CAN TRANSPORT DELIVER GHG REDUCTIONS AT SCALE? AN ANALYSIS OF GLOBAL TRANSPORT INITIATIVES

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EXECUTIVE SUMMARY

The transport sector accounted for nearly a quarter of global energy-related carbon dioxide emissions in 2011. With motorization expected to rapidly increase in the developing world, growing emissions from the transport sector could pose a serious challenge to global efforts to address climate change. In response, a variety of efforts and recommendations are either proposed or underway to reduce greenhouse gas emissions.

This paper examines seven global transport initiatives to reduce emissions. The initiatives are among fifteen presented as part of the Paris Process on Mobility and Climate and the Lima-Paris Action Agenda—both platforms for mobilizing non-state actors under the auspices of the UN Framework Convention on Climate Change. The initiatives include efforts in planning, non-motorized transport, public transport, freight, aviation, fuel economy, intelligent transport systems, and electric vehicles.

The paper assesses the seven initiatives using the "Global Calculator" — an open-source tool for exploring emissions reduction actions in energy, land, and food systems up to 2050 and the consequences of those actions through 2100. Developed by the UK Department of Energy and Climate Change with input from academic and civil society partners (including the World Resources Institute), the calculator helps users understand the relative impact of actions in different sectors on reducing emissions. It also addresses some of the challenges of comparing actions and assumptions across different models and analyses.

CONTENTS

Working Papers contain preliminary research, analysis, findings, and recommendations. They are circulated to stimulate timely discussion and critical feedback and to influence ongoing debate on emerging issues. Most working papers are eventually published in another form and their content may be revised.

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Initiatives were evaluated based on their individual impact and their combined impact. The research also uses the Global Calculator to consider untapped potential or missing initiatives. The analysis shows the impact of the transport initiatives on global emissions and costs, using common baselines and clear assumptions. Through its analysis, the paper encourages further discussion of the initiatives it considers. Are they feasible? Are their levels of ambition necessary? Are there significant gaps or overlaps? Are there synergies that can be leveraged? What cross-sectoral approaches or regional variations are needed?

Findings

The results of the analysis are presented with respect to the International Energy Agency (IEA) 6 degree scenario (6DS) as mapped in the Global Calculator. The 6 degree scenario in the Global Calculator is an approximation of the 6 degree scenario in IEA's Energy Technology Perspectives and is an extension of current trends, representing a doubling of energy use, more than double total greenhouse gas (GHG) emissions by 2050 (compared to 2009), and an average of at least 6 degrees Celsius temperature rise by 2100 (DECC 2015a).

The findings show that the initiatives are generally very ambitious and would lead to a 3.7 percent reduction in global energy-related emissions by 2050 through actions in the transport sector. The largest emissions reduction could come from mode-shifting initiatives, either to rail or public transport (up to a 2.42 percent reduction in emissions), but would also require a very high level of effort to achieve. Both have significant cost savings due to a reduction in the assumed number of vehicles purchased and infrastructure needs. The electric vehicle targets also are very ambitious and have large emissions reduction benefits. The light-duty vehicle fuel efficiency initiative has large emissions reduction potential (0.67 percent), and the airplane efficiency initiative has large emissions reduction potential (0.10 percent) with respect to the size of the sector.

Changes in demand, mode, and technology could further impact the results as the level of effort required for each initiative depends on the effort made in other areas. For example, if mode-shifting is successful, it makes it easier and less costly to achieve targets in vehicle efficiency or electrification of the fleet because it will reduce the total number of vehicles needed. Similarly for emissions reduction, the calculator shows that the carbon intensity of the grid, which impacts the emissions reduction potential from the initiatives related to electric vehicles, is highly dependent on total energy demand. Therefore, the lower the demand from all sectors, the lower the carbon intensity of electricity used in electric vehicles.

The analysis also shows that while the initiatives cover many of the important areas for reducing emissions in the transport sector, targets are not set for all of the most important opportunities to reduce emissions in the transport sector, such as reducing emissions from heavy-duty vehicles and reducing total travel demand. Understanding the collective emphasis of the initiatives, possible synergies to leverage, and regionalization of targets can lead to a more cost-effective and achievable strategy for emissions reduction in transport.

To improve the effectiveness of the initiatives, more clarity is needed regarding emissions-reduction targets for some initiatives, stronger linkages are needed among various efforts, complementary policies are needed to increase the effectiveness of initiatives, and wider geographical coverage is desirable. Generally, the transport initiatives are well-connected to cities and organizations globally. However, it will still be important to create the right linkages among different levels of government and the private sector, as well as to create access to finance and planning to make these initiatives a reality.

1. INTRODUCTION

The transport sector is a major contributor to greenhouse gas (GHG) emissions, accounting for 23 percent of global energy-related carbon dioxide (CO_2) emissions in 2011 (Sims et al. 2014). In developed countries there have been trends toward reducing private motorized travel and improving vehicle efficiency (ITF 2012; GFEI 2016). In developing countries— where high-quality public and non-motorized transport options remain limited—motorization is projected to increase rapidly (UN-Habitat 2013). Transport emissions are projected to increase more rapidly than other sectors, by approximately 80 percent during the period from 2010 to 2050 (Sims et al. 2014). Furthermore, transport growth has historically been connected with economic growth (ITF 2012) and impacts everyone in their daily lives—making strategies to reduce transport emissions both important and challenging.

Considerable research has been devoted to reducing emissions in the transport sector. Nevertheless, evaluating the impact and feasibility of different mitigation actions across various models—or comparing assumptions from different analyses—remains difficult. To address this challenge, the

UK Department of Energy and Climate Change (now part of the Department of Business, Energy, and Industrial Strategy) released the Global Calculator in 2015 to help users understand the relative climate impacts of different actions in different sectors, and how these actions are linked. The calculator is an engineering-based,[1] open-source tool for exploring different emissions reduction actions in energy, land, and food systems up to 2050, and to see corresponding consequences through 2100. It includes five sectors—transport, buildings, manufacturing, land and bioenergy, and energy—and considers the interactions among them. Users control the calculator with around 40 "levers" that drive activity in the different sectors (DECC 2015b).

In this paper, we use the Global Calculator to analyze a set of global transport initiatives. Our analysis illustrates how the calculator can be used to evaluate the impacts of various actions in the transport sector; lessons from this analysis can help inform the global LPAA initiatives process. The transport initiatives we consider were presented at the UN Climate Summit in 2014 and at the 21st Conference of the Parties (COP 21) to the United Nations Framework Convention on Climate Change (UNFCCC) as part of the Paris Process on Mobility and Climate and the Lima-Paris Action Agenda (LPAA) (see Box 1). The transport initiatives under the Lima-Paris Action Agenda and the Paris Process on Mobility and Climate include

Table 1 | **PPMC transport initiatives**

***The Low Carbon Rail Transport Challenge Action Plan** was released by International Union of Railways (UIC) to increase rail modal share and reduce energy intensity and GHG emissions.
*** The International Association of Public Transport (UITP) Action Plan** includes UITP's target to double public transport mode share globally by 2025.
*** The Urban Electric Mobility Initiative (UEMI)** was released under the lead of UN-Habitat in 2014 with the target to achieve 30 percent of urban travel by electric vehicles by 2030.
*** The World Cycling Alliance (WCA) and the European Cyclists' Federation (ECF)**, have a voluntary commitment to double the cycling mode share in Europe by 2020 and increase cycling worldwide.
***The C40 Clean Bus Declaration** was established by the Low Emission Vehicles Network under C40, with the aim to reduce emissions and improve air quality in signatory C40 cities by incorporating low- and zero-emission buses in the fleets.
ZEV Alliance (the International Zero-Emission Vehicle Alliance) is an international alliance that covers 13 countries and states (provinces) in Europe and North America, with the International Council on Clean Transportation as the secretariat. The alliance seeks to make all passenger vehicle sales in participating jurisdictions ZEVs as fast as possible, and no later than 2050.
***The ICAO/ATAG Aviation Action Plan** aims at improving global aviation fuel efficiency with a target improvement rate, as well as stabilizing net carbon emissions.
***The Vehicle Fuel Efficiency Accelerator** is a part of the UN SE4ALL platform, with the Global Fuel Economy Initiative's (GFEI) targets to improve fuel efficiency of light-duty vehicles globally.
MobiliseYourCity is a global initiative supporting local governments in developing countries to improve or draft a Sustainable Urban Mobility Plan, with the aim to reduce by at least 50 percent urban transport-related emissions by 2050, under the support of a coalition of international organizations.
Intelligent Transportation Systems (ITS) for the Climate is led by ATEC ITS France to identify and share best practices for intelligent transportation systems to reduce emissions.
Taxis4SmartCities is an initiative composed of taxi companies in ten countries with an aim of transitioning fleet energy by 2020–30.
The Low Carbon Road and Road Transport Initiative (LC2RTI) is led by the World Road Association (PIARC). Its objective is to build strong and sustainable adaptation policies for the road network, including sensitive engineering structures and infrastructure (bridges, rural roads, etc.).
The Navigating a Changing Climate Initiative is led by the World Association for Waterborne Transport Infrastructure (PIANC). Its goal is to have a better waterborne transport sector regarding infrastructure, accessibility, mitigation and adaptation, and integrated sustainability solutions.
Airport Carbon Accreditation is led by ACI Europe with the objective to "reduce carbon emissions and achieve best practice in carbon management from operations fully within the control of the airports, with the ultimate target of becoming carbon neutral."
The Global Green Freight Action Plan was released by the International Council on Clean Transportation, Smart Freight Centre, and Clean Air Asia, with a focus of reducing black carbon and particulate matter emissions from heavy-duty vehicles.

* Denotes initiatives tested in this paper

Source: ATAG 2013; ATEC-ITS France 2015; C40 2015; Climate Summit 2014a, 2014b, 2014c; CODATU 2015; ECF 2015; Global Green Freight 2015; GFEI 2016; PIANC 201; PPMC 2015b; Taxis4smartcities 2015; UITP 2015b; PIARC 2015; ZEV Alliance 2015.

Box 1 | **The Lima-Paris Action Agenda and the Paris Process on Mobility and Climate**

The Lima-Paris Action Agenda is "a joint undertaking of the Peruvian and French COP presidencies, the Office of the Secretary-General of the United Nations and the UNFCCC Secretariat" (LPAA 2015). The LPAA aims to accelerate action of state and non-state actors through climate change mitigation and adaptation initiatives (GGCA 2015), by mobilizing global action, providing a platform for visibility, and providing support to initiatives (LPAA 2015).

The Paris Process on Mobility and Climate is a platform for organizations and initiatives acting in the area of transport and climate. "The PPMC was created in early 2015 to strengthen the voice of the sustainable transport community in the UNFCCC process, especially with a view to the Conference of Parties (COP21) in December 2015 in Paris" (PPMC 2015a).

efforts in planning, non-motorized transport, public transport, freight, aviation, fuel economy, intelligent transport systems, and electric vehicles. A short description of each initiative is shown in Table 1.

Although fifteen initiatives were presented, we consider only the seven with clear emissions reduction targets that could be mapped into the calculator for our analysis. We evaluated them by looking at (a) their individual impact, (b) their combined impact, and (c) untapped potential or missing initiatives. Our analysis shows the global emissions and costs impact of the transport initiatives using common baselines and clear assumptions; it also gives a sense of the feasibility of the initiatives. We hope the analysis will spur discussion of the following questions: Are all of these initiatives feasible? Is the level of ambition among the initiatives necessary? Are there significant gaps or overlaps? Are there synergies to leverage? What cross-sectoral approaches or regional variations are needed?

In the following subsection, we describe emissions reduction potential in the transport sector. After that, we describe the Global Calculator and explain why it is a valuable tool for comparing initiatives. Next, we use the Global Calculator to analyze the initiatives and the untapped potential of the transport sector. Because we look at the global impact of actions, not only the transport-sector impact, the results help to contextualize the transport sector and the need for cross-sectoral actions. We conclude with a summary of emissions reductions actions for transport and recommendations for moving forward with the Lima-Paris Action Agenda global initiatives.

1.1 Transport Sector Context

Reducing transport emissions is essential if the world is to meet the goal introduced at COP 21 to "keep global temperature rise this century well below 2 degrees Celsius and to drive efforts to limit the temperature increase even further to 1.5 degrees Celsius above pre-industrial levels" (UNFCCC 2015a). There have been a variety of attempts to estimate and model emissions in the transport sector as part of the effort to identify actions to curb these emissions. They generally include econometric modeling and accounting. Econometric modeling tends to be used at the national level and accounting at the sectoral level (Bhattacharyya and Timilsina 2009).

In all attempts to model the transport sector, base year estimates vary as do projected emissions totals by 2050. The International Transport Energy Model Comparison Project shows the challenges in comparing results from different models (Fulton et al. 2014). Notable findings include large differences in historical data among models, particularly in developing countries in terms of passenger cars and 2-3 wheelers (2-3W). The models use different estimation methodologies to determine total travel. For example, in China, the variation in vehicle-kilometers traveled is over 50 percent among models. The models also use different accounting systems to determine GHG emissions.

The wide variety of assumptions and focuses for the models can lead to a variety of recommended actions, making policy development and phasing difficult. Analysis using the International Council of Clean Transportation Global Transportation Roadmap model, released in 2012, shows that accelerated policy adoption on stringent fuel and vehicle standards can bring important emissions reductions (Chambliss et al. 2013). The Global High Shift Scenario—developed by the Institute for Transportation and Development Policy and UC Davis in 2014—shows that a large shift toward public transport can provide similar mobility needs in terms of passenger-kilometers traveled (PKT) compared to the IEA 4 degree scenario (4DS) baseline in 2050, and could reduce CO_2 emissions sharply in a less expensive and more equitable way (Replogle and Fulton 2014). Recently, a Global High Shift Cycling Scenario showed that a future with a dramatic increase in cycling could bring an 11 percent CO_2 reduction compared to the previous High Shift scenario (ITDP and

UC Davis 2015). According to the IEA (2015b), some of the key measures for emissions reduction lie in the transport sector, such as increasing energy efficiency in transport and increasing the share of alternative fuel vehicles on the road. Alternative fuels are a common recommendation; however, recent work shows that biofuels perhaps should not be considered carbon-neutral (Searchinger and Heimlich 2015).

Many processes and plans are in place to set and achieve emissions reduction goals at the local and national level. But it is not clear that all of these plans can reduce emissions as much as necessary to reach the target of "well below" 2 degrees. For example, the Nationally Determined Contributions (NDCs) are country commitments for reducing emissions in all sectors, including transport. "Emission Reduction Potential in the Transport Sector by 2030,"released by the Paris Process on Mobility and Climate (2015), compares transport-related NDCs to the IEA 2 degree scenario (2DS), looking at possible mitigation magnitude by 2030. Among the 138 countries analyzed, only 10 percent of the NDCs proposed transport sector emissions reduction targets. The study also looked at low-carbon scenarios (average and aggressive) that are based on over 350 global and national mitigation potential studies. These show that emissions can be reduced by 24 percent from the business-as-usual scenario, but that would still leave a 23 percent gap compared to the IEA 2 degree scenario. The study concludes that current NDCs are not sufficient to achieve the IEA 2 degree scenario within the transport sector by 2030. Because of the lock-in effect of decisions regarding transport infrastructure and equipment that are made today, some solutions would need to be developed much more rapidly to reach the 2 degree scenario by 2030, such as carbon capture and storage, electric vehicles, advanced biofuels, and sustainable urban planning (IEA 2015b).

2. GLOBAL CALCULATOR BACKGROUND AND ANALYSIS METHODOLOGY

2.1 Global Calculator Background

The Global Calculator (globalcalculator.org) is an engineering-based scenario model that allows users to assess the GHG and cost impacts of the different transport initiatives, individually and collectively. Led by the UK Department of Energy and Climate Change, the calculator was developed with Climate-KIC, the World Resources Institute, Energy R&D International, EY India, Climact, the London School of Economics, Imperial College London, the National Development and Reform Commission (China), and the Climate Media Factory.

The calculator contains an extensive, referenced, and strictly peer-reviewed database that allows users to evaluate the level of ambition of various actions (DECC 2015a). This was developed through a literature review of each sector to develop the base year and levels of ambition for each sector. The review process for the database and model included data review and input from the IEA, peer review and workshops on the levels of ambition with experts and stakeholders in each sector, a public opening of a draft version of the tool with a call for evidence, and a DECC review panel. Throughout this process, hundreds of experts were consulted for data validation and modeling.

The calculator was developed because while more complex models exist, they often focus on one sector or have assumptions that are difficult to follow, making it hard for policymakers and the public to understand the meaning of their results. The calculator's simplicity allows these audiences to engage in the debate more fully and helps users understand the relative impact of actions in different sectors to reduce emissions. The calculator concept has been used to develop country calculators in addition to the Global Calculator. These calculators have been used by governments in a number of countries, including the United Kingdom and China, to test different policy options and to see their impact at a high level. It has also been used by Colombia, Vietnam, Nigeria, and India to develop Intended Nationally Determined Contributions (INDCs) for COP21 in Paris.

The calculator is user-friendly and completely open source, which is useful for a high-level understanding of different emissions reduction actions. However, it does not allow for detailed or regionalized modeling. It also does not provide information about particulate matter and other co-benefits. A similar type of modeling exercise to look at co-benefits could be beneficial—particularly for developing countries, where co-benefits can be more important in decision making than CO_2 emissions reduction.

2.2 Model Structure

The model includes five basic sectors—transport, buildings, manufacturing, land and bioenergy, and energy—and considers the interactions among them (DECC 2015a). In each sector, different levers of action are mobilized to control emissions from now until 2050. For each lever, the user can choose different levels of effort or ambition: from level 1 (make minimal effort to tackle climate change) to level 4 (make an extraordinarily ambitious and extreme level of abatement effort). Levels 1 to 4 were developed based on a literature review that reflects different growth assumptions for each sector. Users can also change population and urbanization levers, as well as the emissions trajectory post-2050.

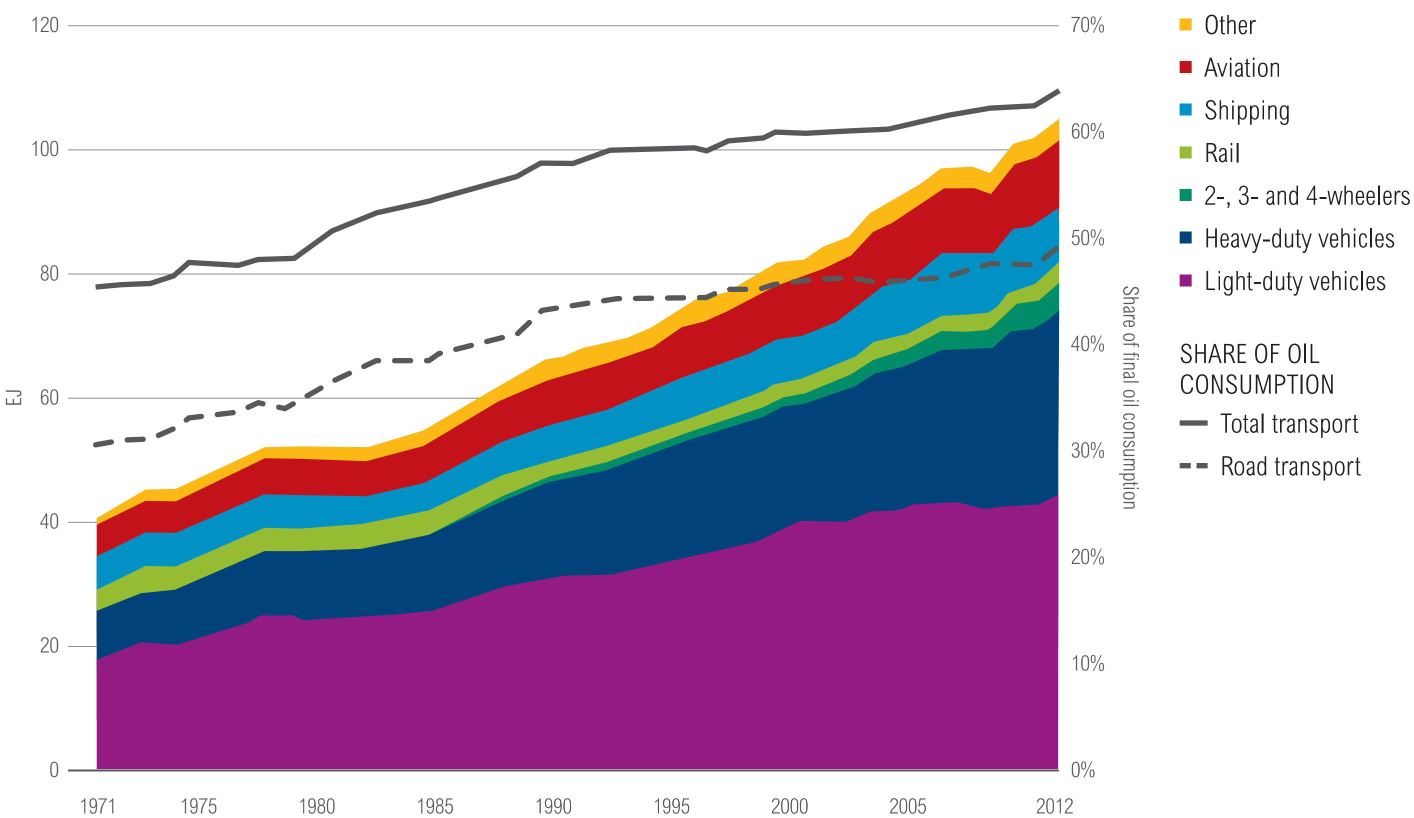
Every time the user changes a lever, there is a resulting impact on energy demand and supply, CO_2 emissions, and the climate. Total energy demand is summed among sectors, and the model automatically matches global energy supply and demand at a yearly level, based on user choices. Energy from fossil fuels is automatically used to fill in any gaps between supply and demand based on user choices.

Although the model contains information about the price of different energy sources and materials, it makes no assumptions about the way people's behavior changes in relation to supply and demand, but there are levers of action for the key behavior changes that users can choose to mobilize. The model does not automatically optimize the energy system based on price or any other factor. However, the calculator estimates a cost based on physical units with respect to gross domestic product (GDP) for each tested scenario.

Modeling Energy Demand From the Transport Sector

The transport sector modeling approach was developed to capture the variation in possible futures for the transport sector in terms of travel, modes, and technologies. Figure 1 shows the contribution of different vehicle categories toward total transport energy demand in 2015. The figure shows that light- and heavy-duty vehicles make up the largest portion of energy demand, while aviation and

Figure 1 | **World transport energy use by mode**



Source: IEA 2015a.
Notes: Light-duty vehicles are cars and light trucks (up to 3.5 tonnes); heavy-duty vehicles are trucks and buses. Aviation and shipping include international bunkers, i.e., fuels used for international aviation and navigation.

shipping energy demand also is significant. Additionally, heavy-duty vehicle use and air travel are expected to grow rapidly, and two- and three-wheelers make up a small but quickly growing portion of energy use. The transport sector modeling approach includes all of the vehicle categories in Figure 1 and focuses on those that currently contribute the most to energy demand or emissions and the areas where emissions growth is expected to be very significant, such as light- and heavy-duty vehicles.

In the calculator, the total energy demand from the transport sector is based on user selections for the following levers:

- passenger demand
- freight demand
- mode
- load factors and occupancy
- car own or hire
- electrification
- transport efficiency

A range of projections, from level 1 to 4, were developed for each of the levers by using the categories of passenger travel or freight travel. Passenger travel was further divided into urban, rural, and international travel categories. For urban travel, three categories of cities were developed to characterize travel growth projections through 2050: automobile cities (representing urban areas in places like the United States), transit cities (representing urban areas in Europe and Latin America), and booming cities (representing urban areas in Asia and Africa). For rural and international travel, the categories of developed and developing countries were used to develop growth projections. Freight travel was divided into domestic and international freight. These categories were further divided into developed and developing countries to create travel growth projections through 2050.

Similar to Schipper et al. (2009), total energy demand in the transport sector is calculated in a standard formula: activity (travel demand), * mode (passenger/freight), and * modal energy intensity.

However, in contrast to other models, total emissions are not calculated for each sector in the calculator. Total energy demand among all sectors is summed; total energy supplied is calculated based on total demand, and emissions factors are applied to energy sources.

Cost Savings or Increase

The cost of each pathway is an output of the model. As described by DECC (2015c), the costs shown in the model reflect the total energy system cost of the pathway selected. This includes the capital, operating, and fuel costs of the global energy system out to 2050. Some of the specific costs included are building and maintaining power stations, wind turbines, heat pumps, boilers, cars, trains, planes, roads, railways, clean technology used in manufacturing, and fuel prices. The opportunity cost of finance used to fund capital expenditure also is included.

The cost estimates are all compared to the IEA 6 degree scenario, and shown as a percent of GDP calculated as: (average annual cost of the energy system in the user's pathway over period 2011–2050 - average annual cost of the energy system in the counterfactual pathway over 2011–2050) / average annual global GDP over the period 2011–2050 x 100 percent.

In this paper, point estimates and high-low ranges are calculated for each pathway. The point estimate data is in most cases from the TIAM-UCL model (ERC 2011). This source is a well-respected, widely used variant of the TIMES model (IEA 2005) with cost data taken from published, open sources. The ranges are based on published studies for what costs could be in 2050. Where high or low costs were not available, costs were inflated or deflated by 20 percent. Costs change linearly between 2011 and 2050.

For the transport sector, infrastructure investment costs are estimated per road kilometer traveled and per rail kilometer traveled and include parking. This approach could underestimate some of the infrastructure costs for public transport because it uses a value per road or rail kilometer and does not consider underground or above ground transit line costs. However, the total estimated vehicle kilometers traveled by cars is far larger than for public transport. The transport sector costs also include the number of vehicles and fuel consumption and have an impact on fuel production.

There are some key concepts and assumptions for interpreting the cost savings approach and results. First, costs in 2050 are extremely uncertain, particularly for fuels. The costs are based on US data, under the assumption that the uncertainty in future costs within one country, in this case the United States, is greater than the variation of costs between the United States and other regions at any point in time. Also, it is difficult to estimate the total energy system cost without double counting. The costs of a car, counted in the transport costs, will include the cost of electricity used in the production of the car. The cost of the electricity is also counted in the power sector costs. The model's costs do not try to avoid this double counting, as to do so would be highly complex. Therefore it presents an index of costs over time to show how the costs could change.

The Global Calculator is based on engineering relationships rather than economic relationships. This means that the tool will cost whatever combination of technologies and actions the user specifies; it does not take into account price interactions between supply and demand to determine what actions take place. Also, costs are exogenous. For most technologies, costs decline over time as they follow a learning curve. In this model, while the cost of an electric vehicle changes over time, for any given year, the price is fixed regardless of whether there is a high or low deployment of electric vehicles in that year.

Some costs are not included, either due to time, uncertainty, or the potential negligible nature of costs. It was not possible to estimate costs for insulation, transport efficiency, appliance efficiency, fossil fuel efficiency, and the greenhouse gas removal levers. Because this model looks at component costs, broader system costs, such as energy security impacts or costs resulting from damage due to climate change can be significant, but are also not included.

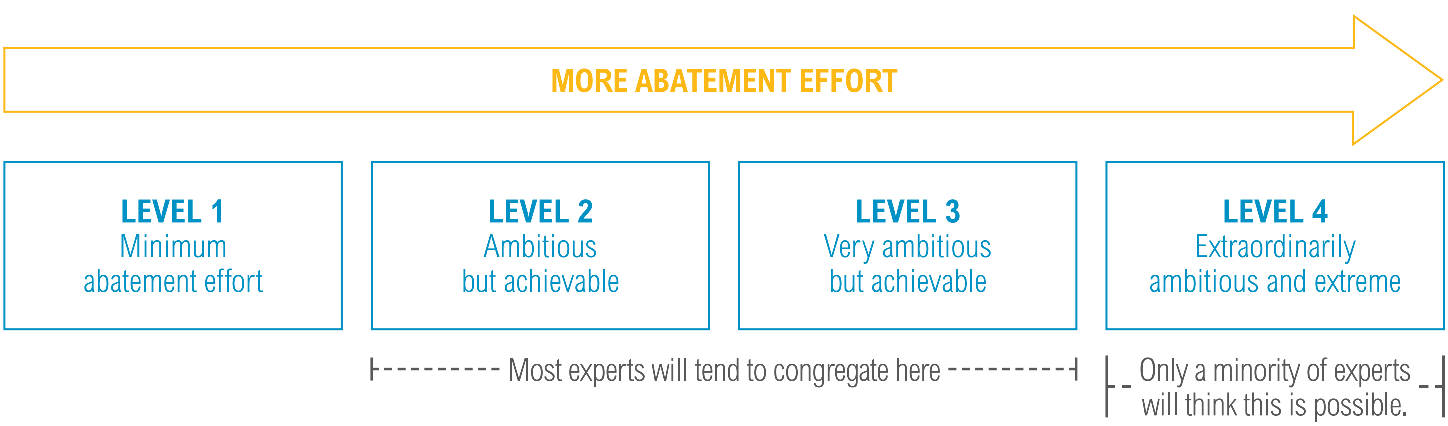
Feasibility

The feasibility of each initiative is discussed with respect to the levels of effort 1 to 4 in the Global Calculator (Figure 2). The levels are meant to represent a wide range of possibilities within each of the levers of the transport sector. The review process for the levels of effort included the IEA, peer review and workshops with experts and stakeholders in each sector, and a public opening of a draft version of the tool with a call for evidence.

For reference, level 2 for the transport sector is based on these assumptions (the full list of assumptions for all levels is in Appendix 4):

1. **Passenger Demand:** Some action is taken to curtail growth in passenger distance traveled. Cities with established development patterns, as well as growing cities, pursue initiatives to reduce the need for travel throughout the city.
2. **Freight Demand:** Global freight continues to experience strong growth.
3. **Mode:** Cities make an effort to shift trips to walking, cycling, and public transport instead of by car. Some effort is made in logistics and rail infrastructure.
4. **Occupancy:** Car occupancy remains at 2011 levels, which is around the same as the occupancy seen in the United Kingdom today.

Figure 2 | **Global Calculator levels 1 to 4**



Source: DECC 2015b.

5. **Car Ownership:** The distance traveled per car is the same as today's levels. Similar to today, car rental or sharing is a niche concept. The vast majority of cars remain privately owned and used.
6. **Vehicle Efficiency:** Annual improvement roughly corresponds with improvements achieved over the last decades. For example, by 2050, the average urban passenger car (with an internal combustion engine) will use 5.3 liters of fuel per 100km.
7. **Electrification of Vehicles:** By 2050, there is an increased share of new technologies in the vehicle fleet. The percentage of hybrid and electric vehicles increases for passenger cars, buses and 2-3 wheelers.

2.3 Analysis Methodology

The analysis of initiatives was done by matching the user selection inputs in the Global Calculator to the targets and years they are meant to be achieved under the initiatives and comparing the emissions and cost outputs to the IEA 6 degree scenario as mapped in the calculator (assumptions can be found in Appendix 2). Feasibility is described with respect to Levels 1 to 4 in the calculator as well as the 6 degree scenario.

For any initiatives that call for mode shifting, the assumed shift was from vehicles that use fossil fuels (or internal combustion engine vehicles) to other modes—public transport, rail, or non-motorized transport. There are two ways to look at the mode share: percent of trips or percent of person-kilometers traveled. When using the latter, modes like walking and biking will result in a much smaller share than if comparing share of trips due to shorter distances traveled using these modes. This analysis considers mode share as a percentage of person-kilometers traveled to capture both mode and distance.

The matching of inputs was done for individual levers and no additional changes or assumptions were made to other levers or sectors unless explicit. Specifically, no changes were made regarding types of fossil fuel and how it is distributed across energy demand from different sectors. The emissions reductions values represent the emissions changes from 2011 through 2050 in terms of total energy-related emissions, not only the transport sector.

The 6 degree scenario developed by the IEA was mapped in the calculator using the levels of effort that most closely matched the assumptions for behavior and technology change through 2050. (Note: The IEA 6 degree and 4 degree scenarios have similar behavioral assumptions (i.e., vehicle kilometers traveled) but different technology assumptions. Therefore, if the 4DS was used as the baseline for this analysis, the results would be similar for behavior-related initiatives and different for technology initiatives). Because the 6 degree scenario makes assumptions about changes over time in different levers, it is important to keep in mind these baseline values related to each initiative in order to interpret the results.

For certain very ambitious initiatives and to give additional context, we tested related scenarios beyond the initiative. This helped show the specific actions that could make a larger impact and whether meeting the full set of targets was necessary to make a large overall impact with that mode or lever. Many of the initiatives mention a variety of measures to reduce emissions, but we tested only the portions of the initiatives with clear targets.

3. ANALYSIS OF INITIATIVES

The analysis using the Global Calculator looks at feasibility, emissions impact, and cost impact of the various initiatives. The analysis looks at individual initiatives first, followed by the collective impact and untapped potential.

3.1 Analysis of Individual Initiatives

In this paper, we analyze seven initiatives, or portions of initiatives, with clear greenhouse gas (GHG) emission targets. This means the initiatives have targets associated with specific levers in the calculator, and the impact can be tested at the global level without making many new assumptions. The analyzed initiatives are the following:

- Low Carbon Rail Transport Challenge Action Plan
- International Association of Public Transport Action Plan
- Voluntary Commitment from the World Cycling Alliance and European Cyclists' Federation
- Urban Electric Mobility Initiative Action Plan
- C40 Clean Bus Declaration
- Vehicle Fuel Efficiency Accelerator
- Aviation Action Plan

For each initiative, we provide information on the targets as well as the background and trends related to that target. Where there are targets relating to multiple levers, we give background information on each of the different targets. This background information helps to contextualize the feasibility of the initiative and results of the analysis. For each initiative, we provide details on the assumptions changed in the calculator in order to analyze the impact, along with related scenarios to help demonstrate feasibility. Finally, we present cost and emissions results along with graphics showing energy demand and emissions change over time. We discuss the results along with complementary measures.

Initiative | Low Carbon Rail Transport Challenge Action Plan

The targets for this initiative were developed with modeling support from the IEA and approved by the International Union of Railways (UIC) General Assembly on June 27, 2014. Among the initiatives, it has some of the most clear and detailed targets.

TARGETS AND BASELINES

Reduction in specific final energy consumption from train operations:

- 50 percent reduction by 2030 (per passenger-km or ton-km relative to a 1990 baseline)
- 60 percent reduction by 2050 (per passenger-km or ton-km relative to a 1990 baseline)

Reduction in specific average CO_2 emissions from train operations:

- 50 percent reduction by 2030 (relative to a 1990 baseline)
- 75 percent reduction by 2050 (relative to a 1990 baseline)

Railway share of passenger transport (passenger-km):

- 50 percent increase by 2030 (relative to a 2010 baseline)
- 100 percent increase (doubling) by 2050 (relative to a 2010 baseline)

Railway share of passenger transport (passenger-km):

- equal with road by 2030
- 50 percent greater than road by 2050

BACKGROUND AND TRENDS

The following is a discussion of past and current trends pertaining to each of the targets.

Energy Consumption and CO_2 Emissions. While final energy consumption of rail did not decrease between 1990 and 2012, the energy consumption per kilometer decreased by roughly 50 percent per passenger-kilometer and roughly 35 percent per freight ton-km during the same period (based on International Union of Railways 2015 data). Additionally, CO_2 emissions per pkm and ton-km have decreased roughly 40 percent and 30 percent since 1990 (International Union of Railways 2015). This demonstrates that significant progress has already been made toward meeting the targets. According to the initiative (Climate Summit 2014a), "these targets will be achieved by railway companies across the world through electrification of existing lines, decarbonization of electricity supply, improving load factors, procurement of more efficient rolling stock, energy management systems, and efficient driving." The energy demand targets can be met through work in the rail sector alone, but meeting the CO_2 targets will depend to some extent on changes in the energy sector.

Passenger Rail. In 2010, global passenger-kilometers were 2,765 billion (UIC 2011). Therefore, the target to reach a 50 percent increase in rail passenger kilometers traveled (PKT) by 2030 relative to a 2010 baseline equals a 1,382 billion increase in passenger-kilometers. This is roughly a 2.5 percent increase per year. Based on statistics from the International Union of Railways (2011), total rail passenger-kilometers have increased by 20 percent between 2006 and 2011, or 4 percent per year, showing major growth in Asia and the Americas. If this trend continues, the 2030 goal will be attainable. However, the highest total PKT growth rate in the Global Calculator is on average assumed to be 1.1 percent per year through 2050. This initiative represents a large continued increase in the share of rail PKT. The baseline estimate of global rail passenger-kilometers in 2011 was 5 percent of the total global PKT, and is assumed to decrease to 3 percent in 2050 (based on the Global Calculator).

Freight Rail. Global freight ton-km totaled 9,281.2 billion in 2010 (UIC 2011). In terms of freight transport, roughly one-third each of the total ton-km traveled were in the Americas or Asia, Oceania, and Middle East regions, with another 20 percent in Russia. There was a similar growth rate in rail freight to passenger rail between 2006 and 2011. At the same time, a large portion of freight growth is assumed to take place on-road in the future; the share of road freight of international ton-km is expected to increase by about 65 percent between now and 2050 (ITF 2012). Therefore, in terms of freight, this is quite an ambitious target.

ANALYZING IMPACT AND FEASIBILITY

The impact and feasibility was tested by mapping the targets for each of the areas the initiatives cover.

Energy Consumption. Since 1990 there has been a significant reduction in energy consumption per kilometer in the rail sector. Table 2 shows the actual change in energy consumption from 1990 to 2011 as well as the UIC target and the projected future change from the IEA 6DS. This shows the baseline estimate from the IEA 6 degree scenario meets the target per passenger-km and comes close to the target for the freight ton-km. Of the three factors that impact efficiency used in the calculator—fleet efficiency, occupancy/load, and electrification—fleet efficiency improvements of roughly 2 percent per year would make the largest impact on reducing emissions and allow the International Union of Railways to achieve these targets. Electrification, depending on the grid, can also have a larger impact on reducing emissions.

Table 2 | **Reduction in energy consumption: Actual, targets, and 6 degree scenario**

		% REDUCTION PER RAIL TON-KM		
		1990-2011	2030	2050
Actual	Passenger	50		
	Freight	35		
IEA 6DS	Freight			60
	Passenger			40
UIC target	Total		50	60

Passenger Rail. When matching the targets to the levers in the calculator, there are many possible approaches for increasing the share of passenger rail. Some of the factors that will impact the share of rail include total passenger travel demand and shifting from different modes. In this case, total passenger demand was not changed from the growth projected under the 6 degree scenario. Level 3 was chosen as a reference for a new mode share in 2050, and from Level 3, changes were made to all motorized travel shares to create the shift toward rail that would match the target.

Table 3 | **Urban areas scenario: Rail percent of total PKT (model input for commitment plus reference scenarios)**

SCENARIO	2011	2030	2050
IEA 6DS baseline	5.16	4.11	3.04
Level 3	5.16	4.54	3.99
Level 4	5.16	5.04	5.10
UIC commitment (urban)	5.16	7.50	10.01

Two scenarios are used: one doubles rail PKT in urban areas only, and one doubles PKT for all rail travel. The changes made to rail PKT to represent the commitment are shown in Tables 3 and 4, along with the reference scenarios of the baseline, Level 3 and Level 4 in the Global Calculator. The Global Calculator assumptions show that in 2011, urban and non-urban rail travel made up 58 percent and 42 percent of rail PKT, respectively. Each of the scenarios in the table assumes a growth in rail PKT of at least 75 percent. Because motorization is projected to increase very rapidly, rail PKT would also need to grow very rapidly to increase the share of total PKT or to have the capacity to offset some of the growth in motorization.

Table 4 | **Urban and non-urban areas scenario: Rail percent of total PKT (model input for commitment plus reference scenarios)**

SCENARIO	2011	2030	2050
IEA 6DS baseline	8.15	7.24	6.65
Level 3	8.15	7.89	8.13
Level 4	8.15	8.99	10.02
UIC commitment (urban and non-urban)	8.15	12.01	16.03

Table 5 | **Mode percent of ton-km (model input for commitment plus reference scenarios)**

SCENARIO	MODE % OF TON-KM IN 2030				MODE % OF TON-KM IN 2050			
	HEAVY TRUCK	TRAIN	SHIP	PLANE	HEAVY TRUCK	TRAIN	SHIP	PLANE
IEA 6DS baseline	12.3	9.3	78.2	0.2	13.1	8.9	77.7	0.2
Level 3	11.4	9.9	78.5	0.2	10.7	9.8	79.3	0.2
Level 4	10.1	11.1	78.6	0.2	7.7	12.9	79.3	0.2
UIC commitment (freight)	10.5	11.1	78.2	0.2	8.9	13.1	77.8	0.2

Freight Rail. When matching the freight rail targets to the levers in the calculator, there are many ways to increase the share. The factors that will impact the share of rail include total freight demand and shifting from different modes. The freight demand (ton-km) was not changed from the growth projected under the 6 degree scenario.

Table 5 shows the changes made with respect to mode for the analysis. Level 4 very closely matches the rail and truck percentages of ton-km for the UIC initiative. Without a change in freight demand, this represents as much as 200 percent growth in freight ton-km from 2010 to 2050. If there is a change in freight demand or distance traveled, this may represent only a doubling of rail ton-km.

RESULTS

The emissions reductions with respect to total energy-related emissions through 2050 and cost reductions related to total GDP are presented in Table 6. This shows that mode-shifting leads to the largest reductions in energy demand and CO_2 emissions, as well as cost savings. This is because this analysis assumes a scenario where most of the mode shift will come from light- or heavy-duty vehicles, which produce the most GHG emissions. Growth in passenger rail could shift travel from non-motorized transport; however, it is unlikely to be a large impact since rail trips are typically much longer and not interchangeable with non-motorized trips. In addition, there is a relatively small impact from efficiency improvements partly because the efficiency improvements assumed in the baseline are very close to the targets of the initiative. Figure 3 and 4 also show the change in energy demand and CO_2 emissions through 2050.

Table 6 | **Emissions and cost reductions from rail scenarios**

SCENARIO	EMISSIONS CHANGE (% OF TOTAL CO_2e EMISSIONS, 2011 TO 2050)	COST CHANGE (% GDP, 2011 TO 2050)
Urban passenger and freight shift	-1.05	-0.80 to -1.47
All passenger and freight shift	-1.52	-1.34 to -2.51
All passenger and freight + efficiency	-1.62	-1.43 to -2.73
Efficiency	-0.05	-0.05 to -0.14

COMPLEMENTARY MEASURES

The goals overlap with initiatives in public transport and potentially with goals for green freight. The electricity grid also will have an impact on total emissions reduction if much of the rail is electrified.

Figure 3 | **Transport sector energy demand based on rail scenarios**

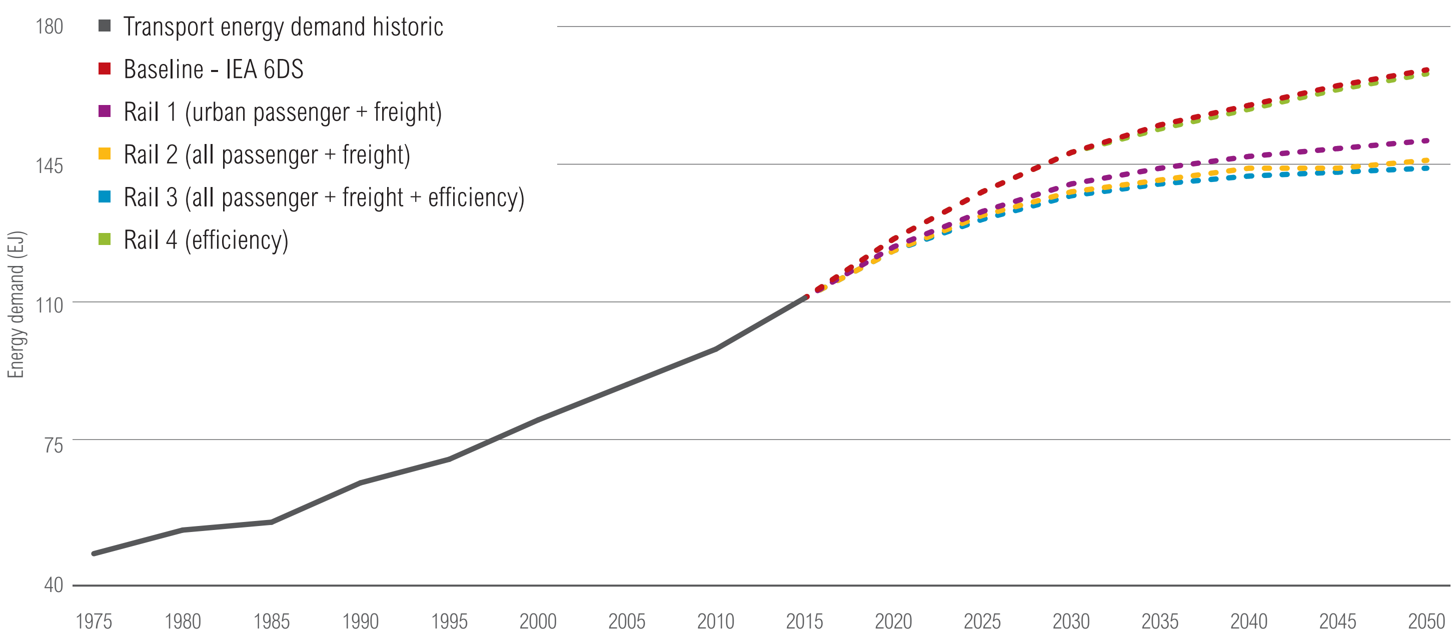
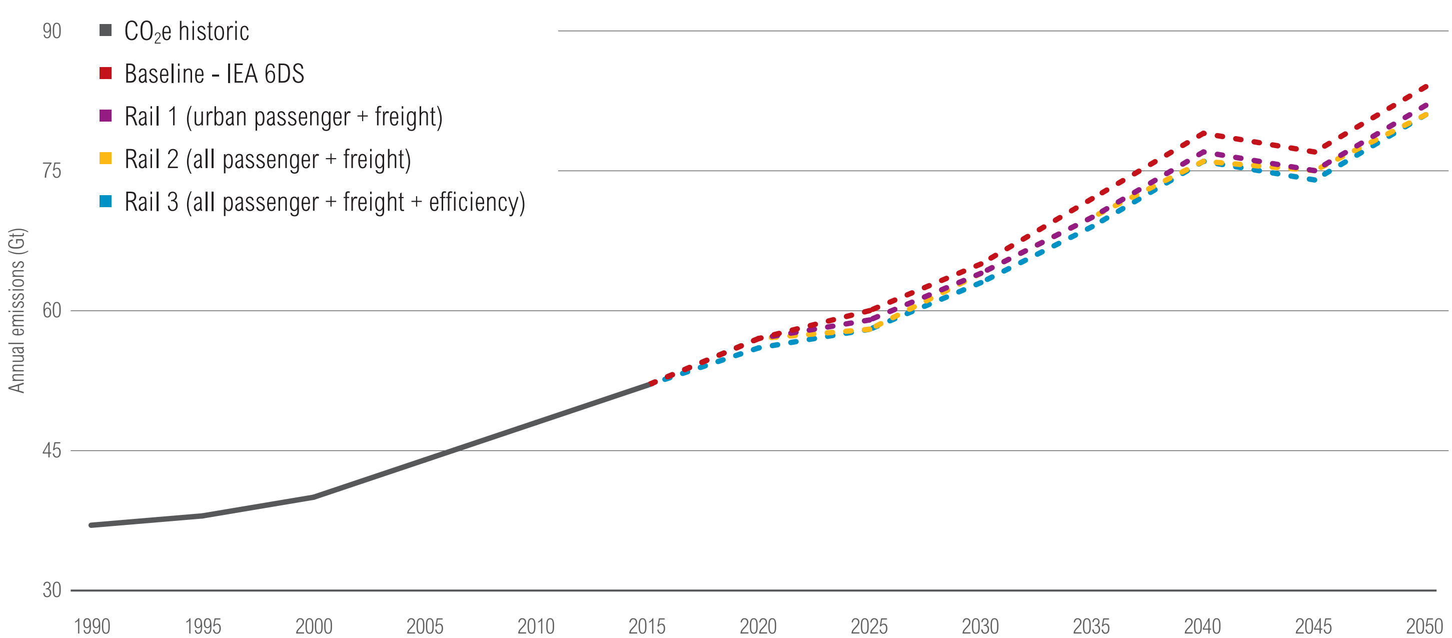


Figure 4 | **Global CO_2e emissions based on rail scenarios**



Initiative | International Association of Public Transport Action Plan

TARGETS AND BASELINES

> The goal is to "double the market share of public transport worldwide by 2025."

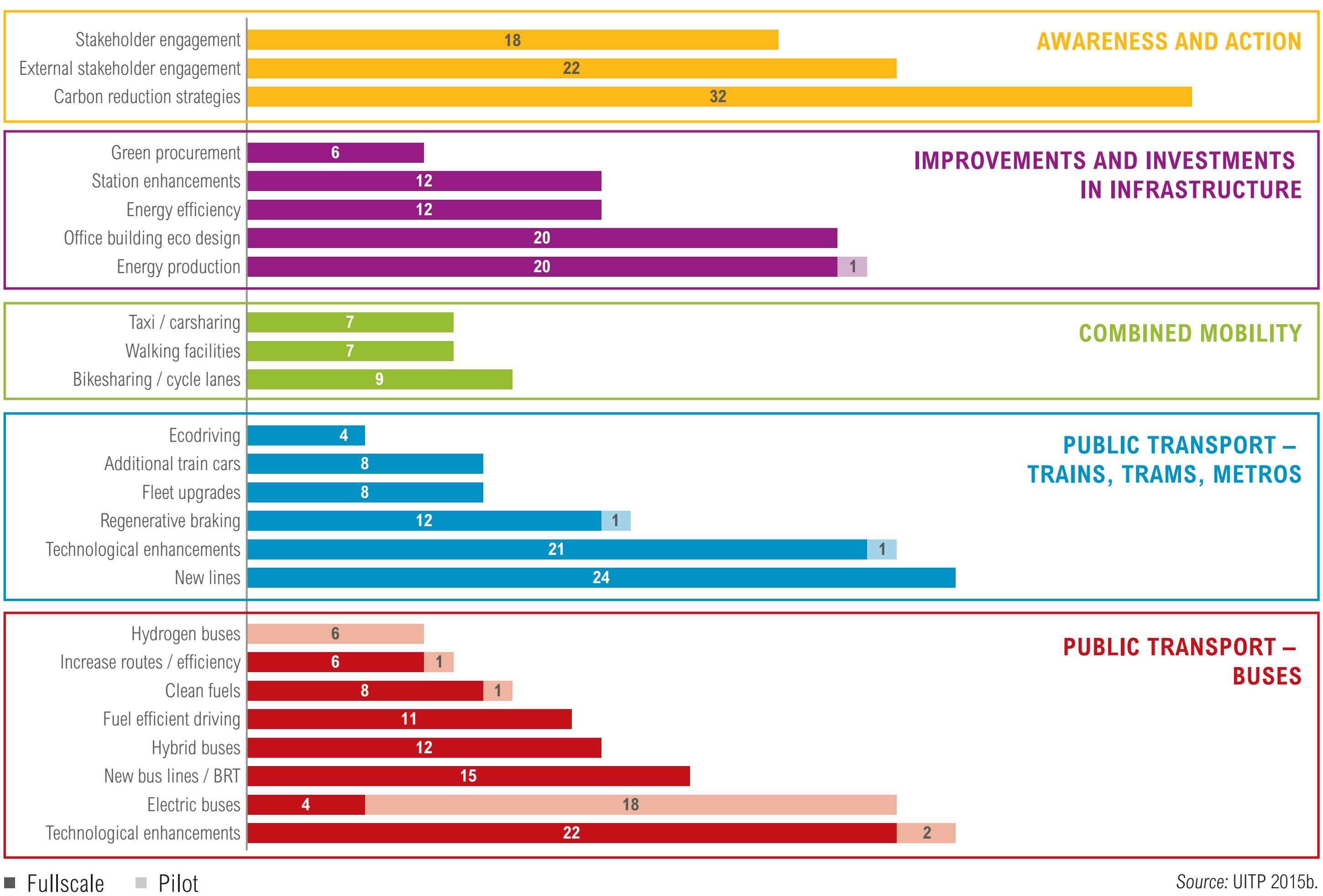
The International Association of Public Transport Action Plan initiative taps into interest among many cities in increasing the use of public transport. The International Association of Public Transport is tracking initiatives aimed at making public transport more attractive. Figure 5 shows that these actions are generally related to reducing emissions, though about half focus on emissions reductions through technology rather than directly increasing public transport use. It is difficult to assess which projects will increase public transport use, but improving transit along with engaging stakeholders and increasing intermodal connectivity will be important steps.

BACKGROUND AND TRENDS

Figure 6 shows example cities and market shares of various modes in terms of total number of trips at present. Many cities around the world have roughly one-third private vehicle transport, one-third public transit, and one-third non-motorized transport. North American cities have many more private vehicle trips, and many developing cities are rapidly motorizing.

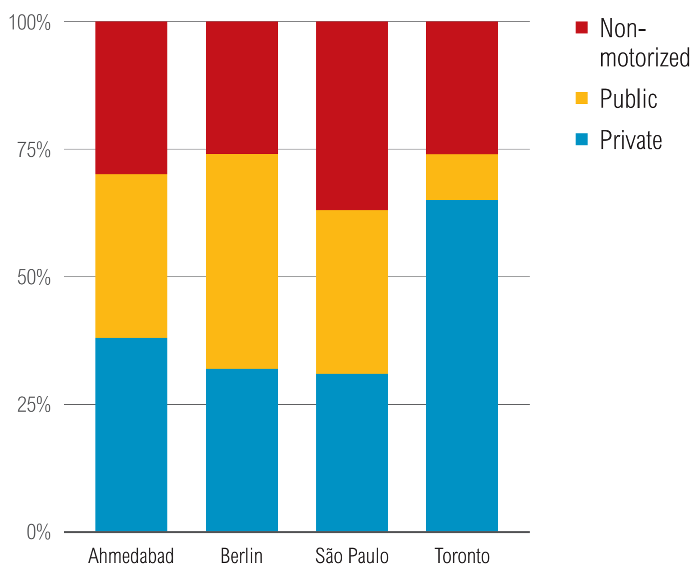
In 2010, public transport made up about 40 percent of PKT globally (Replogle and Fulton 2014). However, the numbers vary significantly between the OECD and non-OECD countries (20 percent vs. 50 percent). Under the 2050 high-shift scenario, which is considered to be a maximum of possible shift in urban areas, about 55 percent of PKT will be made by public transport. Much of the growth in travel will take place in developing countries where currently a high percentage of travel is by public transport. However, with high rates of motorization, it will likely be difficult to maintain the high levels of public transport (IEA 2009).

Figure 5 | **Worldwide climate action with public transport (number of projects)**



Source: UITP 2015b.

Figure 6 | **Mode shares by percent of trips in four cities**



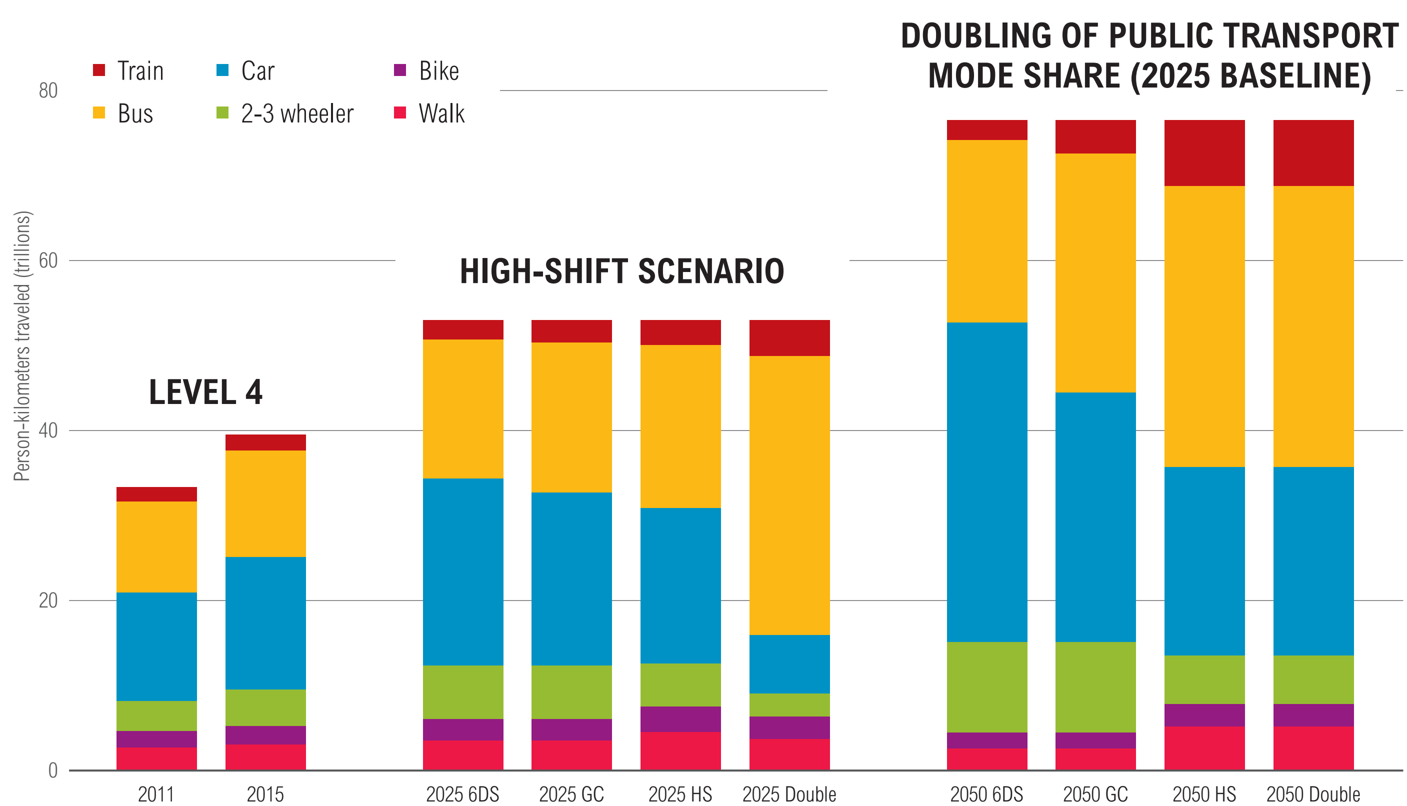
Sources: LTA Academy 2015.

The high-shift scenario (Replogle and Fulton 2014) also estimates that in OECD countries the amount of urban travel from light-duty vehicles can be reduced to roughly 45 percent of travel from what it is today and that much of this shift would be toward urban buses and commuter rail. This may be challenging in places that already have very high public transport mode shares. However, there may be more opportunities in places like the United States, where areas that are often considered car-oriented have made efforts to expand biking and walking opportunities. There is also evidence that peak travel has been reached in many developed countries (Navigant 2013).

ANALYZING THE IMPACT AND FEASIBILITY

We tested this initiative's impact by matching the initiative target in 2025 and carrying trends forward into 2050. Because the target is extremely ambitious, additional scenarios are shown for context. The mode share assumptions of different scenarios in different years that were entered into the calculator are shown in Figure 7. The first scenario shows Level 4 in the calculator, the second maps the high-shift

Figure 7 | **Public transit scenarios model inputs (person-kilometers traveled)**



Notes: 6DS = 6 degree scenario, GC = Global Calculator Level 4, HS = High-shift Scenario, Double = Double public transport commitment.

Table 7 | **Emissions and cost reductions from public transport scenarios**

SCENARIO	EMISSIONS CHANGE (% OF TOTAL CO_2e EMISSIONS, 2011 TO 2050)	COST CHANGE (% GDP, 2011 TO 2050)
Public Transport Level 4	-1.17	-1.43 to -3.07
Doubling mode share by 2025	-2.42	-2.63 to -4.80
High-shift scenario	-1.47	-1.84 to -4.01

scenario, the third shows the doubling of public transport mode share by 2025 and a slowdown in the growth rate, matching the high-shift scenario by 2050. Because it would be extremely difficult to double public transport using a 2010 baseline (many developing countries have rates of public transport use above 40 percent), it is assumed here that the doubling is with respect to a 2025 baseline.

The mode shift assumed in the scenarios is generally from urban car and motorbike to public transport and other modes, as this would lead to the largest emissions reduction. This also fits the target in the action plan, as it indicates that, along with increasing public transport share, it is important to encourage walking and biking, and develop related facilities to encourage low-carbon transport. The public transport share from Level 4 of the calculator is much lower than the other scenarios because the calculator assumes larger growth into 2-3 wheelers. While high growth in public transport is possible, it is also possible there will be continued rapid growth in 2-3 wheelers.

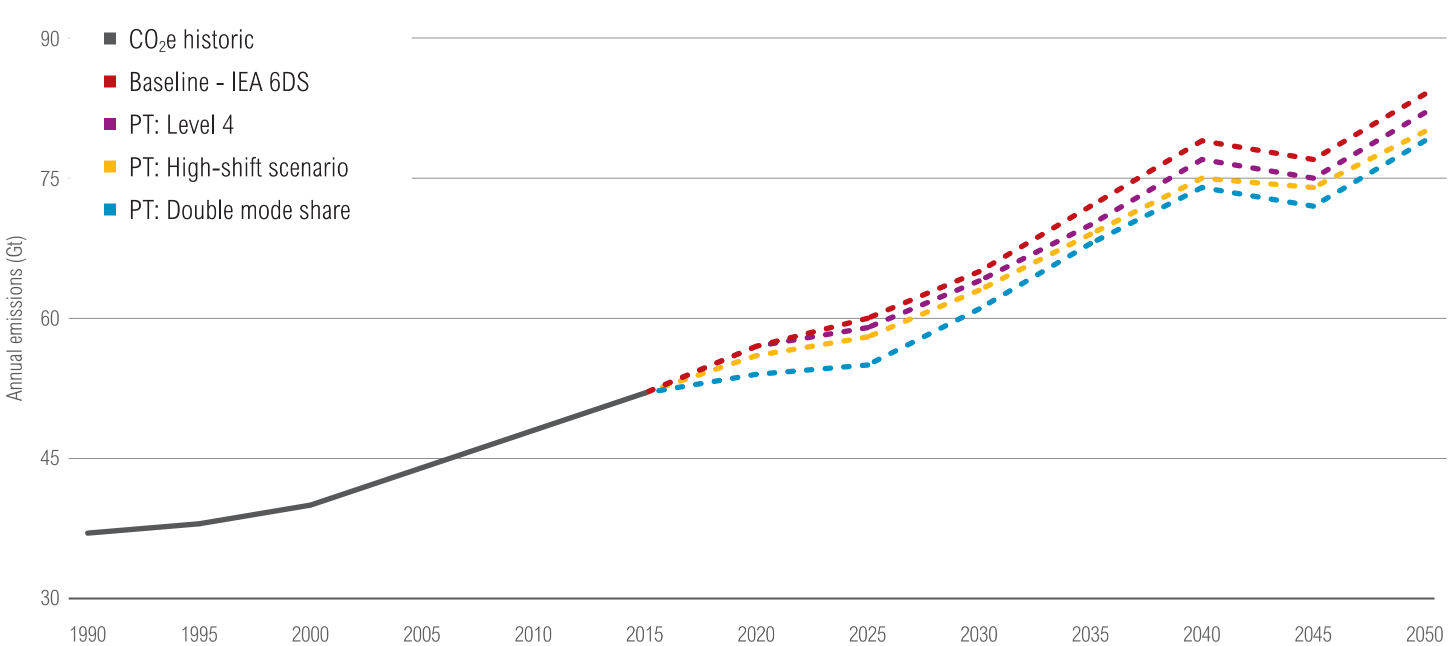
RESULTS

The emissions reductions and cost results for each of the three scenarios are shown in Table 7. They show a very large reduction potential from this initiative. Figure 8 shows the CO_2e emissions for each scenario over time. Interestingly, doubling mode share by 2025 is not significantly more effective than the high-shift scenario in reducing emissions. This is likely a result of heavy-duty vehicle efficiency improvements over time. There are also major reductions in cost from the public transport scenarios, largely because they represent an extremely ambitious shift to public transport, which is calculated as a reduction in infrastructure needs for cars, a large reduction in vehicles needed, fuel consumption, and fuel production.

COMPLEMENTARY MEASURES AND RELATED INITIATIVES

This initiative is related to the International Union of Railways initiatives in terms of passenger mode share. It also can be complemented by the C40 Clean Bus initiative and having more efficient public transport vehicles.

Figure 8 | **Global CO_2e emissions based on public transport scenarios**



Initiative | Voluntary Commitment from World Cycling Alliance (WCA) and European Cyclists' Federation (ECF)

TARGETS AND BASELINES

The goal of the initiative is to double the cycling mode share in Europe by 2020 and increase cycling worldwide.

BACKGROUND AND TRENDS

This initiative aligns with goals of many cities around the world to increase or maintain cycling mode share. Around 70 cities and regions have set targets to at least double their cycling mode share over the next decade. Some of the targets more than double the share of cycling from current levels (ECF 2015). This initiative can reduce emissions significantly given the relatively small actions and resources needed in many cases, as well as the speed with which these changes could be made.

ANALYZING IMPACT AND FEASIBILITY

The total passenger demand and mode shifting are the two levers that can contribute to the total cycling share. Table 8 shows the changes made to mode share in the model in cycling kilometers traveled for "transit cities" under three different scenarios: the 6 degree scenario, Level 4, and doubling cycling in Europe. Transit cities represent Europe and Latin America, and the percentages for the WCA/ECF commitment in Table 8 only reflect doubling in Europe (based on share of cycling PKT for Latin America and Europe). The mode-shift is assumed to be away from passenger cars since the goal is to reduce emissions. This initiative is more ambitious than Level 4 through 2020 because of how rapidly the doubling in cycle mode share is expected to take place.

Table 8 | **Cycling mode shares for EU commitment (model input) and reference scenarios (percent)**

SCENARIO	2015	2020	2050
Transit cities–WCA/ECF commitment	2.6	3.6*	3.8
Transit cities–IEA 6DS	2.6	2.5	2.1
Transit cities–Level 4	2.6	2.8	3.8

Note: *Not an exact doubling because it is based on the share of European PKT in transit cities.

Table 9 | **Cycling mode shares for a worldwide initiative (model input) and reference scenarios (percent)**

SCENARIO	2015	2020	2050
Automobile cities			
Worldwide goal	0.4	0.8	1.0
IEA 6DS	0.4	0.5	1.0
Level 4	0.4	0.7	2.7
Transit cities			
Worldwide goal	2.6	5.0	5.0
IEA 6DS	2.6	2.5	2.1
Level 4	2.6	2.8	3.8
Booming cities			
Worldwide goal	8.4	8.4	8.4
IEA 6DS	8.4	7.0	2.7
Level 4	8.4	7.4	5.0

As an extension of the European commitment, Table 9 shows the changes made in the model to cycling share for the three different types of cities, to roughly match the worldwide goal. This includes doubling in both automobile and transit cities; however, doubling in booming cities compared to current levels would be a very ambitious target, as mode shares of cycling in many cities in India and China are already very high (automobile, transit, and booming cities are defined in Section 2.1). Therefore, the share of cycling in booming cities is held constant, implying an increase in total cycling travel given the rapid rate of travel growth projected.

RESULTS

The emissions reductions and cost results for the two scenarios are shown in Table 10. They show that while doubling cycling in Europe makes a small impact in terms of total emissions, large emissions reductions versus the baseline come from maintaining high cycling shares in Asian cities, while total passenger travel continues to increase rapidly. Growth in cycling also has the potential to keep many new cars off the road and reduce the need for both vehicles and infrastructure.

Table 10 | **Emissions and cost reductions from cycling scenarios**

SCENARIO	EMISSIONS CHANGE (% OF TOTAL CO_2e EMISSIONS, 2011 TO 2050)	COST CHANGE (% GDP, 2011 TO 2050)
Doubling cycling in Europe	-0.02	-0.03 to -0.06
Doubling cycling worldwide	-0.55	-0.64 to -1.47

COMPLEMENTARY MEASURES AND RELATED INITIATIVES

It will be very important to link this initiative to those involved in city planning worldwide to have the largest possible impact.

Initiative | Urban Electric Mobility Initiative (UEMI) Action Plan

TARGETS AND BASELINES

The Urban Electric Mobility Initiative has various targets:

- Increase the market share of electric vehicles (light-duty vehicles and motorized 2-3 wheelers) to 30 percent in cities by 2030.
- Increase the stock of electric vehicles to 15 percent by 2030. Apart from increasing the market share of new electric vehicles, encouraging the maximum use of electric vehicles ("higher travel per electric vehicle") and less carbon-intensive travel modes (such as car-sharing systems, bus rapid transit, etc.) through planning efforts can contribute to the stock share, as indicated by the Urban Electric Mobility Initiative.
- At the same time, significantly increase electric mobility in public transit systems (such as light-rail transit, metro, and bus rapid transit systems), and reduce personally operated internal combustion engine vehicles in cities.

The Urban Electric Mobility Initiative is one of many efforts that aim to increase the number of electric vehicles. The impact of electric vehicles was tested focusing on the Urban Electric Mobility Initiative targets because they assume a very rapid increase in electric vehicles (30 percent urban mode share by 2030 and 15 percent of vehicle stock by 2030). The initiative also is working with similar initiatives in order to achieve 35 percent of global electric vehicle (also includes light commercial vans, buses, trucks, and others) sales by 2030 (UNFCCC 2015b).

BACKGROUND AND TRENDS

The term "electric vehicles" often refers to plug-in hybrids, battery electric vehicles, and fuel cell cars, as well as 2-3 wheelers, and depending on the definition, could include the rapidly growing e-bike market. The stock of global electric cars through 2015 was over 1.26 million vehicles (IEA 2016), more than 6.6 times that of 2012. In addition, there were more than 200 million electric 2-wheelers and 170,000 electric buses in 2015. The total passenger car fleet was roughly 850 million vehicles in 2013. Reaching the Urban Electric Mobility Initiative's very ambitious target of 15 percent of the vehicle fleet by 2030 means that electric vehicle sales would need to account for roughly 15 percent of vehicle sales by at least 2023 (Kromer 2007). According to the Global Electric Vehicle Outlook 2015 (IEA 2016), the aggregate goals for all countries with "individual country commitments" could add 13 million electric cars by 2020. The Electric Vehicle Initiative (a policy forum related to UEMI) has a target of 20 million electric cars by 2020, which would require a 74 percent annual growth rate.

Electric vehicle (EV) sales have increased rapidly. Among Electric Vehicle Initiative countries, seven had an electric car market share at or above 1 percent in 2015: Norway (23.3 percent), the Netherlands (9.7 percent), Sweden (2.4 percent), Denmark (2.2 percent), France (1.2 percent), China (1 percent), and the United Kingdom (1 percent) (IEA 2016). Programs and incentives in these countries have increased the adoption of electric vehicles. However, recent data show that as these programs have been discontinued in the Netherlands, there has been less growth in the number of new electric vehicles (European Alternative Fuels Observatory 2016). In addition, the market share in the United States dropped from around 1.5 percent in 2014 to 0.7 percent in 2015 (IEA 2015c, 2016). The Electric Vehicle Initiative data show that EV sales more than doubled between 2011 and 2012, while between 2014 and 2015 the growth rate declined to 80 percent (IEA 2016). These trends suggest that incentives and programs have been valuable in increasing the electric vehicle share and will be needed to reach these very ambitious targets.

Table 11 | **Electric vehicle uptake for commitment (model input) and reference scenarios (percent of car and 2-3W PKT by hybrid, electric, or hydrogen vehicles)**

SCENARIO	2030					2050				
	IEA 6DS	UEMI TARGET	EV ONLY	LEVEL 3	LEVEL 4	IEA 6DS	UEMI TARGET	EV ONLY	LEVEL 3	LEVEL 4
Car										
Plug-in	3	13	3	11	15	5	28	3	25	33
Electric	1	10	27	9	16	2	23	27	20	35
Hydrogen	0	7	0	6	9	0	17	0	15	20
2-3 W										
Electric	21	30	30	34	38	40	60	30	70	80

ANALYZING IMPACT AND FEASIBILITY

To assess the impact of the UEMI, we used two scenarios (UEMI target and EV only) that shift the number of passenger kilometers traveled by car from internal combustion engine (ICE) vehicles to electric vehicles. Both scenarios match the electric vehicle uptake targets in the Urban Electric Mobility Initiative—15 percent of the fleet by 2030 and 30 percent by 2050. Table 11 shows the two scenarios, and the percent of urban passenger car or 2-3 wheeler kilometers traveled using a mix of technologies and using electric vehicles only. This electric vehicle share of travel lies approximately between Level 3 and Level 4 of the "electric and hydrogen" lever of the model. Total passenger demand and mode shift also can impact the results of this initiative but were not changed for this analysis.

RESULTS

The energy demand of different scenarios is shown in Figure 9. The first scenario shows the uptake being spread among different technologies: plug-in hybrid, battery electric, and hydrogen. This shows a decreased total energy demand from the 6 degree scenario baseline. The second scenario shows results if all of the vehicles will be electric. In this case, the energy demand decreases even further.

COMPLEMENTARY MEASURES AND RELATED INITIATIVES

Related initiatives are the C40 Clean Bus initiative, Taxis4SmartCities, and the International Zero-Emission Vehicle Alliance. While the ZEV Alliance targets are similar, they are focused on specific countries or jurisdictions, which cannot be tested with the Global Calculator.

An important complementary measure to electric vehicle uptake is having a low-carbon electricity grid. In addition to the two scenarios for "mixed technologies" and "EV only," two scenarios using different energy supply scenarios were also tested. The energy supply scenarios used are the 6 degree scenario (approximately 15 percent renewable) and the 2 degree scenario (approximately 50 percent renewable).[2] Table 12 shows the emissions reductions and cost results for each of the four scenarios. Figure 10 also shows the emissions changes for the scenarios. The results shows that the mix of vehicles and energy grid are important for total emissions reductions. A mix of vehicles increases emissions by 0.32 percent through 2050, but it is a smaller increase, 0.25 percent, under the 2 degree

Table 12 | **Emissions and cost reductions from electric vehicle scenarios**

SCENARIO	EMISSIONS CHANGE (% OF TOTAL CO_2e EMISSIONS, 2011 TO 2050)	COST CHANGE (% GDP, 2011 TO 2050)
From current grid baseline		
Mixed technologies + current grid	+0.32	+1.45 to +2.11
Electric vehicles + current grid	-0.25	+1.50 to +2.27
From 50% renewable grid baseline		
Mixed technologies + 50% renewable grid	+0.25	+1.68 to +2.18
Electric vehicles + 50% renewable grid	-0.32	+1.70 to +2.32

Figure 9 | **Transport sector energy demand for different electric vehicle scenarios**

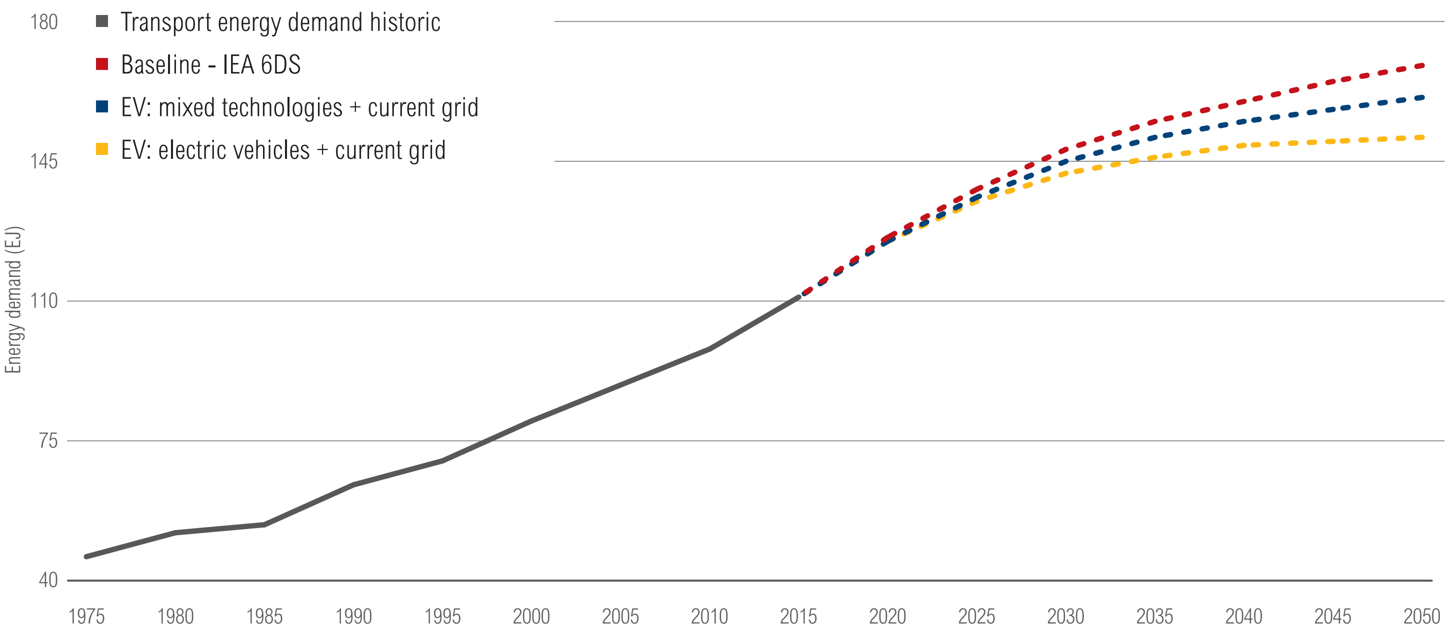
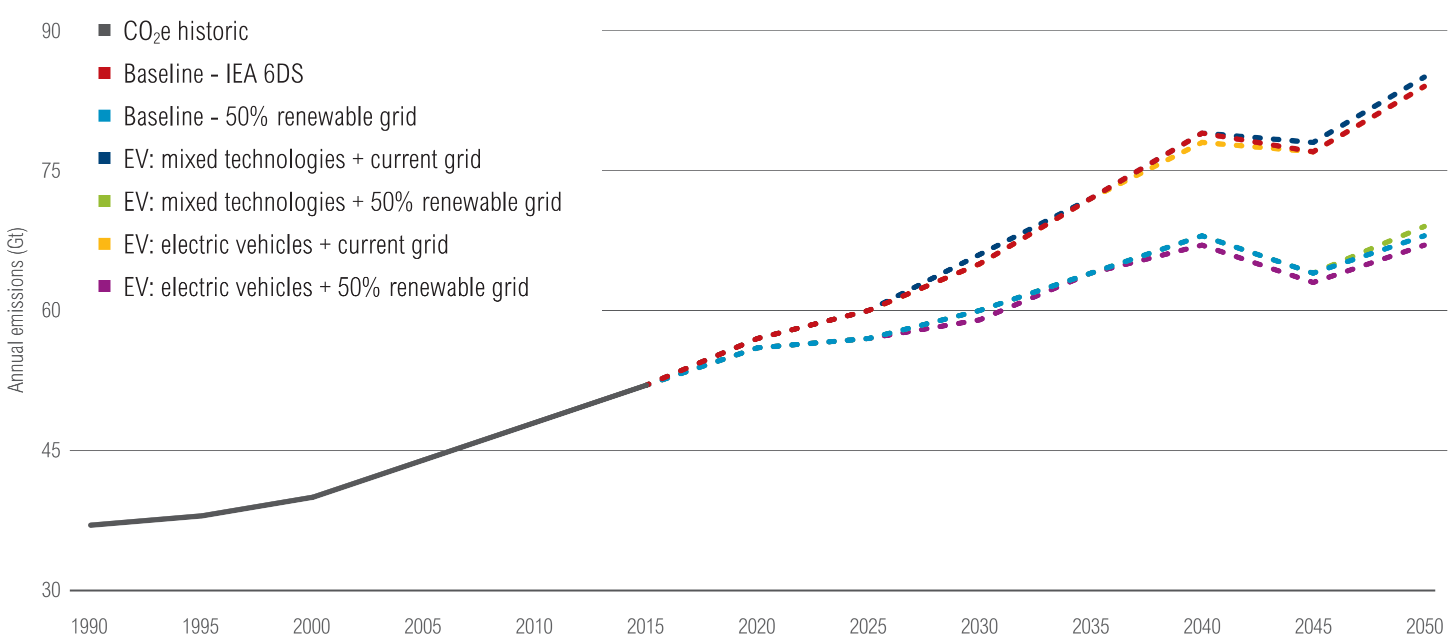


Figure 10 | **Global CO_2e emissions for electric vehicle scenarios**



scenario. This is because of the energy required to produce hydrogen along with more use of fossil fuels with hybrids. A full switch to electric vehicles is the only option to reduce emissions because it reduces energy demand enough that it offsets the assumed increase in the use of coal power. Additional details on energy demand are available in Appendix 3.

This also shows that electric vehicles may be a good option for reducing air pollution and CO_2 emissions where the grid is clean. However, globally, they may not be a major contributor to emissions reductions. If we use only electric vehicles (not hydrogen and hybrids), we see emissions reductions in both scenarios. At the same time, if clean energy supply cannot meet the demand for more energy, or electricity generation, fossil fuels will be used to meet the increasing demand.

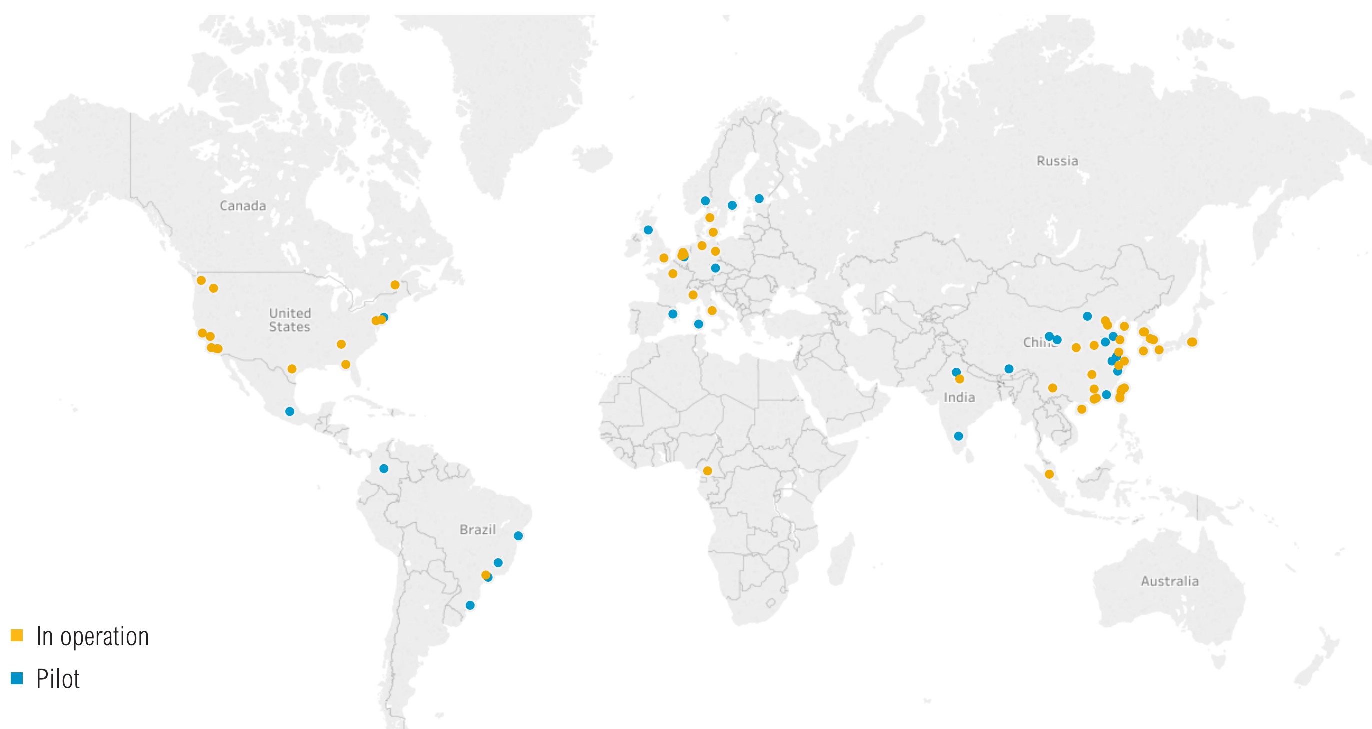
Initiative | C40 Clean Bus Declaration

TARGETS AND BASELINES

The C40 Clean Bus Declaration was established by the Low Emission Vehicles Network under C40, with the aim of reducing emissions and improving air quality in signatory C40 cities by incorporating low- and zero-emission buses into the fleets.

The C40 declaration has been signed by 23 signatory cities, representing 166,876 buses around the world. In this case, clean buses are considered low- and zero-carbon buses. With the current declaration, there will be roughly 40,000 new buses by 2020 (C40 2015).

Figure 11 | **Battery electric buses in operation or piloting worldwide**



Note: Size of piloting and operations in each city can vary significantly.
Source: Author analysis.

Table 13 | **Assumptions for percentage of total urban bus PKT with different technologies for worldwide initiative (model input)**

SCENARIO	2011	2015	2020			2050		
			IEA 6DS	LEVEL 2	LEVEL 3	IEA 6DS	LEVEL 2	LEVEL 3
Bus								
Hybrid	0	1	1	1	2	3	5	10
Electric	0	2	1	3	6	1	15	30
Hydrogen	0	0	0	0	1	0	0	10

BACKGROUND AND TRENDS

There are many programs globally to encourage the use of hybrid, electric, and hydrogen buses. Several pilot programs have shown these technologies to be viable, and many national governments, local governments, and manufacturers have or are considering incentive programs to support the growth of these technologies. Figure 11 shows the piloting or use of electric buses globally.

ANALYZING IMPACT AND FEASIBILITY

This initiative allows for a variety of clean technologies, including gas, plug-in hybrid, electric, and hydrogen fuel cells. The initiative will need to expand to make a global impact. While details are not available on the composition of the fleets, if this initiative expanded globally, it would be roughly equivalent to level 3 in terms of electrification of public transport. The analysis assumes a mix of hybrid, electric, and fuel cell buses by 2050 (10 percent, 30 percent, and 10 percent, respectively). Table 13 shows the percentage of the urban bus fleet that is assumed to be hybrid or electric for our analysis. Level 3 in Electrification of Vehicles was used to approximate the global reach of the initiative. However, the impact of this initiative also could be affected by changing the total passenger demand and passenger mode shares.

RESULTS

Table 14 shows the emissions reductions and cost results for this scenario. It shows that a global effort to electrify buses results in a 0.02 percent increase in emissions but roughly a 1 percent decrease in energy demand. The grid assumptions again are important in understanding this difference. It means that with the 6 degree scenario in energy supply, also assuming demand is not changing in other sectors, this initiative would increase emissions. This is partly due to the mix of propulsion technologies as well, similar to the Urban Electric Mobility Initiative; full-electric vehicles powered by renewable energy will reduce emissions.

This also does not mean that regional or country-specific actions to move to hydrogen, electric, or hybrid fleets will not have an important impact. The emissions impact of this initiative is small compared to some others, but it can reduce exposure to pollutants for people riding buses and accessing major bus routes.

COMPLEMENTARY MEASURES AND RELATED INITIATIVES

The UEMI and the ZEV Alliance are related, though they apply to light-duty vehicles. The renewable energy considerations will be similar for electric buses, though they will not affect overall demand as much as light-duty vehicles. The C40 initiative is also related to goals for improving the public transport fleet in the Urban Electric Mobility Initiative.

Table 14 | **Impact of global bus electrification**

SCENARIO	EMISSIONS CHANGE (% OF TOTAL CO_2e EMISSIONS, 2011 TO 2050)	COST CHANGE (% GDP, 2011 TO 2050)
C40 Bus Declaration	+0.02	+0.28 to +0.34

Initiative | Aviation Action Plan

TARGETS AND BASELINES

The goal of the International Civil Aviation Organization includes achieving a global average fuel efficiency improvement of 2 percent per year until 2020 and an aspirational global fuel efficiency improvement rate of 2 percent per annum from 2021 to 2050. They also aim to stabilize net emissions from 2020 through carbon-neutral growth, subject to concerted industry and government initiatives, and reduce net aviation carbon emissions 50 percent by 2050 relative to 2005 levels.

Among the various aviation organizations there have been goals and plans for reducing emissions from the sector since 2008. The goal for improving fleet efficiency by 2 percent per year was adopted by the International Civil Aviation Organization (ICAO) in 2010 (Climate Summit 2014b). The cost of fuel can be the largest expenditure for airlines, and they therefore have a great incentive to improve fuel economy, thereby reducing CO_2 emissions for each flight.

BACKGROUND AND TRENDS

According to IATA (2009), an "industry rule of thumb is that each new airplane model should be 10 to 15 percent more economical in terms of fuel economy." Airlines have adopted a voluntary fuel efficiency goal. This is to reduce fuel consumption and CO_2 emissions (per revenue ton-kilometer) by at least 25 percent by 2020, compared to 2005 levels. World air passenger traffic is projected to grow 5 percent annually, and the commercial airplane fleet is expected to nearly double by 2032 (IATA 2009). IATA (2009) estimates the reduction of CO_2 emissions through fleet renewal at 600 million tons by 2030, while biofuels would reduce these emissions by 150 million tons. However, while many transport sector initiatives call for the use of biofuels, recent research indicates that the carbon impact of biofuels may be higher than some earlier studies suggested (Searchinger and Heimlich 2015).

Table 15 | **Aviation annual improvement rate assumptions for commitment (model input) and reference scenarios**

SCENARIO	ANNUAL PERCENTAGE IMPROVEMENT THROUGH 2030	ANNUAL PERCENTAGE IMPROVEMENT 2030–50
Baseline	1.40	1.00
Level 3	1.70	1.80
Level 4	1.70	2.40
Aviation commitment	2.00	2.00

ANALYZING IMPACT AND FEASIBILITY

Improving efficiency of planes at 2 percent per year through 2050 is between Level 3 and 4 in the calculator, but higher than Level 4 through 2020. This is the only lever that was changed, though changing passenger demand, mode shares, and technologies would change the resulting impact of this initiative. Table 15 shows the assumptions used to test the commitment and reference scenarios.

RESULTS

Table 16 shows the emissions reductions and cost results of this scenario. This shows a 0.10 percent reduction in aviation emissions by 2050. Considering that aviation contributes to roughly 3 percent of global emissions, 0.1 percent represents a sizeable reduction in emissions from improving plane efficiency.

Table 16 | **Emissions and cost reductions from aviation plan**

SCENARIO	EMISSIONS CHANGE (% OF TOTAL CO_2e EMISSIONS, 2011 TO 2050)	COST CHANGE (% GDP, 2011 TO 2050)
Aviation	-0.10	-0.02 to 0.01

COMPLEMENTARY MEASURES AND RELATED INITIATIVES

Most of the initiatives relate to modes other than air travel; the Airport Carbon Accreditation is the only initiative that is clearly related. However, improvements in rail travel could have an impact on air travel demand.

Initiative | Vehicle Fuel Efficiency Accelerator

TARGETS AND BASELINES

Launched in 2009, the Global Fuel Economy Initiative has a goal of 30 percent reduction in liters per 100 kilometers (L/100km) by 2020 in all new cars in OECD countries, a 50 percent reduction in L/100km by 2030 in all new cars globally, and a 50 percent reduction in L/100km by 2050 in all cars globally. At COP 21, the Global Fuel Economy Initiative also launched a campaign "100 [countries] for 50 by 50" to involve more countries in the initiative (FIA Foundation 2015).

The Vehicle Fuel Efficiency Accelerator is a part of the UN Secretary-General's Sustainable Energy for All global initiative (SE4All). SE4All shows that energy efficiency measures, including transport, can contribute to deliver 50 percent of the emissions reduction required to put the world on a 2° C pathway by 2020 according to the IEA (SE4All 2014).

The Vehicle Fuel Efficiency Accelerator uses the Global Fuel Economy Initiative's (GFEI) targets for improving fuel efficiency of light-duty vehicles globally. Since the GFEI's launch in 2009, this initiative has already had success in improving fuel economy policies and measures and providing support to 27 countries. This includes "consultation and discussion, evidence-based approaches, benchmarking against best practice, technical coherence, and evaluation" (FIA Foundation 2015). This initiative focuses on light-duty vehicles, but it is also beginning to work on heavy-duty vehicles. It provides annual reports on the state of fuel economy globally to help monitor progress.

BACKGROUND AND TRENDS

The world's light-duty vehicle fleet is expected to increase "from around 850 million passenger cars in 2013 to over 2 billion by 2050" (GFEI 2016). Some 90 percent of this growth is expected in non-OECD countries, particularly China and India. The IEA (2008) has estimated that fuel consumption and emissions of CO_2 from the world's cars will roughly double between 2000 and 2050. Improving efficiency along with hybridization will make it possible to reach the goals stated in the initiative. Figure 12 shows that many governments have already committed to significantly reducing CO_2 emissions from their light-duty fleet. Furthermore, the original SE4AII document states that "CO_2 savings would exceed 1Gt CO_2 annually by 2025, going to 2Gt CO_2 annually by 2050" (SE4All 2014). These figures were updated to 0.5Gt/year by 2025 and 1.5Gt by 2050 in Fuel Economy State of the World 2016 (GFEI 2016), partly due to already accomplished fuel economy achievements (Clarke 2015).

ANALYZING IMPACT AND FEASIBILITY

Table 17 shows the composition of the vehicles assumed for 2050, as well as the annual fuel economy improvement rate needed over time to reach the target of 50 percent fuel economy improvement across the whole fleet by 2050. Table 18 shows improvement rates for related scenarios as reference. The level of ambition for the commitment is roughly equivalent to Level 3 in the calculator. This initiative's potential impact will be heavily related to total passenger demand and mode share. In the future, the total impact also will depend on the percentage of the vehicle fleet powered by fossil fuel.

RESULTS

Table 19 shows the emissions reductions and cost results for each of the four scenarios. This shows that focusing on improving light-duty vehicle efficiency can make a large

Table 17 | **Assumptions for rate of improvement for commitment: Model input to meet 50 percent improvement in fuel economy by 2050**

COMMITMENT	VEHICLE FLEET BY 2050 (%)	FUEL ECONOMY IN 2011 (KWH/KM)	ANNUAL IMPROVEMENT RATE THROUGH 2020 (%)	ANNUAL IMPROVEMENT RATE THROUGH 2020–50 (%)
ICE	93	0.76	2.50	1.80
Hybrids	5.0	0.57	1.80	1.80
Electric	2.0	0.21	1.00	0.50

Table 18 | **Reference scenarios for efficiency improvement for ICE vehicles**

ICE	ANNUAL IMPROVEMENT RATE THROUGH 2020 (%)	ANNUAL IMPROVEMENT RATE 2020–50 (%)
Baseline	1.5	1.0
Level 3	1.7	1.8
Level 4	1.7	2.5

contribution to emissions reductions with cost savings, improving vehicle efficiency by 50 percent through 2050. The total impact of the initiative will depend on total vehicle demand and turnover rate of the vehicle fleet.

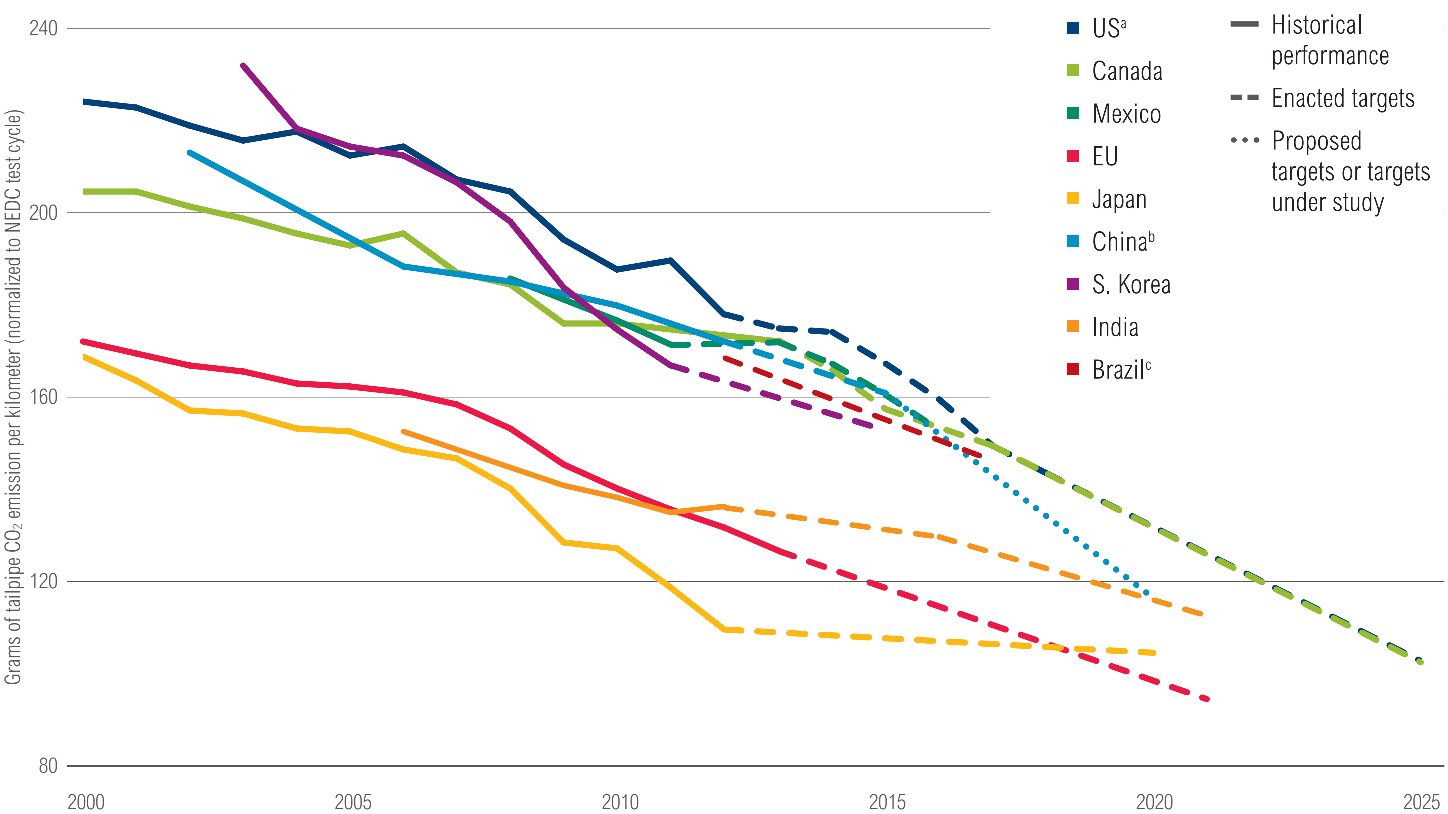
Table 19 | **Emissions and cost reductions from light-duty vehicle efficiency**

SCENARIO	EMISSIONS CHANGE (% OF TOTAL CO_2e EMISSIONS, 2011 TO 2050)	COST CHANGE (% GDP, 2011 TO 2050)
LDV efficiency	-0.67	-0.03 to -0.09

COMPLEMENTARY MEASURES AND RELATED INITIATIVES

This is the only initiative that focuses primarily on improving light-duty vehicle fuel economy. The Taxis4SmartCities initiative aims to increase the uptake of vehicles with improved fuel economy. The GFEI will begin work on electric vehicles and heavy-duty vehicles. This will relate to the Global Green Freight Initiative, UEMI, and ZEV Alliance.

Figure 12 | **Comparison of light-duty vehicle CO_2 emission rates**



Source: ICCT (2012).
[a] US fuel economy stadards set by NHTSA reflecting tailpipe GHG emission (i.e., exclude low-GWP refrigerant credits).
[b] China's target reflects gasoline vehicles only. The target may be higher after new energy vehicles are considered.
[c] Gasoline in Brazil contains 22% of ethanol (E22), all data in the chart have been converted to gasoline (E00) equivalent.
[d] Supporting data can be found at: http://www.theicct.org/info-tools/global-passenger-vehicle-standards.

Summary of Individual Impact

Figure 13 shows the impacts of each of the initiatives discussed previously, plotted on one graph comparing emissions reduction, cost, and level of effort. Table 20 shows the emissions reductions and cost results for each of the scenarios. The initiatives' results are shown as a percentage of total global energy-related emissions. Even though the values may be small, all of these initiatives represent a significant reduction in transport emissions.

This shows that the largest effort and biggest reduction in emissions come from mode-shifting, either to rail or public transport. Both also have significant cost savings due to a reduction in the number of vehicles purchased and infrastructure needed. The cycling initiative only reflects Europe, so the impact is smaller in a global sense. However, all of these represent extremely ambitious scenarios in terms of behavior change. The large mode-shifting assumed under these initiatives has been difficult to achieve thus far, with many trends still toward private motorization and using heavy trucks for freight. Tracking mode shares globally over the next decade will help show if these initiatives are achievable.

The light-duty vehicle fuel efficiency initiative has large emissions reduction potential, and the airplane efficiency initiative has large emissions reduction potential with respect to the size of the sector. They both have some cost savings and are very ambitious. However, these initiatives have large global reach and a long history, so there is a good sense of what is achievable in these areas. The electric vehicle targets are also very ambitious and have large emissions reduction benefits. These are more costly due to the assumed increased cost per vehicle, at least in the short term. It is not clear if the very rapid uptake in electric vehicles is achievable and how that would interact with greatly improving the efficiency of light-duty vehicles.

There are many synergies among the initiatives that could be explored further. The level of effort required for each initiative depends on the effort made in other areas. For example, if mode-shifting is successful, it makes it easier

Figure 13 | **Impact, cost, and levels of effort for individual initiatives (% change vs. 6DS global emissions)**

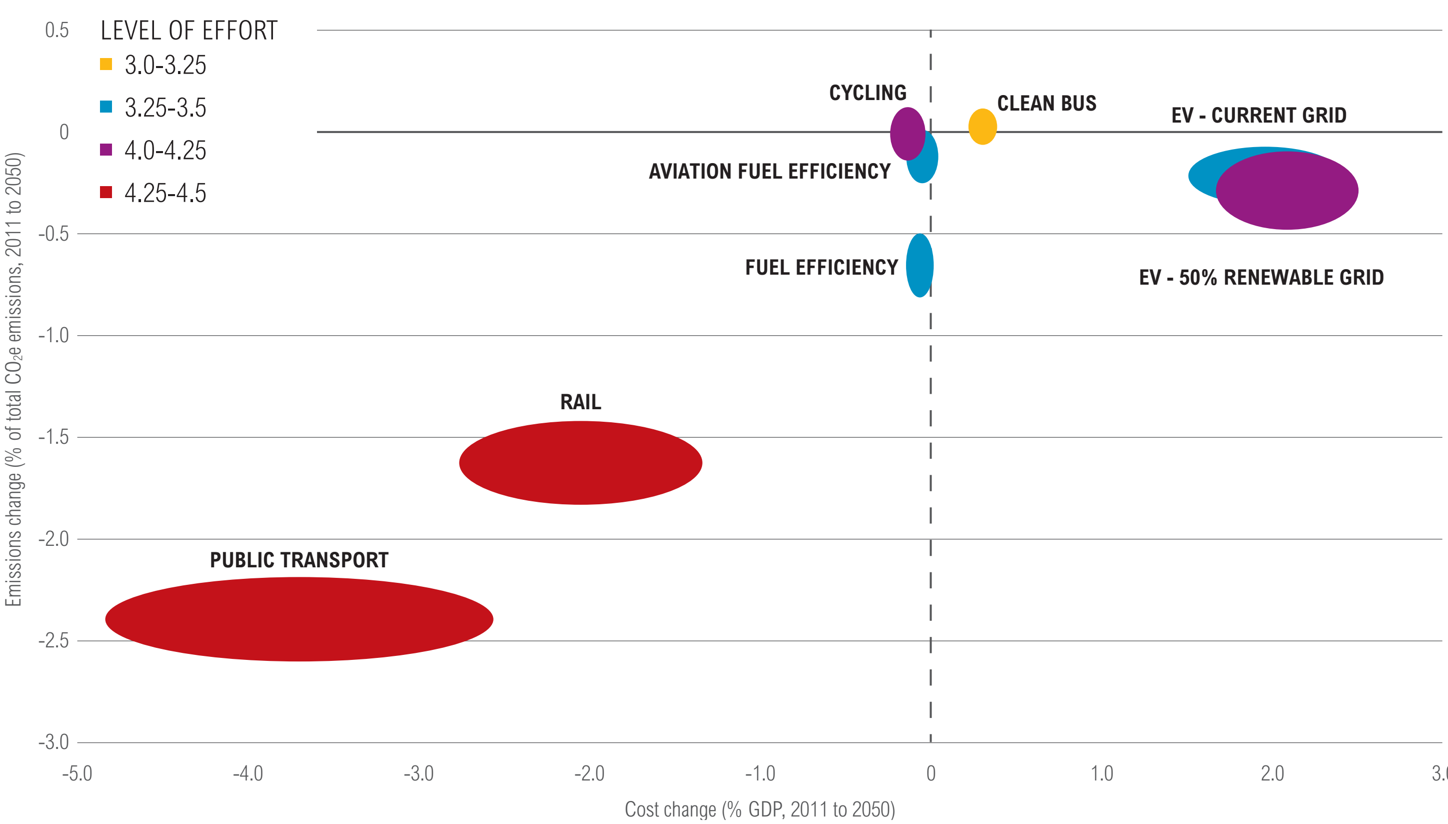


Table 20 | **Summary of emissions and cost reductions from initiatives (with respect to 6DS)**

SCENARIO	EMISSIONS CHANGE (% OF TOTAL CO_2e EMISSIONS, 2011 TO 2050)	COST CHANGE (% GDP, 2011 TO 2050)	LEVEL OF EFFORT
Public transport	-2.42	-2.63 to -4.80	4.5
Rail	-1.62	-1.43 to -2.73	4.5
EV (electric, 6DS)	-0.25	+1.50 to +2.27	3.3
EV (electric, 2DS)	-0.32	+1.70 to +2.32	4.15
Fuel efficiency	-0.67	-0.03 to -0.09	3.4
Aviation	-0.10	-0.02 to 0	3.4
Clean bus	+0.02	+0.28 to +0.34	3.0
Bicycle (EU)	-0.02	-0.03 to -0.06	4.0

and less costly to achieve targets in vehicle efficiency or electrification of the fleet because it will reduce the total number of vehicles needed. Similarly for emissions reduction, the calculator shows that the carbon intensity of the grid, which impacts the emissions reduction potential from the electric vehicles initiatives, is highly dependent on total energy demand—the lower the demand from all sectors, the lower the carbon intensity of electricity.

3.2 Aggregate Impact and Untapped Potential

Next, we looked at the aggregate of the initiatives. This does not represent the sum of the previous initiatives, rather it takes the maximum effort in each of the levers under all of the initiatives tested. For the International Union of Railways initiative, it uses the highest passenger and freight mode shares as well as reduction in energy use. For the International Association of Public Transport Action Plan and cycling initiatives, it uses the highest bus and non-motorized transport assumptions. It also includes, in a similar way, the efficiency improvements from planes and light-duty vehicles, as well as a rapid increase in electric vehicles. Because the tested initiatives focus on different areas, there is not a lot of overlap. However, adding all of the mode-shifting initiatives together leads to a large reduction in passenger car use from the baseline for 2050 (down to 29 percent of PKT).

The aggregate of the initiatives is compared to the additional scenarios included in Table 21 and Figure 14. These scenarios reflect all Level 3 and all Level 4 for the transport sector, showing the "very ambitious" and "extremely ambitious" potential of the transport sector. This means that for all of the transport levers, covering both lifestyle and technology, level 3 or level 4 were selected. These reference scenarios are shown with and without changes to passenger and freight demand, which changes the total PKT and freight ton-km in the model. A reduction in these factors reflects either a reduced number of passengers or freight trips, or shorter trips.

Overall, the findings show the aggregated initiatives would lead to a 3.69 percent reduction in total CO_2e emissions by 2050 through actions in the transport sector from the IEA 6DS baseline; collectively, this is an extremely ambitious effort with respect to lifestyle changes and technology improvements. In Table 21, Level 4 shows that the maximum potential for emissions reduction in the transport sector as 6.58 percent of total emissions. The emissions reduction total under all Level 3 is 3.86 percent. Therefore, the aggregate of all of the initiatives is slightly less than all Level 3 in the transport sector. All Level 3 and Level 4 show significant cost savings because they include many lifestyle factors that reduce the use of private vehicles, either through occupancy, ownership, or mode shifting. Reducing the number of vehicles needed reduces costs, along with a reduced need for road infrastructure and fuel.

The initiatives focus on technology improvement rather than behavior or lifestyle factors. While reducing the energy consumption of vehicles is important, a rapid growth in

Table 21 | **Initiative aggregation compared to transport Level 3 and Level 4 (with respect to 6DS)**

SCENARIO	EMISSIONS CHANGE (% OF TOTAL CO_2e EMISSIONS, 2011 TO 2050)	COST CHANGE (% GDP, 2011 TO 2050)
Aggregate of initiatives	-3.69	-2.2 to -4.5
All transport Level 3 (w/o demand)	-2.79	-1.99 to -5.42
All transport Level 3 (w/ demand)	-3.86	-2.97 to -7.12
All transport Level 4 (w/o demand)	-4.98	-3.71 to -8.96
All transport Level 4 (w/ demand)	-6.58	-5.30 to -11.65

demand can make this a costly option. Shifting modes or reducing travel demand can be more cost-effective options. However, the tested initiatives all reflect a high level of ambition. The scenarios in Table 21 show that spreading the effort among a variety of initiatives can be helpful for achieving emissions reduction.

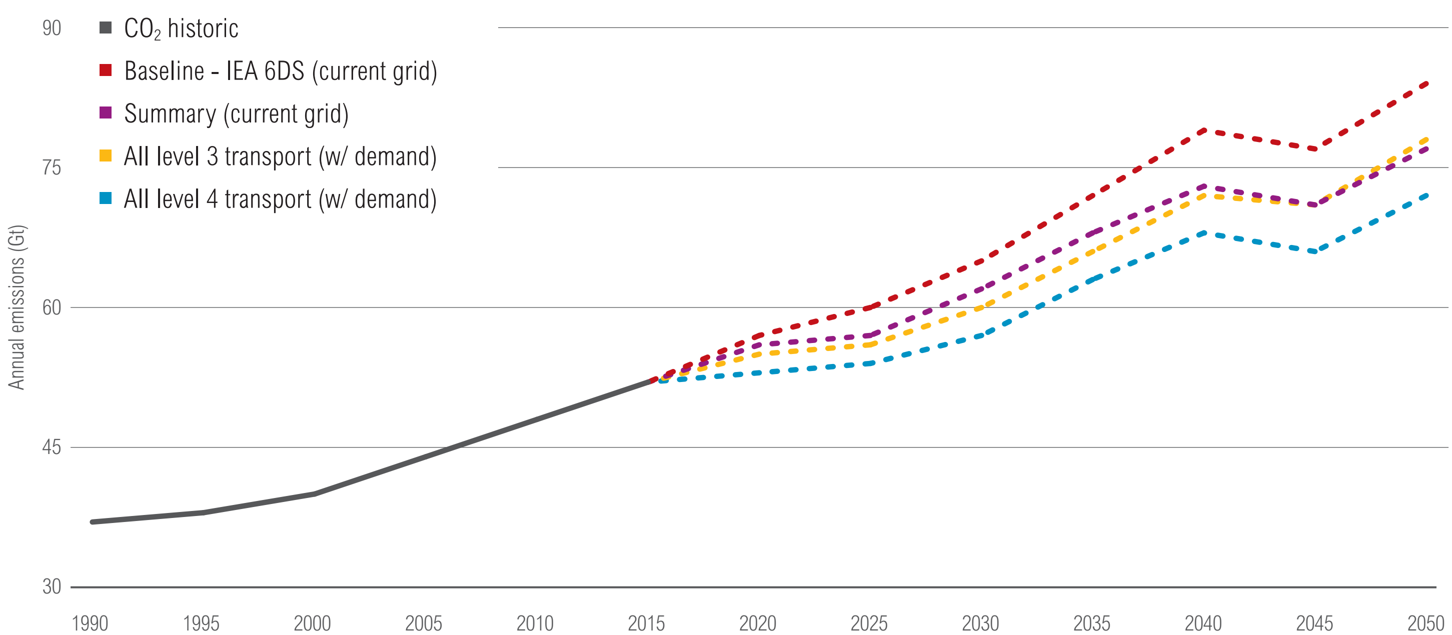
For example, reducing passenger demand and mode-shifting will make reaching fuel efficiency and electrification initiative targets more feasible and cost effective.

These initiatives do not represent all possible actions in the transport sector. Increasing the feasibility of significantly reducing transport sector emissions may require focused efforts on levers other than those we tested, as we discuss in the following section.

Untapped GHG Reduction Potential

Finally, we looked at the potential impact of calculator levers that are not explicitly mobilized in this set of initiatives, shown in Table 22. This includes heavy-duty vehicle efficiency, ship efficiency, and freight efficiency in general. It also includes reductions in demand, including passenger demand and freight demand. It also includes improvements in freight load factor and passenger occupancy as well as vehicle ownership.

Figure 14 | **Global CO_2e emissions for summary scenarios**



Note: The drop in emissions between 2040 and 2045 is due to changes in the land use/bio sector and is present in all of the CO_2e summary tables.

Table 22 | **Costs savings and emissions reductions from untapped potential (with respect to 6DS)**

SCENARIO	EMISSIONS CHANGE (% OF TOTAL CO_2e EMISSIONS, 2011 TO 2050)	COST CHANGE (% GDP, 2011 TO 2050)
HDV efficiency only	-0.57	-0.03 to -0.08
Ship efficiency	-0.40	-0.02 to -0.06
Passenger demand	-0.17	-0.23 to -0.44
Freight demand	-1.15	-0.86 to -1.57
Freight load factor	-0.17	-0.41 to -0.79
Passenger occupancy rate	-0.95	-1.29 to -2.68
Car ownership	-0.32	-1.80 to -3.34
Aggregate of untapped potential	-3.51	-4.28 to -8.22

Table 22 shows the impact of shifting those levers to level 3 versus the IEA 6 degree scenario. This shows that the efficiency of freight vehicles can greatly reduce emissions. Heavy-duty and ship efficiency can bring major reductions as well. Additionally, reducing travel demand for both passengers and freight can be important contributors to emissions reduction. Part of the reason freight demand reduction appears very high here is because little adjustment is expected from the current trends in the IEA 6 degree scenario. The passenger occupancy rate also has large emissions reduction potential, which is also partly because little change is expected from the current trends in the IEA 6 degree scenario. Shared taxis and other ride-sharing changes also may make large impacts on passenger occupancy. It also shows that the aggregate impact of action in these areas is similar to that of the existing initiatives.

4. SUMMARY AND CONCLUSIONS

The transport initiatives under the Lima-Paris Action Agenda and the Paris Process on Mobility and Climate could significantly contribute to emissions reductions from the sector. This analysis is one step toward understanding the relative and collective impact of the initiatives and what additional initiatives could advance emissions reduction.

Our findings show that in general, the initiatives are very ambitious and would together lead to a 3.69 percent reduction in global CO_2 emissions by 2050 from an IEA 6DS baseline. The largest emissions reduction could come from mode-shifting initiatives, either to rail or public transport (up to 2.42 percent reduction in emissions), but would also require a very high level of effort. Shifts to rail or public transport also have significant cost savings due to reductions in the assumed number of vehicles purchased and infrastructure needs. The electric vehicle targets also are very ambitious and have large emissions reduction benefits. The light-duty vehicle fuel efficiency initiative has large emissions reduction potential (0.67 percent), and the airplane efficiency initiative has large emissions reduction potential (0.10 percent) with respect to the size of the sector.

Mode shift can be important to reducing emissions among the initiatives partly because of the very high levels of ambition in mode shift assumed compared to the more realistic levels of ambition assumed under the technology initiatives. The level of effort in the calculator that corresponds to achieving the major behavioral changes required for the initiatives' levels of public and non-motorized transport is very high (from level 3 to higher than level 4), while switching to electric vehicles and vehicle efficiency are considered ambitious but more feasible (level 3).

While the individual initiatives alone may be challenging in terms of feasibility, there are potential synergies among changes to demand, mode, and technology that could impact results. The level of effort required for each initiative depends on the effort made in other areas. For example, if mode-shifting is successful, it makes it easier and less costly to achieve targets in vehicle efficiency or electrification of the fleet because it will reduce the total number of vehicles needed. Similarly, for emissions reduction, the calculator shows that the carbon intensity of the grid, which impacts the emissions reduction potential from the initiatives related to electric vehicles, is highly dependent on total energy demand. Therefore, the lower the demand from all sectors, the lower the carbon intensity of electricity used in electric vehicles. Generally, the analysis shows that while an extreme effort can be made in certain areas and will have a major impact in emissions reduction, making a strong effort in many areas may result in greater impact and be more cost-effective.

The high-level of ambition among the initiatives is aligned with the objective of the Lima-Paris Action Agenda. However, in allocating funds, and considering the many competing initiatives in other sectors, it makes sense to focus on those initiatives, or group of initiatives, that are feasible and cost-effective, and perhaps achieve a variety of other goals, such as providing affordable transportation for all and reduction in air pollution. Testing the initiatives with the calculator supports the findings from the Lima-Paris Action Agenda analysis: more clarity is needed regarding targets, greater linkages are needed among various efforts, and greater geographical coverage would be desirable. More guidance from the Action Agenda on creating ambitious and achievable initiatives could enhance the effectiveness of the initiative process.

While the analysis shows that there is very little direct overlap among targets for these initiatives, many of the initiatives are clearly linked, such as increasing the passenger rail share and increasing the use of public transit. Having linked goals is beneficial as it means that multiple organizations are working toward the same end. In this case, coordinating targets and efforts can send clear messages of support to the global community and stakeholders implementing these initiatives. Furthermore, many of these initiatives include a host of additional measures that overlap with other initiatives, addressing more efficient vehicles, electric vehicles, and shifting modes, for example. These additional measures should also be aligned with the major initiative that supports that measure.

The initiatives made to date under the Lima-Paris Action Agenda and the Paris Process on Mobility and Climate do not cover all opportunities for emissions reductions in the transport sector. Using the Global Calculator allowed us to identify gaps. Heavy-duty and freight vehicle efficiency, along with higher passenger car occupancy rates and reducing freight demand, can make big reductions in emissions. The Paris Process on Mobility and Climate can encourage ambitious activities in these areas. It also shows that demand reduction, logistics, and planning can be major contributors to emissions reduction.

Finally, this paper considers only one set of initiatives among many that impact transport and development. The organizations supporting these initiatives should begin connecting with related initiatives and working with governments at all levels and the private sector to create detailed implementation plans that are sensitive to local goals and funding possibilities. For example, some places with more advanced public transit systems may have less scope to increase public transit market share. International organizations can help to identify funding sources or make the best use of existing funding and help with monitoring, tracking, and reporting. Because of the ambitious nature of the targets and relatively short time frames, we may need extensive effort in tracking trends to make sure we are achieving these goals. Because of the effort and funding required to achieve these targets, they will need to be aligned with other goals and aspirations of the cities and countries, along with the Nationally Determined Contributions and Sustainable Development Goals.

APPENDIX 1. MODELING APPROACH AND SUMMARY OF CHANGES TO THE CALCULATOR BY INITIATIVE

The Global Calculator has seven levers in the transport sector that are used to calculate total emissions: passenger distance, freight distance, mode, load factors and occupancy, car own or hire, electrification, and transport efficiency. The main way to create scenarios to reflect transport initiatives is thus to change these levers and calculate respective emissions.

For the initiative analysis, the most frequent changed levers were mode, transport efficiency, and electrification. Although in some initiatives other levers are affected, such as load factor and car own or hire, the targets and impacts are either rough or hard to estimate, and thus are not included. Also, some initiatives have targets related to impacts rather than activity, such as the energy consumption and CO_2 emissions reduction targets in the railway sector initiative. They are an output of the model and are therefore not included in establishing the scenarios.

When we established new scenarios regarding mode changes, we made the shift of mode from internal combustion engine vehicles and passenger vehicles to other modes. This is in line with our general targets to reduce the use of traditional fuel vehicles, and encourage more low-carbon transportation methods, such as walking, cycling, and public transport.

Furthermore, almost no initiatives address reducing travel demand in general. Thus, for passenger distance and freight distance levers, we used the assumptions in the baseline scenario(s).

Table A1 | **Levers changed to test initiatives**

LEVER	TRANSPORT INITIATIVES
Mode share	Public Transport (UITP), Rail (UIC), Cycling (WCA)
Efficiency	Fuel Efficiency (SE4ALL), Aviation (ICAO, ATAG)
Electric and hydrogen	Electric Vehicle (UEMI), Clean Bus (C40)
Electricity generation	Electric Vehicle (UEMI), Clean Bus (C40)

APPENDIX 2. BASELINE ASSUMPTIONS

The baseline (IEA 6DS as mapped in the Global Calculator) included the following assumptions for each of the levers:

Passenger Demand: On average, the passenger demand annual growth rate from 2011 to 2050 is around 2.15 percent for urban areas, 1.04 percent for rural areas, and 2.44 percent for international. These are taking population growth into consideration.

For per person per year travel demand annual growth rates (2011–2050 average), trends generally are decreasing over time—urban automobile city 0.02 percent, urban transit city 0.69 percent, urban booming city 0.85 percent, rural developed 0.38 percent, rural developing 1.69 percent, international slow growth 0.96 percent, and international fast growth 3.48 percent.

Freight Demand: On average, the freight demand annual growth rate from 2011 to 2050 is around 2.03 percent for domestic, and 2.21 percent for international.

Mode: For passenger travel in 2050 for urban areas, the mode shares are walking, 3 percent; biking, 2 percent; 2-3 wheelers, 14 percent; cars, 49 percent; buses, 28 percent; and trains, 3 percent. For rural areas, the mode shares are walking, 1 percent; biking, 2 percent; 2-3 wheelers, 16 percent; cars, 55 percent; buses, 13 percent;and trains, 12 percent. And for international travel, the mode shares are short-distance planes, 23 percent; long-distance planes, 62 percent; trains, 15 percent.

For freight in 2050, for domestic travel the mode shares are light trucks, 4.3 percent; heavy trucks, 43.5 percent; trains, 40.2 percent; and ships, 12 percent. For international travel, the mode shares are heavy trucks, 4.1 percent; trains, 0.8 percent; ships, 94.8 percent; and planes, 0.3 percent.

Occupancy: (passenger/vehicle): Passenger-urban and rural walk and bike are not changing; urban and rural 2-3 wheelers, +2.8 percent; urban and rural cars and trains, -6 percent; urban and rural buses, -14 percent; international short planes, long planes, and trains, +4 percent.

Freight (load factor): (ton/vehicle) Domestic light trucks, heavy trucks, trains, ships, international heavy trucks, and trains, +4 percent; international ships and planes, +2 percent.

Car Ownership: For passenger modes, the ownerships are all the same with the baseline situation.

Vehicle Efficiency: For passenger vehicles, the efficiency improvement rates are positive, but roughly are all decreasing over the years. The improvement rates in 2050 for different modes are: 0.5 percent for ICE 2-3 wheelers, ICE and plug-in hybrid cars and buses, non-electric train, and non-electric planes; and 0.1 percent for battery electric and hydrogen 2-3 wheelers, cars, buses, trains, and planes.

For freight, the efficiency improvement rates are roughly around 0–1 percent through 2050. Most traditional fuel vehicles have a constant improvement rate, which means a continued increasing efficiency through 2050; whereas the improvement rate for most electric or hydro modes reach 0 percent by 2050.

Electrification of Vehicles: For urban and rural passenger vehicles in 2050, the share of electric vehicles in each mode are: 40 percent for 2-3 wheelers, 9 percent for cars (0 percent hydrogen car), 4 percent for buses (0 percent hydrogen car), and 90 percent and 67 percent for urban and rural trains, respectively.

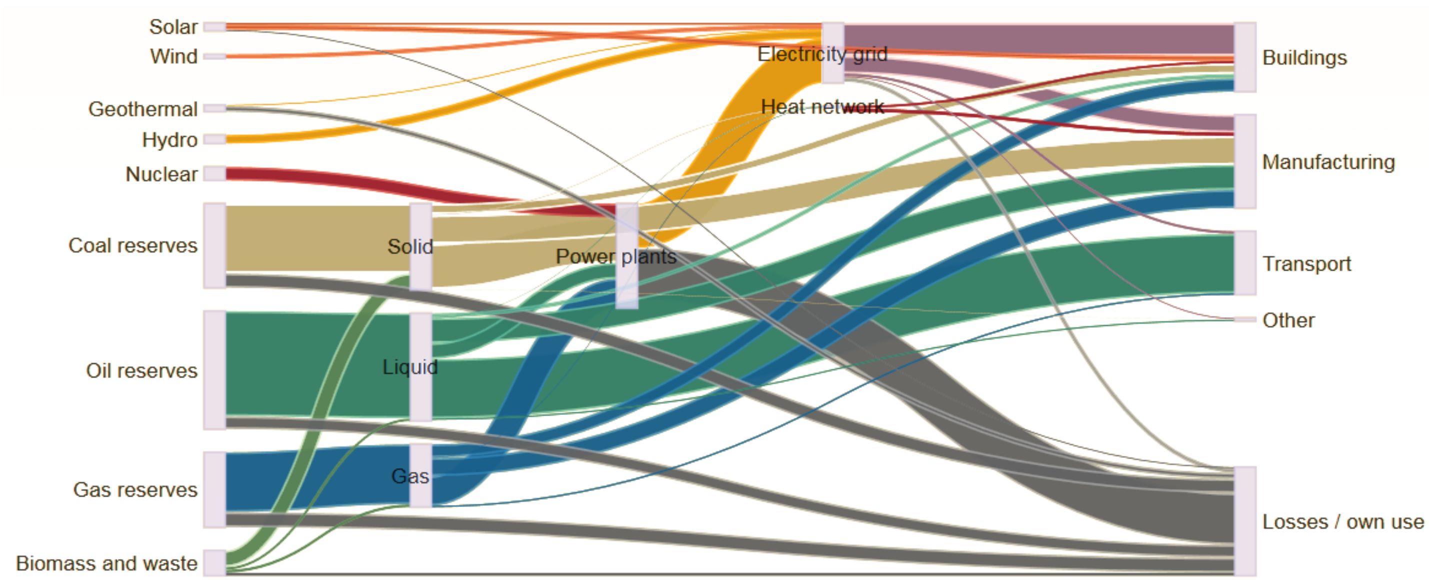
For international travel, only passenger trains can have 50 percent electric by 2050.

For freight in 2050, electric vehicles' share in each mode are: 10 percent for domestic light trucks, domestic and international heavy trucks; 60 percent for domestic and international trains; and 0 percent for ships and planes.

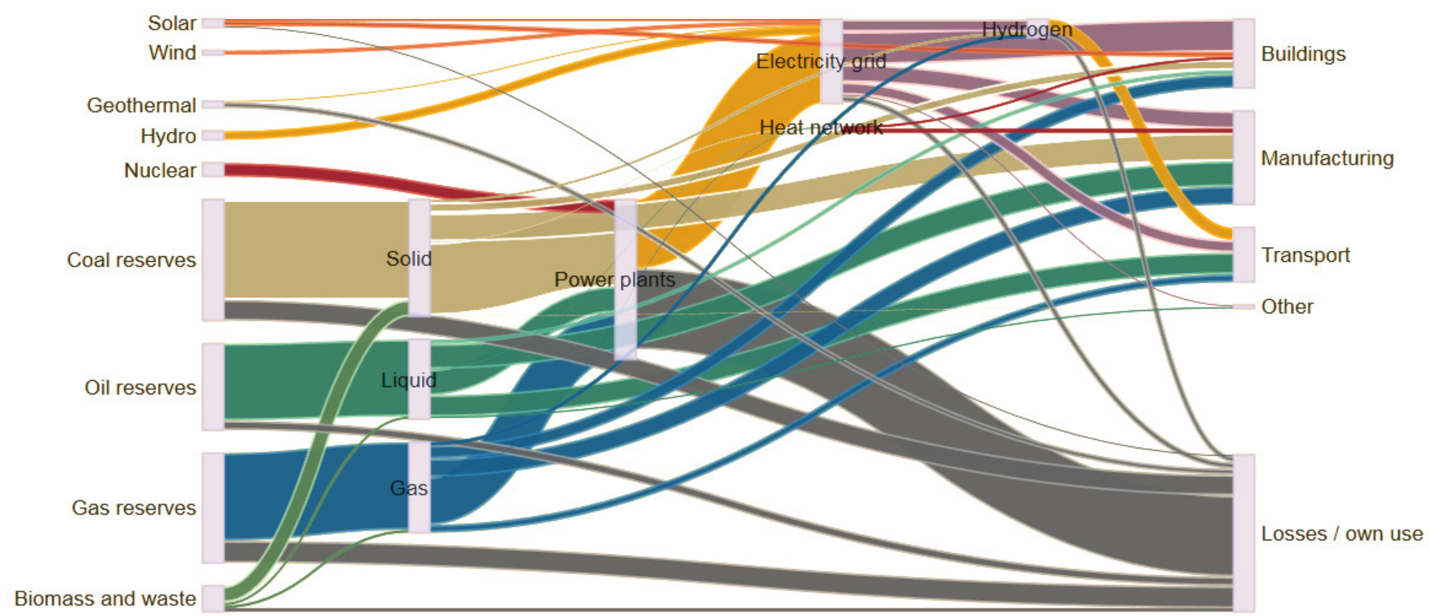
APPENDIX 3. ENERGY DEMAND DIAGRAMS

The figures below from the online Global Calculator tool show how energy distribution changes with high and low electric vehicle uptake under the 6 degree energy scenario (these examples do not correspond directly to the UEMI). It shows that the model assumes much of the energy needed to meet the higher demand for electricity would come from coal power, which has high emissions as well as high energy losses due to low power plant efficiency.

Sankey Energy Diagram (6DS with low EV uptake)



Sankey Energy Diagram (6DS with high EV uptake)



APPENDIX 4. LEVEL DESCRIPTIONS AND VALUES

Table A2 | **Level descriptions**

LEVEL	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4
Passenger demand	Very high growth in travel distance per person, with no efforts to constrain it.	This represents a situation where some action is taken to curtail growth in passenger distance traveled. Cities with established development patterns, as well as growing cities, pursue initiatives to reduce the need for travel throughout the city.	Cities with established development patterns, as well as growing cities, pursue initiatives to reduce the need for travel throughout the city via "smart" city planning. Global distance traveled per person increases, but less dramatically.	Cities make a significant effort to develop as transit-oriented, multi-use cities along with significant advances in communication technologies. In "automobile cities" (such as Atlanta), travel distance would decrease under this scenario.
Freight demand	Very high growth in freight demand. Freight transport more than doubles between 2011 and 2050.	Global freight continues to experience strong growth.	Under this scenario, freight demand does not rise as quickly. This could be due to "smarter" technologies or having more local freight distribution processes.	Global freight breaks its historically strong growth pattern. While it still increases, there is much less correlation with global GDP growth. This could be driven by technology improvements (e.g. 3D printers reducing the need for freight) or infrastructure investments. This could also be consistent with a world which has become less globalized and is increasingly manufacturing and consuming products more locally.
Mode	Car use continues to increase with GDP, with particularly high increases in the developing world. No effort to reduce urban sprawl, or to invest in rail and public transport infrastructure.	Cities make an effort to shift trips to walking, cycling and public transport instead of by car. Some effort in logistics and rail infrastructure.	Cities make substantial effort to stem the shift toward cars and create incentives for walking, cycling, public transport, and 2-3 wheelers.	Cities make extreme effort to shift people away from private vehicles as well as reduce travel demand. This level represents extreme effort on rail infrastructure and logistics.
Occupancy and load	Under this scenario, people continue to prefer single-occupancy driving, and public transport occupancy levels are relatively low. Car occupancy falls by 10 percent from 2011 levels. This is similar to the level seen in Austria today.	Car occupancy remains at 2011 levels, which is around the same as the occupancy seen in the United Kingdom today.	Vehicle occupancy increases, possibly driven by technology, which makes car-pooling easier and which plans public transport logistics more efficiently. Car occupancy increases by 10 percent, while improved logistics and coordination improves freight load factors.	In level 4, regulatory constraints, costs, and smarter digital applications to coordinate our car demand makes car pooling more attractive. In 2050 car occupancy is 20 percent higher than today and the average occupancy for other transport is also higher. With investment in logistics, load factors for freight increase by an unprecedented level.

SCENARIO	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4
Car ownership	The average car travels 20 percent fewer km than today, with little sharing or hiring of vehicles. Cars remain an important luxury item and people want to own their own car, even if they use it less due to increased congestion. There are no incentive systems to share your car with others.	The distance traveled per car is the same as today's levels. Similar to today, car rental or sharing is a niche concept. The vast majority of cars remain privately owned and used.	The average urban vehicle travels twice as far in 2050 than in 2011 (rural vehicles travel 50 percent of the 2011 distance). This would be a world where many people in urban areas share or rent cars, rather than owning their own vehicle. Incentives or high costs of owning a car may support the car-sharing communities, or there may be significant use of self-driving cars.	The average urban vehicle travels 260 percent further than 2011 (with rural vehicles traveling double the 2011 distance). Car sharing and self-driving cars are probably a mainstream feature, and are optimized to make the best use of the system.
Efficiency	This assumes less improvement in efficiency than has been achieved over the last decades. For example, by 2050 the average urban passenger car (with an internal combustion engine) will use 5.9 liters of fuel per 100km.	Level 2 assumes annual improvement roughly corresponding with improvements achieved over the last decades. For example, by 2050 the average urban passenger car (with an internal combustion engine) will use 5.3 liters of fuel per 100km.	Level 3 surpasses improvement rates of the last couple of decades. For example, by 2050 the average urban passenger car (with an internal combustion engine) will use 4.3 liters of fuel per 100km.	This scenario entails that cars, trucks, and trains would use only half as much fuel in 2050 for the same distance traveled in 2011. For example, by 2050 the average urban passenger car (with an internal combustion engine) will use 3.6 liters of fuel per 100km.
Electrification of vehicles	By 2050 the percentage of hybrid and electric vehicles remains low for passenger cars and heavy-duty vehicles buses, and decreases for 2-3 wheelers. Few new technologies are adopted for ships or airplanes.	By 2050, there is an increased share of new technologies in the vehicle fleet. The percentage of hybrid and electric vehicles increases for passenger cars, buses, and 2-3 wheelers.	By 2050 there is significant adoption of low emission vehicles. The percentage of hybrid, electric, and hydrogen vehicles increases for passenger cars, buses, and 2-3 wheelers. In freight, new technologies are only barely starting to be adopted for ships or airplanes.	By 2050 there is major deployment of low emission vehicles. The percentage of hybrid, electric, and hydrogen vehicles increases dramatically for passenger cars, buses, and 2-3 wheelers. In freight, new technologies are starting to be adopted for around 10 percent of ships and airplanes.

Table A3 | **Level values**

LEVEL	BASE YEAR	2050 IEA 6DS	2050 LEVEL 1	2050 LEVEL 2	2050 LEVEL 3	2050 LEVEL 4
Passenger demand						
Average urban passenger distance per person (km/year)	9,187	12,072	13,292	12,396	11,933	11,533
Average rural passenger distance per person (km/year)	5,653	8,808	10,765	9,571	8,481	7,843
Average global passenger distance by flight or long-distance train (international) (km/year)	766	1,458	2,575	1,888	1,273	788
Freight demand						
Total freight (Gton-km per year)	85,163	196,730	209,419	184,790	159,249	129,362
Average freight per person (ton-km per year)	12,225	20,600	21,900	19,300	16,700	13,500
Mode						
Urban—% of domestic km traveled by car	38	49	65	53	43	29
Rural—% of domestic km traveled by car	45	55	62	59	49	42
International—% of km moved from planes to other modes of international travel	0	14.8	0	12	19	32
Occupancy and load						
Average urban car occupancy (passengers per vehicle)	1.6	1.48	1.4	1.6	1.8	1.9
Average rural car occupancy (passengers per vehicle)	1.8	1.68	1.6	1.8	2	2.2
Average freight load factor—Domestic light truck (tons per vehicle)	0.24	0.248	0.24	0.26	0.29	0.31
Car ownership						
Distance traveled by urban average car with internal combustion engine (km/year)	15,000	15,000	12,000	15,000	30,000	54,000
Distance traveled by rural average car with internal combustion engine (km/year)	15,000	15,000	12,000	15,000	22,500	30,000
Efficiency						
Efficiency for passenger car with internal combustion engine (lge per 100 km)	8.6	5.66	5.9	5.3	4.3	3.6
Efficiency for car with electric engine (lge per 100 km)	2.4	2.16	2.2	2.1	1.9	1.7
Freight efficiency for domestic light truck (lge per 100 km)	10	7.18	7.9	6.1	5.1	4.5

LEVEL	BASE YEAR	2050 IEA 6DS	2050 LEVEL 1	2050 LEVEL 2	2050 LEVEL 3	2050 LEVEL 4
Electrification of vehicles						
% urban passenger cars that are either hydrogen or electric	0	2	2	10	35	55
% urban passenger trains that are powered by electricity	90	90	90	95	97	100
% light freight vehicles with zero emissions (electric and hydrogen)	0	0	0	10	25	45
% light freight vehicles with zero emissions (e.g. hybrid)	0	5	5	10	15	20

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ENDNOTES

1. The Global Calculator is an engineering-based model; that is, it models the world’s energy supply and demand by modeling physical units such as land, cars, and power plants. The user chooses the characteristics, deployment, and use of these different technologies. It makes no assumptions about the way people’s behavior changes in relation to supply and demand. It does not automatically optimize the energy system based on price or any other factor (DECC 2015d), though it does calculate a cost for each user-selected scenario.

2. The use of the 2 degree energy scenario only includes changes to energy assumptions. No changes are made to other assumptions to align with the 2 degree scenario.

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ABOUT WRI ROSS CENTER FOR SUSTAINABLE CITIES

WRI Ross Center for Sustainable Cities works to make urban sustainability a reality. Global research and on-the-ground experience in Brazil, China, India, Mexico, Turkey and the United States combine to spur action that improves life for millions of people.

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ABOUT WRI

World Resources Institute is a global research organization that turns big ideas into action at the nexus of environment, economic opportunity and human well-being.

Our Challenge
Natural resources are at the foundation of economic opportunity and human well-being. But today, we are depleting Earth's resources at rates that are not sustainable, endangering economies and people's lives. People depend on clean water, fertile land, healthy forests, and a stable climate. Livable cities and clean energy are essential for a sustainable planet. We must address these urgent, global challenges this decade.

Our Vision
We envision an equitable and prosperous planet driven by the wise management of natural resources. We aspire to create a world where the actions of government, business, and communities combine to eliminate poverty and sustain the natural environment for all people.

Our Approach
COUNT IT
We start with data. We conduct independent research and draw on the latest technology to develop new insights and recommendations. Our rigorous analysis identifies risks, unveils opportunities, and informs smart strategies. We focus our efforts on influential and emerging economies where the future of sustainability will be determined.

CHANGE IT
We use our research to influence government policies, business strategies, and civil society action. We test projects with communities, companies, and government agencies to build a strong evidence base. Then, we work with partners to deliver change on the ground that alleviates poverty and strengthens society. We hold ourselves accountable to ensure our outcomes will be bold and enduring.

SCALE IT
We don't think small. Once tested, we work with partners to adopt and expand our efforts regionally and globally. We engage with decision-makers to carry out our ideas and elevate our impact. We measure success through government and business actions that improve people's lives and sustain a healthy environment.