European Commission mentioned that if feasible, they will model a net zero GHG emission scenario while commissioner Arias Cañete mentioned during another meeting that the Commission will look into a pathway to net-zero GHG emissions by 2050[lv]. Fourteen Member States, including France and Germany, have insisted on a net zero scenario[lvi].

The 2050 strategy must include net zero emissions as a central scenario. More ambitious scenarios such as zero emissions in the energy, buildings, and waste sectors (with only agriculture non-zero) should be investigated. In addition to these scenarios, the relative contribution of each sector to the overall decarbonization should be assessed through a sensitivity analysis to capture possible different contribution across sectors. As most transport sectors have very clear decarbonisation pathways, scenarios should also be developed in a way that brings forward decarbonisation from 2050, but anytime earlier, whenever it may be, to evaluate the cost potential of shifting a timeline. Energy efficiency should be a cornerstone of these scenarios.

To ensure the PRIMES modelling is more transparent and robust, expert institutions should be able to take part in the modelling exercises directly. For transport, this may involve using some of the key exogenous inputs that drive travel demand (e.g. fuel prices, battery costs, etc...), and to compare different modelling approaches with based on their key results (such as fleet compositions, technical and economical potentials, infrastructure roll out costs, etc.) with PRIMES.

Commission documents show that Ricardo was commissioned to undertake a study at looking at the options for 2030 transport decarbonisation[lvii], including technological improvements to cars and vans until 2030, but we can see no record of this being published. This report should be released so that a like-for-like comparison with PRIMES can be made, and the merits of each approach objectively compared. Comparisons like this would take significant resources and coordination. However, as stressed throughout this report, the importance of the 2050 strategy to the future of EU climate policy warrants a collaboration with appropriate stakeholders.

Since the Paris Agreement, several organisations have released roadmaps to achieve decarbonisation pathways for transport, for example heavy duty vehicles[lviii] and shipping[lix]; there are many others. This is something that organisations such as Transport & Environment are continuing to develop for all modes, based on independent research that investigates technical and economic viability of a range of solutions, extensive in-house modelling, and consultation with key stakeholders. These roadmaps to zero emission transport should be used as a guideline to indicate how disruptive technologies may penetrate the market, which PRIMES has so far not been able to show accurately.

7. Conclusions and recommendations

Transport & Environment call the European Commission to act on the above mentioned issues, in particular: Implement a transparent process with more active stakeholder involvement.

- Public information on the modelling and input parameters are scarce. T&E welcomes the stakeholder consultation held in May 2018 and organised by the European Commission. From this consultation, it was clear to stakeholders that more transparency is needed on underlying costs assumptions and general costs figures (e.g. costs of li-ion batteries for vehicles), more granularity for transport-sector related technology are also needed. However, other reflections on the model design and operation itself were explicitly excluded from the debate of this consultation. A more transparent process is needed beyond this one-off consultation. The process should be extended to provide the possibility for experts and stakeholder to provide feedback on the model design. An iterative process would also help build trust for the strategy and scenarios being developed. Finally, technical experts under strict conditions should be able to review the model itself, with sufficient time to run comparisons and understand discrepancies.

- Modelling the transport sector. The PRIMES-TREMOVE model is inadequate to model the transport sector and its evolution. A stronger focus should be given on the potential of zero-emissions technologies as electro-mobility to achieve full decarbonization in an efficient and timely manner. So far the model has performed poorly on modelling the penetration of electro-mobility and any other new technology. Most transport sectors have very clear decarbonisation pathways, so scenarios should also be developed in a way (e.g. sensitivity analysis) that brings forward decarbonisation from 2050, but anytime earlier, whenever it may be, to evaluate the cost potential of shifting a timeline.

- Include the economic climate impact of non-action. Because of the model's calculations, excluding the costs of in-actions causes would cause the high ambition scenarios to be discredited since policy makers would only see the higher investment costs and not the hidden costs in the low ambition scenarios. The EPA estimate the social cost of carbon to assess the benefits of reducing GHG emissions, the European Commission also needs a similar cost in its model to incorporate the damage of emitting CO2.

- Sharing the efforts between the sectors included: The Commission's modelling should capture correctly the share of the transport sector; the high potential from road transport to rapidly reduce GHG emissions and reach zero net emission in a cost effective way (especially when compared to other sectors as buildings) and the realistic contribution of the complex shipping and aviation sectors.

The Commission should address all doubts and criticisms from stakeholder to enable a process of such importance to have the trust of all stakeholders and not be discredited or -more importantly- lead to irreconcilable legislation.

Endnotes

[i] https://unfccc.int/sites/default/files/english_paris_agreement.pdf
[ii] https://www.transportenvironment.org/sites/te/files/publications/2050%20ESR%20targets%20v5.pdf
[iii] http://www.europarl.europa.eu/legislative-train/theme-resilient-energy-union-with-a-climate-change-policy/file-mid-century-zero-emissions-strategy-for-the-eu
[iv] https://www.ecologique-solidaire.gouv.fr/sites/default/files/2018.06.25_statement_ggg_climat.pdf
[v] http://www.europarl.europa.eu/legislative-train/theme-resilient-energy-union-with-a-climate-change-policy/file-mid-century-zero-emissions-strategy-for-the-eu
[vi] https://ec.europa.eu/transport/themes/strategies/2011_white_paper_en
[vii] https://ec.europa.eu/energy/sites/ener/files/documents/2012_energy_roadmap_2050_en_0.pdf
[viii] https://ec.europa.eu/clima/policies/strategies/2050_en
[ix] http://www.consilium.europa.eu/en/press/press-releases/2018/03/23/european-council-conclusions-22-march-2018/

[x] https://ec.europa.eu/clima/policies/strategies/analysis/models_en
[xi] PRIMES-TREMOVE model documentation: https://ec.europa.eu/clima/sites/clima/files/strategies/analysis/models/docs/primes_tremove_en.pdf
[xii] Modes covered: private and public road passenger, passenger rail, freight rail, passenger aviation (split into distance classes), freight and passenger inland navigation and short sea shipping, bunkers. Numerous classes of vehicles and transport means with tracking of technology vintages.
[xiii] Additional details on the coverage by the model:
Region and road type: No spatial resolution is assumed below country levels; trip classes distinguished between urban and inter-urban areas;
Time of day/trip: off peak and peak time travelling relevant for congestion; passenger trips are distinguished into non-working, commuting and business trips; freight split into bulk, cargo and unitized.
Trip distances: based on the histogram of trips types according to distance
Energy: all crude oil derived fuels, biofuels, CNG, LNG, LPG, electricity and hydrogen.
Stock of vehicles: full dynamis of stock turnover for all road and non-road transport means.
[xiv] https://ec.europa.eu/energy/en/data-analysis/energy-modelling
[xv] https://ec.europa.eu/clima/policies/transport/vehicles/proposal_en#tab-0-2
[xvi] Technical report on EUCO scenarios, page 71. Available: https://ec.europa.eu/energy/sites/ener/files/documents/20170125_-_technical_report_on_euco_scenarios_primes_corrected.pdf
[xvii] https://www.bloomberg.com/news/articles/2017-12-05/latest-bull-case-for-electric-cars-the-cheapest-batteries-ever
[xviii] https://www.bloombergquint.com/markets/2017/04/26/the-cheap-energy-revolution-is-here-and-coal-won-t-cut-it
[xix] https://ec.europa.eu/energy/en/content/setting-3-target-public-building-renovation
[xx] EU 2016 reference Scenario. Page 57.
[xxi] EU 2016 reference Scenario. Page 58
[xxii] https://journals.ametsoc.org/doi/full/10.1175/BAMS-D-13-00089.1
[xxiii] http://iopscience.iop.org/article/10.1088/1748-9326/aa5ba0
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