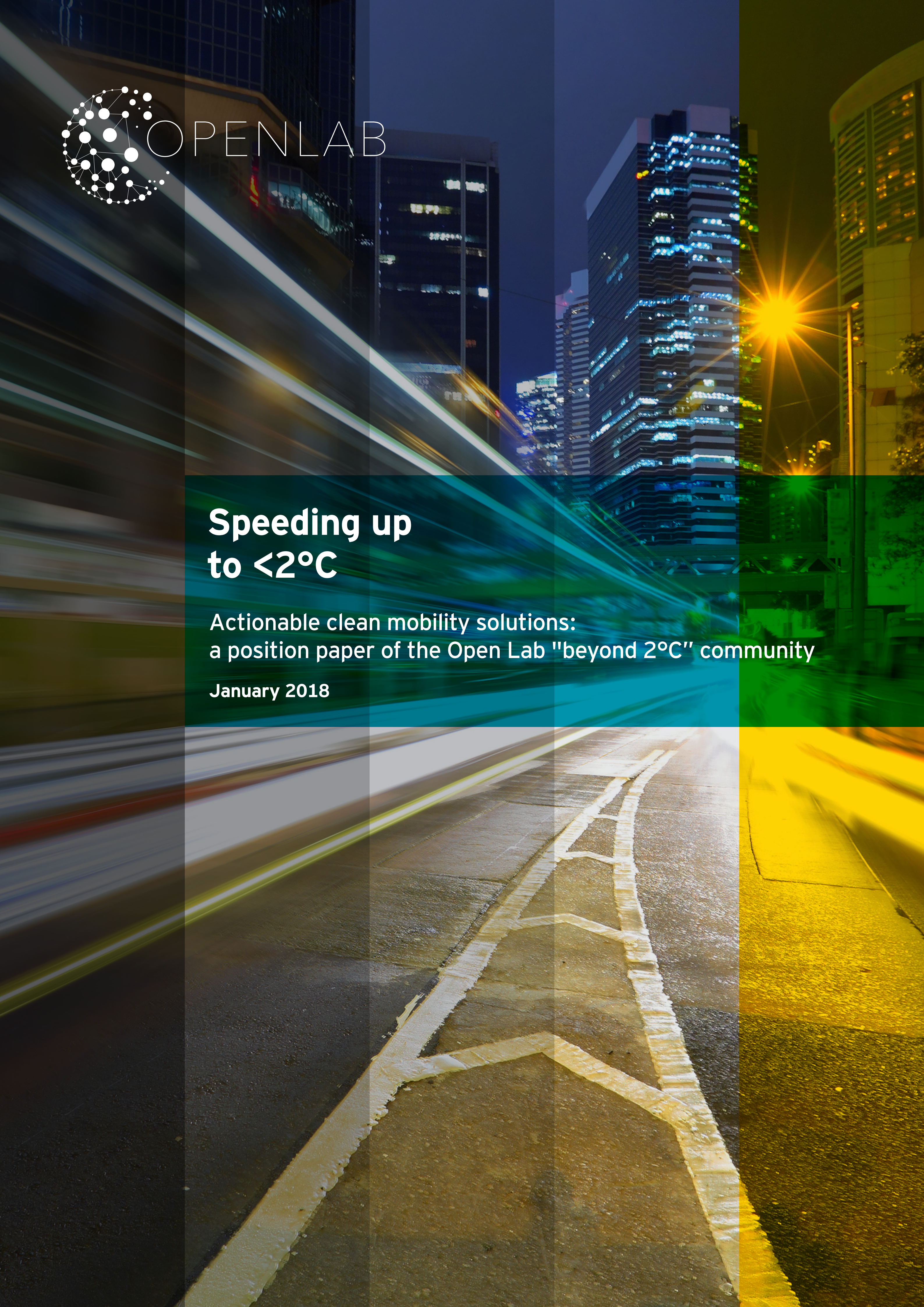

OPENLAB

Speeding up to <2°C

Actionable clean mobility solutions: a position paper of the Open Lab "beyond 2°C" community

January 2018

EDITORIAL

As part of the Open Lab, our community brings together several major companies in the mobility sector who are committed to making a positive contribution to tackling climate change.

The ambition of this community is to build a shared vision of the mobility sector's contribution to a "beyond 2°C" scenario for the transportation of both goods and passengers. Although the whole range of technological and behavioral solutions should be considered and implemented according to local specificities, the objective of this study is to promote solutions that are within reach in the next decade and can make valuable contributions to reducing the carbon footprint of the mobility sector.

This study provides insights into the implementation of seven clean mobility solutions:

- Incentive schemes in favor of behavioral and modal shifts in passenger transportation
- Eco-driving technologies and training programs
- Car-pooling applications and the sharing economy in freight transport
- Sustainable biofuels
- Battery electric vehicles (BEVs)
- Natural gas vehicles (NGVs)
- Hydrogen-based fuel cell electric vehicles (FCEVs)

Solutions that are oriented toward societal and behavior change could have a significant CO_2 mitigation potential in the very short term by acting on the current rolling stock of vehicles. They will contribute to addressing the growing air pollution challenges in urban areas. They require strong political support, collaboration between local authorities and the private sector, and the implementation of new business models. Over the medium term, the potential of alternative fuels and low-carbon vehicles should be fully unlocked and will have a significant impact on a global scale. These solutions are nearly or fully commercially mature, but their large-scale deployment is still curbed by several factors such as the limited charging infrastructure, high production and purchase costs, etc.

This study provides concrete recommendations for policy makers on the implementation and scale-up of innovative clean mobility solutions. It also highlights ways for stakeholders in the sector to support the implementation of these solutions.

The transport sector currently accounts for 9.4 $GtCO_2$ and is projected to emit up to 11.4 $GtCO_2$ by 2030 in a business-as-usual scenario, while a "beyond 2°C" scenario would require limiting CO_2 emissions to 7.9 $GtCO_2$ by 2030. Compared to a business-as-usual scenario, active deployment of the solutions highlighted in this study could lead to reducing CO_2 emissions from the transport sector for 2030 by 0.52 Gt in a conservative scenario and by up 1.3 $GtCO_2e$ in an optimum scenario. This represents 15% to 37% of the mitigation effort for the period up to 2030 in the transport sector according to the IEA's "beyond 2°C" scenario.

This study shows that Governments and the private sector can achieve significant results by working together to implement the right enabling environment, provide positive incentives to foster change, and promote the large-scale development of innovative solutions.

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**in alphabetical order, by company and by name*

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KEY messages

1

A number of clean mobility solutions will contribute to reducing the carbon footprint of goods and passenger transportation. Some solutions have the potential to unlock GHG emission savings very quickly, while others will realize their full mitigation potential in the medium term. Decision-makers must however act on all solutions in the very near term to remove barriers and ensure that all clean mobility solutions contribute to the mitigation effort, in the short and longer term.

2

The most impactful solutions on a global scale rely on technologies or infrastructure that will require very significant capital investment in the long term.
Such solutions include:

- Sustainable biofuels
- Battery electric vehicles
- Natural gas vehicles
- Hydrogen-based fuel cell electric vehicles

The large-scale deployment of these solutions will depend on the implementation of charging and refueling infrastructure, cost optimization in the value chain, market incentives and a safe, accessible supply of low-carbon fuels. For collective transportation and public vehicle fleets, the ramp-up of these solutions may be quicker.

Mitigation potential of the 7 clean mobility solutions presented in this study*

**NB: the mitigation potentials are calculated on different geographical areas, depending on the scope of utmost relevance for each solution (see detailed methodology p.42).*

3

A number of solutions foster the optimization of existing infrastructure and of the current stock of vehicles. They contribute to reducing the demand for mobility or shifting to low-carbon transport alternatives. Such solutions could be promoted to accelerate the transition and trigger emission reductions in the very short term:

- Incentive schemes in favor of behavioral and modal shifts in passenger transportation
- Eco-driving technologies and training programs
- Car-pooling applications and the sharing economy in freight transport

These solutions are particularly relevant for short-term implementation, due to the following factors:

- low capital investments,
- reliance on mature, globally available digital technologies,
- capacity to reduce the cost of transport for users, hence few acceptability issues,
- potential to encourage voluntary behavioral and societal changes,
- contribution to significantly mitigating GHG emissions as well as reducing atmospheric pollutants, reducing noise and stress, creating social well-being, etc.
- capacity to reach a critical mass relatively quickly, using emulation and stimulation among a community of users (reward programs, social networks, digital apps, etc.).

These solutions rely on technologies that are already available on the mass market but require new practices in public policy-making and the development of new types of public-private partnerships, such as:

- Implementing financial incentive programs
- Delegating the operation of public mobility services to digital platforms or start-ups

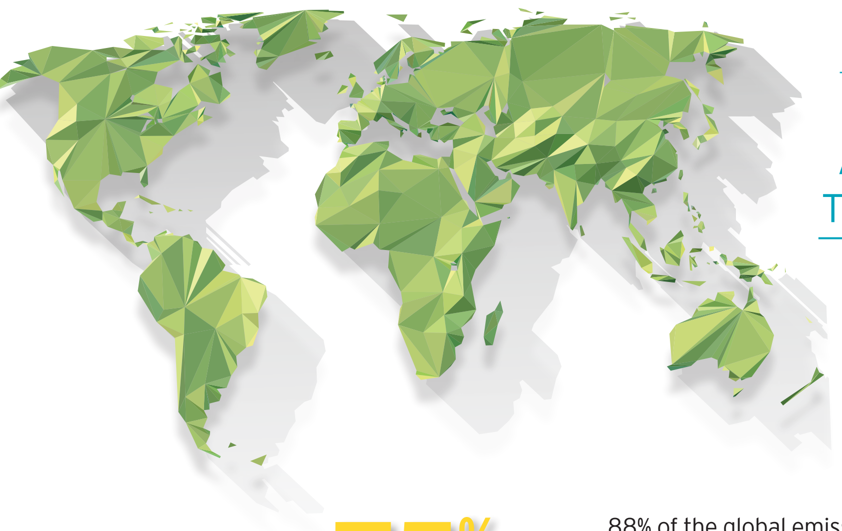
4

Digital technologies and the use of big data solutions will be critical to the scale-up of these solutions, making low-carbon transport alternatives more visible, comparable and attractive than usual transport habits. In particular, the information given to passengers and logistics clients about the carbon footprint of their mobility choices will play an important role: it will add a "carbon content" criterion to decision-making and foster awareness-raising among mobility users.

5

Policy makers and the private sector should collaborate to develop pilot programs in the short term in order to quantify the exact CO_2 emission reduction potential of these solutions and assess their environmental and societal co-benefits (noise reduction, air quality, social well-being, reduction of economic stress on low income families, etc.).

BACKGROUND



THE TRANSPORT SECTOR IS A KEY PLAYER IN ACHIEVING THE <2°C TARGET

The 21st Conference of the Parties (COP21) to the United Nations Framework Convention on Climate Change (UNFCCC), held in Paris in December 2015, resulted in a historic agreement between governments to keep the rise of global temperatures well below 2°C above pre-industrial levels and to pursue efforts to limit the rise of global temperatures to 1.5°C. As of December 2017, 170 parties have ratified the Paris Agreement, accounting for 88% of the global emissions covered by the Agreement. The effective withdrawal of the United States would bring down the share of emissions covered to 68%.

75%

of NDCs identify transport as a priority sector to mitigate national emissions

In the run-up to COP21, parties submitted their Nationally Determined Contributions (NDCs), specifying their national ambition and strategy to decarbonize their economy. More than 75% of NDCs identify transport as a priority sector to mitigate national emissions. The measures proposed in NDCs are however deemed insufficient to achieve the "well below 2°C" target with the expected growth in transport-related total final energy consumption (+20% between 2014 and 2030, and +42% between 2014 and 2050 in a business-as-usual scenario) and consequent growth in emissions.

PRIORITIZING ACTIONS TO REVERSE THE GROWTH OF TRANSPORT-RELATED CO_2 EMISSIONS IN THE NEXT DECADE

The nature of mobility flows differs from one region of the world to another and is shaped by territorial aspects (e.g. differences between urban, peri-urban, and rural areas), cultural habits, infrastructure, technology, the availability of natural resources and the level of socio-economic development. Mobility flows also vary greatly between goods and passenger transportation and between individual and collective transportation. While the full range of solutions should be considered in every region, it makes sense for public authorities to identify which mobility flows should be deemed priority targets to trigger emission reductions over the next decade.

Global transport-related GHG emissions in a business-as-usual scenario

WHAT DOES REACHING THE <2°C TARGET MEAN FOR THE TRANSPORT SECTOR?

The transport sector accounts for 24% of global energy-related CO_2 emissions, making it the third largest contributor. This share is expected to grow to 26% by 2040, with transport-related CO_2 emissions rising from 9.4 Gt (as of 2014) to 14 Gt in 2050, due to a growing demand, recurring oil dependency and the difficulty of achieving large-scale commercialization of new technologies such as electric vehicles. While transport-related emissions grew by 2.5% annually between 2010 and 2015, reaching the <2°C target will mean that transport emissions must peak within the next ten years and decrease thereafter. Meeting this ambitious objective will require actions on the level of mobility demand and the distribution by transport mode ("avoid and shift"), on the energy efficiency of each mode ("vehicle efficiency") and on the carbon content of fuels ("low-carbon fuels"), by means of both technological improvements and behavioral change.

SOLUTIONS THAT WILL CONTRIBUTE TO REDUCING THE TRANSPORT SECTOR'S CARBON FOOTPRINT INCLUDE:

Avoid & Shift:

- Car-sharing and car-pooling
- Traffic control and optimization
- Smart logistics
- Incentive and reward programs in favor of eco-mobility and modal transfers

Vehicle Efficiency:

- Mechanical, technical and physical improvements to vehicles and engines
- Hybrid propulsion
- Eco-driving training and technologies
- Connected and autonomous vehicles

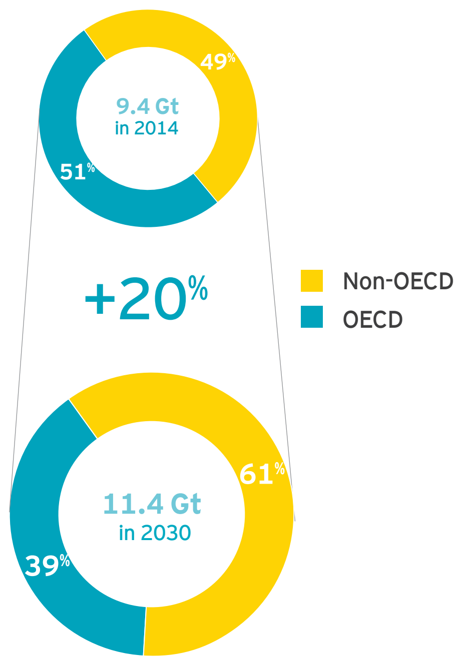
Low-carbon fuels:

- Hydrogen-based fuel cell electric vehicles
- Sustainable biofuels
- Natural gas and biogas
- Battery electric vehicles
- Improvements to conventional fossil fuels

TRENDS DIFFER SIGNIFICANTLY BETWEEN OECD AND NON-OECD COUNTRIES

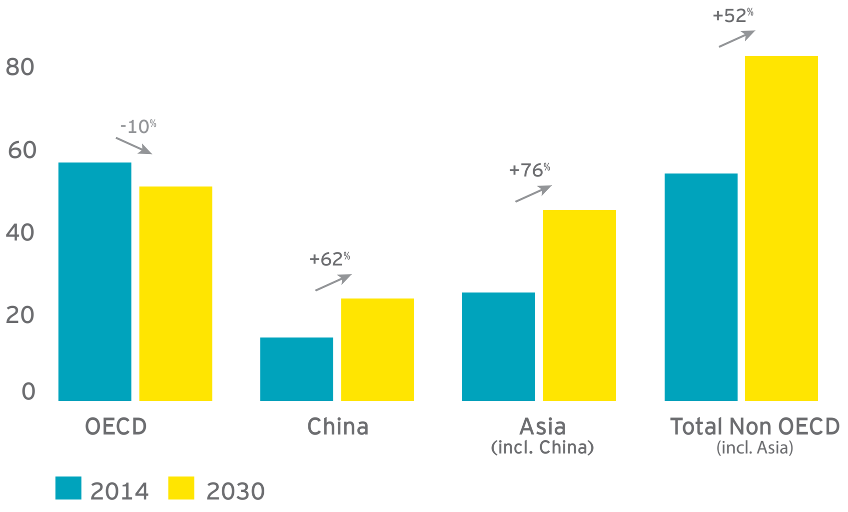
- OECD countries are currently responsible for 51% of global transport-related CO_2 emissions. Trends to 2030 indicate that the transport-related total final energy consumption in OECD countries should start decreasing over the period (-10% between 2014 and 2030).
- While non-OECD countries are currently responsible for 49% of the sector's CO_2 emissions, the transport-related total final energy consumption in these countries is expected to increase sharply over the 2014-2030 period (+52%), leading to a 52% increase in CO_2 emissions. In emerging countries in particular, urbanization, population growth and rising incomes are driving up the demand for mobility.

Transport-related CO_2 emissions by region in a business-as-usual scenario

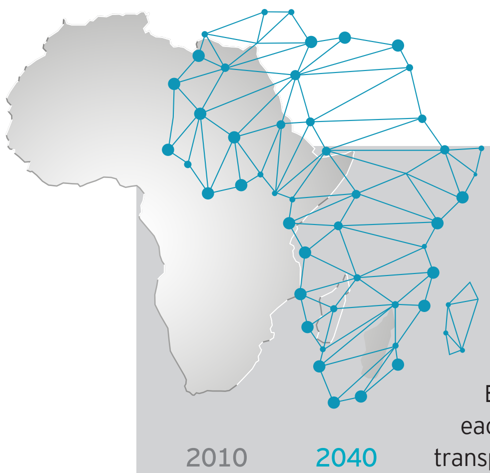


OUTSIDE THE OECD AREA, ASIA AND AFRICA WILL DRIVE THE INCREASE IN DEMAND FOR MOBILITY AND THE TRANSPORT-RELATED TOTAL FINAL ENERGY CONSUMPTION OVER THE COMING DECADE

ENERGY CONSUMPTION IN TRANSPORTATION, 2011-2025 (QUADRILLION BTU)



- Asia alone currently represents more than 20% of the transport-related total final energy consumption, and up to 35% in 2030 (with 20% accounted for by China), led by a rise in demand in China (+62%) and India (+76%).
- Africa currently represents only 4% of transport-related CO_2 emissions, but it is the fastest-growing region after Asia in terms of transport-related energy demand. With less developed infrastructure, the African continent also has the potential to leapfrog mobility orientations and implement alternative new mobility systems.



Leaping forward in Africa

Africa is experiencing fast-paced urbanization (in 2050, 56% of Africans will live in cities), leading to increased demand for mobility, while the largely low-income population is used to spending a very small share of its budget on transport (3 to 5%). To date, Africa's mobility is mostly ensured by the inflow of used and outdated vehicles from Europe and Asia (Africa receives approximately three to four million vehicles from Europe each year). Collective transportation is provided on a very large scale by informal public transport. In addition, Africa's transport infrastructure is still largely underdeveloped and it is estimated that \$68 to \$93bn will need to be invested each year from 2010 to 2040 to redress the situation. Finally, with 42 cars for 1000 inhabitants, Africa is the continent with the smallest motorization rate.

80bn$ of investment needed to develop transport infrastructure

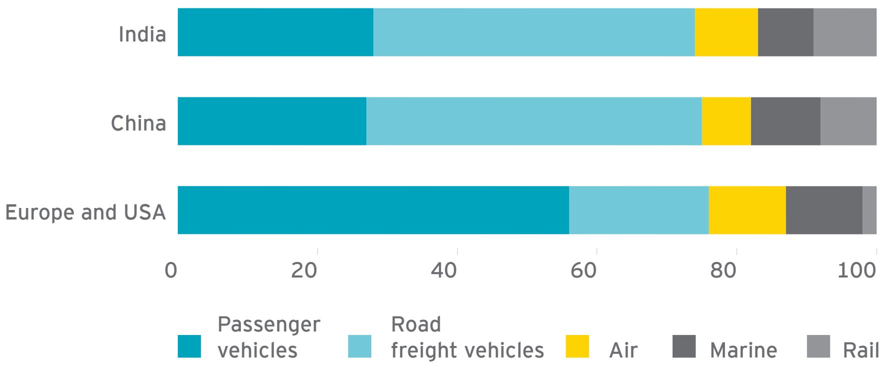
The current lack of infrastructure and low level of motorization represent critical challenges for Africa, but they are also opportunities for the continent to develop alternative mobility solutions unhampered by the weaknesses of existing infrastructure and models.

The current structure of mobility supply, combined with weak transportation planning and road management creates traffic flaws (accidents and traffic jams) and results in major air pollution issues. To achieve the "beyond 2°C" scenario, this pattern needs to be disrupted, as the cyclical renewal of the African car market will not be able to meet the demand while the sector is being decarbonized.

The entrepreneurship culture and the 'Can Do' attitude create fertile ground for innovation. Many initiatives are being developed across the continent to shape a mobility supply tailored to the African socio-economic and cultural context, which could contribute to the so-called 'leapfrog' phenomenon.

ROAD TRANSPORT IS THE LARGEST CONTRIBUTOR TO THE SECTOR'S CO_2 EMISSIONS

ENERGY CONSUMPTION IN TRANSPORTATION BY COUNTRY AND TRANSPORT MODE, 2012 (%)



- Within the OECD countries, passenger transportation is responsible for nearly two-thirds of CO_2 emissions, and is dominated by road transport and the use of private light-duty vehicles (LDVs).
- In Asia, the distribution of CO_2 emissions is relatively balanced between passenger and goods transportation, and the energy demand for passenger transportation is evenly distributed between buses, two- and three-wheelers and private cars.

Road transport is also the largest contributor to CO_2 emissions from freight activities in Asia.

- Passenger air transportation (international and domestic) and air and maritime shipping together account for 18% of current global CO_2 emissions. These transport modes raise cross-sectoral and cross-boundary issues which will require international cooperation to reach adequate, effective solutions.

This study aims to identify solutions that have a high CO_2 abatement potential in the short and medium term and are mature enough to be deployed rapidly, with the objective of addressing the following priority targets:

- Private and collective passenger road transport in OECD countries
- Private and collective passenger road transport in Asia
- Road freight transport in Asia

In the short term, several behavior-oriented solutions seem particularly relevant. They rely on technologies that are already mature and do not require heavy capital investment. With the right incentives (such as policy-making and public funding), the deployment of these solutions could quickly result in a critical mass triggering significant reductions in CO_2 emissions.

These solutions are presented in three detailed case studies on solutions fostering behavioral change:

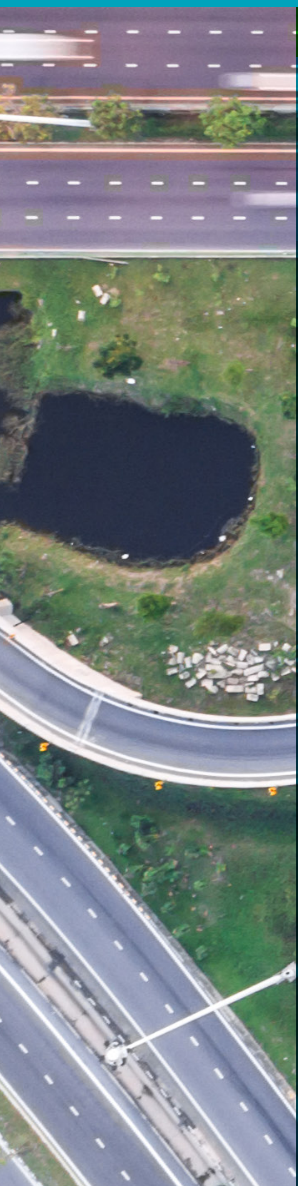
1. Incentive schemes in favor of behavioral and modal shifts in passenger transportation
2. Eco-driving technologies and training programs
3. Car-pooling applications and the sharing economy in freight transport

While improvements in engine and vehicle efficiency will naturally reach the market, several low-carbon fuels will gradually contribute to reducing the carbon footprint of the transport sector.

Their deployment will require strong political support from decision-makers in order to provide the appropriate infrastructure and establish the enabling regulatory framework. They are presented in four focus studies on key technological solutions:

1. Sustainable biofuels
2. Battery electric vehicles
3. Natural gas vehicles
4. Hydrogen-based fuel cell electric vehicles

Given the specificities of the solutions and of each geographical area, the scope considered for the mitigation potential of each solution is indicated in each case study. We distinguish OECD and non-OECD countries, with a specific focus on China within non-OECD countries.

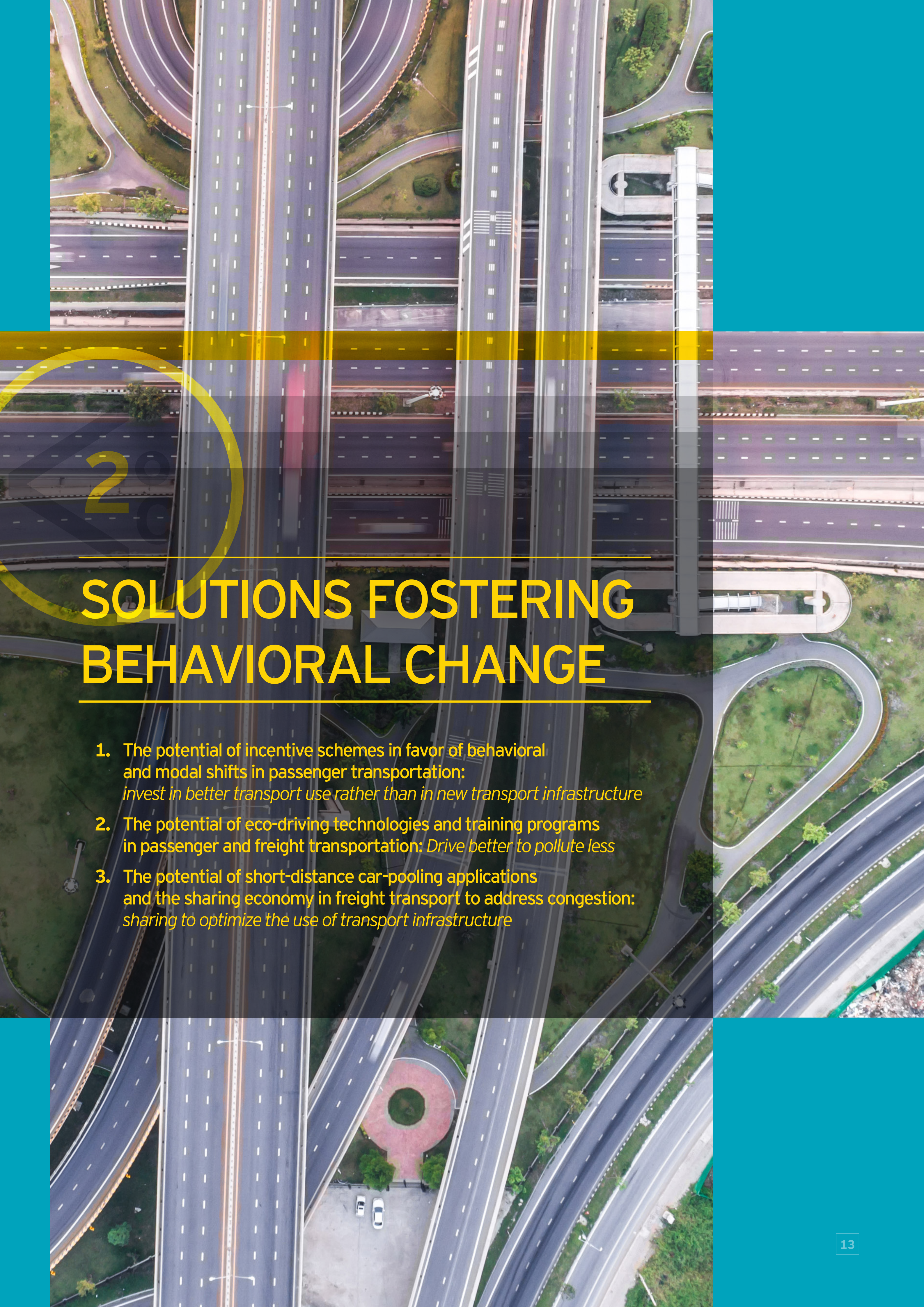


CASE STUDIES

These solutions foster the optimization of the existing infrastructure and the current stock of vehicles, thus reducing the demand for mobility or shifting to low-carbon transport alternatives. They could be promoted to accelerate the transition and trigger emission reductions in the very short term.

These solutions are particularly relevant for short-term implementation, due to the following factors:

- ***low capital investments,***
- ***reliance on mature, globally available digital technologies,***
- ***capacity to reduce the cost of transport for users, hence few acceptability issues,***
- ***potential to encourage voluntary behavioral and societal changes,***
- ***contribution to significantly mitigating GHG emissions as well as reducing atmospheric pollutants, reducing noise and stress, creating social well-being, etc.***
- ***capacity to reach a critical mass relatively quickly, using emulation and stimulation among a community of users (reward programs, social networks, digital apps, etc.).***



2

SOLUTIONS FOSTERING BEHAVIORAL CHANGE

1. **The potential of incentive schemes in favor of behavioral and modal shifts in passenger transportation:** *invest in better transport use rather than in new transport infrastructure*
2. **The potential of eco-driving technologies and training programs in passenger and freight transportation:** *Drive better to pollute less*
3. **The potential of short-distance car-pooling applications and the sharing economy in freight transport to address congestion:** *sharing to optimize the use of transport infrastructure*

OECD | CHINA | NON-OECD
URBAN | PERIURBAN | RURAL
FREIGHT | **PASSENGER**
ROAD | AIR | MARITIME

CASE STUDY 1

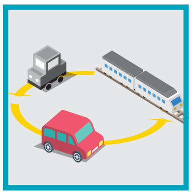
1 THE POTENTIAL OF INCENTIVE SCHEMES IN FAVOR OF BEHAVIORAL AND MODAL SHIFTS IN PASSENGER TRANSPORTATION: INVEST IN BETTER TRANSPORT USE RATHER THAN IN NEW TRANSPORT INFRASTRUCTURE

The need to investigate alternative ways to tackle traffic congestion in emerging countries

In the OECD and emerging countries, cities are facing the critical challenge of tackling traffic congestion, which contributes to air and noise pollution in urban areas. The cost of traffic jams was estimated to reach 1% of the GDP in 2013 in four OECD countries (France, Great Britain, Germany and the USA). In India and China, the disproportion between the growing mobility demand and the current transport infrastructure causes severe traffic jams. Traditional public policies on mobility and notably investments in new urban infrastructure are very costly and often insufficient to limit the growing use of private LDVs. For this reason, public authorities should investigate alternative ways to tackle traffic congestion, by acting on the demand for mobility and optimizing existing transport infrastructure.

How can incentive programs change the story?

The difficulty of reshaping the demand for mobility stems from the lack of flexibility shown by travelers used to a given travel behavior and from the impossibility of adapting transport services due to infrastructure constraints. In addition, building new road infrastructure requires significant capital investment and often only provides a temporary solution to congestion issues: in the long run, new roads are likely to attract more car trips and encourage drivers to keep using their cars (the so-called "rebound effect"). A powerful tool for reducing trips and tackling congestion is **the implementation of reward and incentive programs encouraging private car drivers to avoid travel or to shift to an eco-friendly mode.** These programs incentivize car drivers to:



SHIFT TO A TRIP OPTION THAT GENERATES LOWER GHG EMISSIONS by using a low-carbon vehicle, car-pooling, public transport or commuting outside of rush hours.

REDUCE THE DEMAND FOR MOBILITY in terms of kilometers travelled by adapting daily habits and working from home.

Among the possible approaches, community-based solutions using social networks coupled with reward and loyalty programs are beneficial in creating momentum within a community. They foster a collective behavior change, rather than targeting individuals.

Examples of successful projects

Incentive schemes offer numerous opportunities for startups and public authorities to imagine new services encouraging the reduction of vehicle use in cities and modal shifts towards low-carbon modes. To date, such programs are used in a few cities, mostly in OECD countries:

- In the Netherlands, several cities have delegated the development of these reward schemes to a consortium of highway companies. The consortium is in charge of optimizing vehicle use on their existing road infrastructure. It implemented a reward program based on the selection of a sample of relevant Dutch urban commuters, who were financially rewarded for each car trip not made or rescheduled to avoid rush hours (min.€2.5/trip, funded by public authorities). Automatic Licence Plate Recognition (ALPR) cameras are used to identify the drivers. The program results show an active participation rate of 33% and an 8 to 10% reduction in traffic volume, sufficient to decongest highways during the rush hour.
- Similarly, dynamic pricing in transportation is a powerful tool to encourage users to avoid peak time services and spread demand over a wider period of time for more effective use of infrastructure. Singapore has recently experimented this approach with a trial of free and discounted travel on the metro before 8 a.m. for journeys to key destination stations. The result of the trial showed a 7% shift from peak to pre-peak, illustrating the potential for incentivizing behavior change. Such incentives may attract rush-hour drivers who would prefer an off-peak train ride rather than a rush-hour road commute. A similar system could be tested on road toll fees to encourage commutes outside of peak hours and reduce congestion.

Given the challenges of the extremely fast-growing motorization in Asia, the implementation of such programs to encourage sustainable behaviors could be a relevant solution in the short term.

KEY SUCCESS FACTORS

Guaranteed access to mobility data and a high capacity to regulate traffic

These programs are enabled by the use of tracking and recognition technologies such as GPS and sensor systems. Information systems have to deliver accurate, wireless and continuously updated transport data to travelers and traffic regulators to make the programs efficient and attractive. The level of regulation, digitalization and traffic control might therefore hinder the use of these programs in developing countries with weak transport infrastructure. In addition, infrastructure and technology systems should also ensure that rewards are correctly distributed.

Public authorities should guarantee that real-time transport data is collected and shared with the implementing partners of incentive programs. This is a prerequisite to ensuring that incentive programs are tailored to the specific structure of mobility flows in each region (rush hour, most congested routes, etc.) and that rewards or price cuts address the appropriate mobility flows.

Anticipating costs and benefits

From an economic standpoint, incentive and reward programs need robust economic impact studies to prove that the program funding costs are offset by the costs avoided as a result of traffic optimization. These avoided costs must include indirect costs and benefits such as the improvement of road safety and the impact of better air quality on health.

The ability to quantify the benefits of incentive programs upfront is a prerequisite to justifying their implementation. The success of these programs consequently requires strong collaboration between public authorities and infrastructure operators in order to perform a cost-benefit analysis and fine-tune the characteristics of the program, such as the level of incentives, targeted routes, etc.

Encouraging voluntary behavioral change through positive incentives

The success of incentive schemes in reducing mobility demand at a given time relies on the active participation of daily commuters. Behavioral research shows that voluntary behavior change is more efficient and sustainable than forced change. Consequently, reward programs could be very effective as they translate into direct financial compensation, reductions in monthly insurance fees or free mobility services.

Negative incentives such as taxes on fuel, parking and vehicles can help to limit the increase in car use but do not necessarily trigger sustainable behavioral change.

As decision-makers and funders, public authorities have a crucial role to play in guaranteeing commuter commitment to the programs, through the deployment of positive incentives to reward virtuous behavior.

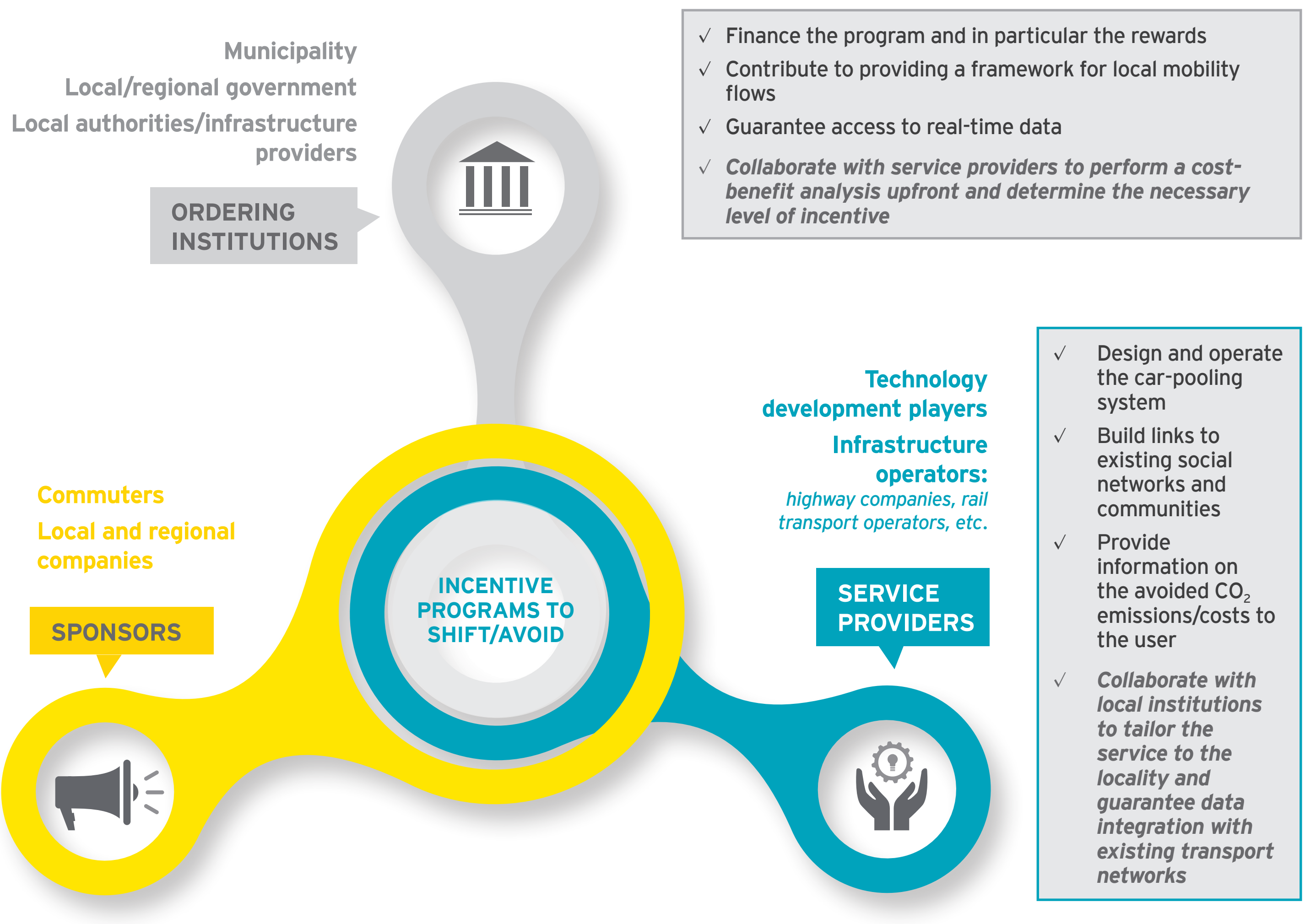
Providing for flexibility in working habits

Traffic patterns are the result of daily commuters' working habits, which are usually responsible for traffic peaks. Increased flexibility in working habits is key to enabling incentive programs. Commuters who are able to work remotely will be more likely to adapt their commuting habits. Similarly, flexible working habits will facilitate the decision to commute outside of peak hours.

To enhance the effectiveness of an incentive program, policy-makers should involve companies and work collaboratively to provide commuters with the necessary flexibility to adapt their commuting behavior.

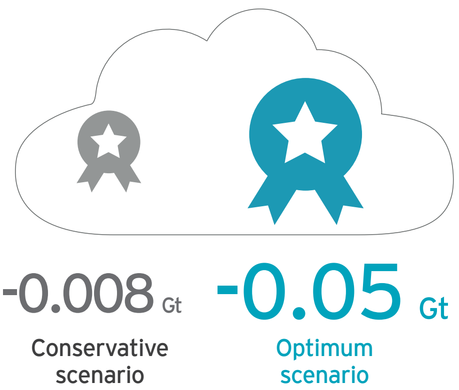
- √ Raise awareness among peers
- √ ***Collaborate with service providers and local institutions to provide the necessary flexibility in working habits***

STAKEHOLDER ECOSYSTEM AND KEY LEVERS



GHG abatement potential contributing to the "beyond 2°C" objective

GHG abatement potential of incentive schemes in major OECD cities for passenger transport
(by 2030, compared to a business-as-usual scenario)



Quantifying the GHG abatement potential of incentive programs raises several methodological issues, linked to the heterogeneity of possible incentives and results between "avoid" and "shift" initiatives. Based on current experiments, a reduction of 8-10% in traffic volumes could be achieved thanks to such programs, resulting in a reduction of CO_2 emissions linked to two factors: the trips avoided and the decongestion of main transport routes. In decongested traffic, vehicles are on average 25% less carbon intensive than in congested traffic, as vehicle emissions are at their lowest when driving at 70 kilometers per hour.

The implementation of incentive programs similar to the one in Rotterdam could lead to reducing annual CO_2 emissions resulting from daily commutes by 7% in moderately dense cities and by 22% in large, very dense cities compared to a business-as-usual scenario. Overall, if such programs were implemented in 40 major cities (moderately dense and very dense) throughout OECD countries, up to 2% of the total CO_2 emissions (-0.008 $GtCO_2$) linked to passenger road transport in the OECD could be avoided each year.

Co-benefits and anticipated risks

Environment and well-being

The reduction of traffic jams in city centers has a positive impact on overall well-being through the reduction of car accidents, noise and stress levels. By promoting active transport such as walking and cycling, incentive programs also contribute indirectly to the physical, mental and social well-being of citizens, enhancing the quality of life in communities.

POSITIVE TOLLS TO FOSTER A CHANGE IN DAILY HABITS IN THE NETHERLANDS, BY EGIS

Egis and its Dutch subsidiary BNV Mobility have developed a solution to smooth peak-hour traffic congestion. This programme, called "Positive Tolls" (Péage positif), aims to reward car drivers who agree not to use their car during peak hours, within a specific geographical area that is usually congested.

Analysis of the factors that generate traffic congestion highlights organizational and societal models as well as deeply rooted individual behavioral patterns: synchronous commutes to work, single-occupancy driving, limited interest in public transport, etc. The positive tolls will challenge these mobility habits and change them seamlessly in a positive, playful way (by nudging and gamification). Unlike congestion charges which penalize drivers, the positive tolls boost individual responsibility and reward virtuous initiatives such as delaying the departure time, modal shifts (public transport, cycling), car-pooling, home working, etc. Drivers participating voluntarily in the program are rewarded (on average €2 to €3 per trip avoided) if they prove that they used an alternative transportation method. This proof, supported by digital technologies (embedded systems, smartphone, license plate recognition) enables participants to ensure their performance and individual progress.

In the Netherlands, where this approach was implemented in 2008, 80% of participants maintain their virtuous habits after taking part in the program. These programs resulted in reducing the number of trips by 8% to 10% on average.

OECD | CHINA | NON-OECD
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FREIGHT | PASSENGER
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CASE STUDY 2

2 THE POTENTIAL OF ECO-DRIVING TECHNOLOGIES AND TRAINING PROGRAMS IN PASSENGER AND FREIGHT TRANSPORTATION: DRIVE BETTER TO POLLUTE LESS

The necessity to reduce emissions by the current rolling vehicle stock

Road transportation accounts for 80% of the final energy consumption of the transport sector in OECD countries. In a business-as-usual scenario, which would lead to a +6°C increase in global temperatures according to the IEA, the final energy demand for road transport remains stable to 2050 in OECD countries. Road passenger and freight transportation is therefore a key priority for policy-makers and car manufacturers aiming for a "beyond 2°C" target.

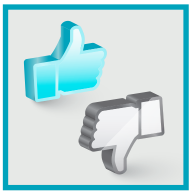
As the pace at which low-carbon vehicles will reach large-scale commercialization is still uncertain, acting on the CO_2 emissions of the current rolling stock of vehicles should remain a priority. Improving driving practices could be a quick win action to reduce road transport emissions and could be easily implemented at lower cost. Eco-driving practices allow for more efficient vehicle use and result in environment-friendly and cost-saving driving practices that are adapted to the current thermal vehicles.

Using technology and training to improve driving styles

Eco-driving practices include avoiding rapid acceleration and unnecessary braking, obeying speed limits, performing timely gear shifting, maintaining steady speeds on the highway, regularly maintaining the vehicle, etc. Likewise, the choice of tires and pressure or the vehicle load are key factors in limiting rolling resistance and ultimately fuel consumption. Smart use of car air conditioning or the use of premium efficient fuels also contribute to saving fuel. Such practices can be encouraged through the use of the following tools:

EMBARKED SOFTWARE AND TECHNOLOGIES

Helping drivers to control their driving style and provide real-time feedback to the latter from the direct environment of the car. These technologies help drivers to drive smoothly and economically.



REWARDS AND GAMIFICATION

Embarked ICT is used to challenge drivers, provide tailored advice, grade drivers and reward them for their eco-driving performance. Through the use of gamification boards, drivers are incentivized to drive in a more eco-friendly manner.

AWARENESS-RAISING AND ECO-DRIVING TRAINING PROGRAMS

Aiming to change driving behavior. Such programs are implemented by various stakeholders from Original Equipment Manufacturers or motor carriers to public bodies and associations.

In optimum eco-driving mode, a vehicle would be equipped with all of the above and act as a real-time training coach for the driver for utmost effectiveness.

Examples of successful projects

Eco-driving training programs are becoming common in Europe, with some of the most extensive ones to be found in the Netherlands, where driving school instructors and examiners are systematically trained in this field. In Sweden, eco-driver training became mandatory for new drivers as from 2006.

In addition to training programs, on-board technology-based applications, increasingly praised by car and truck manufacturers, prompt drivers to drive economically without any conscious or voluntary effort. The first eco-driving technologies such as real-time indication of fuel consumption and speed regulators were rather basic, but technologies have evolved rapidly to promote ever smoother driving. Several car models now offer an on-board personal driving coach service. Today, drivers can benefit from the use of smartphones as in-vehicle feedback devices or the eco-adaptive cruise control systems that adjust speeds based on anticipated road grades. Systems are also developed to utilize real-time traffic and signal timing information to provide eco-driving assistance based on anticipation of conditions ahead.

French car manufacturer Renault pioneered the use of eco-driving technologies in its cars and is considering the implementation of reward-based applications for driving as of 2018.

ACHIEVING CO_2 EMISSION REDUCTIONS THROUGH ECO-DRIVING TRAINING AND SOFTWARE, BY GEODIS

At GEODIS, we have achieved significant fuel consumption reductions over the past decade by training our drivers to drive in a more environmentally friendly manner (eco-driving). New drivers receive eco-driving training and we monitor the performance of all our drivers to provide additional training if needed. We also organize challenges among our drivers to provide further incentives for eco-driving.

While this approach was critical in mitigating our emissions when it was first implemented, and must be maintained, the marginal gain is now lower than it was in the first years of implementation. The next promising step lies in the application of artificial intelligence to vehicle-embarked software to provide real-time coaching for the drivers. Significant gains could be guaranteed if we were able to provide driving assistance based on specific parameters such as truck load, elevation change, traffic information, etc. By factoring in these parameters, we would be able to provide our drivers with precise information on the optimal driving style and to control the breaking or acceleration speed, further reducing fuel consumption and related CO_2 emissions.

KEY SUCCESS FACTORS

Providing a level of driving control and coaching adapted to each driver to foster acceptability

New embarked ICT technologies are enablers that make eco-driving effortless for drivers. However, maximum fuel savings require a significant level of behavioral control over driving practices, either through actual training or through direct coaching by the car's embarked software. To guarantee that eco-driving practices are acceptable and attractive to drivers, it is necessary to provide different levels of control of and delegation to the embarked software. In addition, drivers may be reluctant to use new technologies such as mobile applications in their cars, as they may find electronic devices distracting.

Car manufacturers could commit to commercializing only vehicles with at least the most basic level of embarked eco-driving software, while public authorities could set standards for the integration of eco-driving technologies in new commercialized vehicles.

Providing incentives to enhance eco-driving practices

Savings can be increased if drivers are incentivized to switch to eco-driving practices. Rewards for good eco-driving performance are likely to encourage drivers to improve, in particular those who would be reluctant to adapt their driving habits. These incentives could be provided by insurance companies in the form of insurance bonuses, by local authorities and public transport operators in the form of public transport vouchers, etc. Freight transport companies have for instance implemented reward programs to incentivize their drivers to adopt an environmentally-friendly driving style.

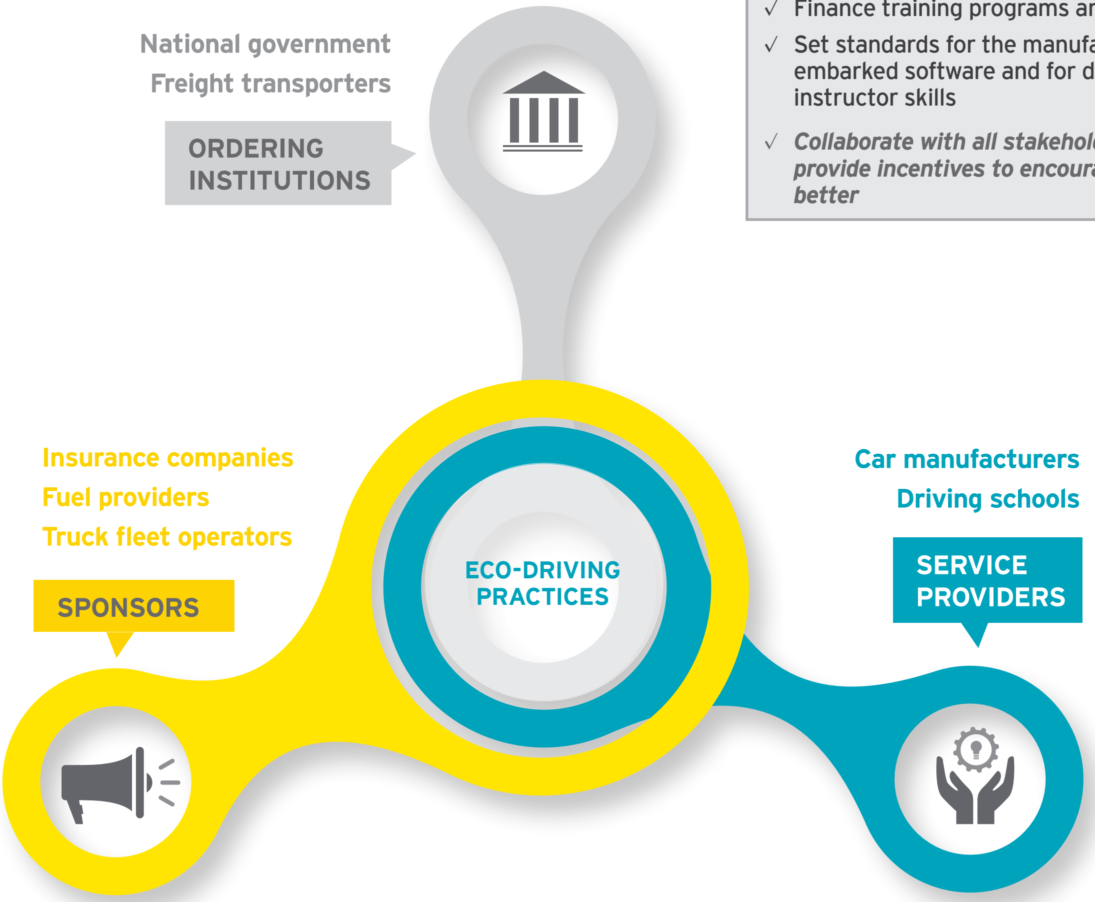
Key stakeholders (car manufacturers, insurers, trasnport authorities) could collaborate to create a system of positive incentives to encourage eco-driving that would also add value to their business model.

Requiring eco-driving practices to be systematically included in all driving license training

Training drivers in eco-driving practices is the most efficient way of achieving the maximum savings possible. Including mandatory eco-driving training in general driving license training would be a strong enabling factor for increasing savings. Private transport companies such as truck fleet operators have a key role to play in promoting eco-driving practices by enrolling drivers in training programs and monitoring their performance.

Eco-driving training could be made compulsory for all new car drivers and offered at a lower cost for current license holders. Freight companies could also provide their drivers with this training and monitor their performance.

STAKEHOLDER ECOSYSTEM AND KEY LEVERS



- ✓ Finance training programs and rewards if any
- ✓ Set standards for the manufacturers in terms of embarked software and for driving schools regarding instructor skills
- ✓ ***Collaborate with all stakeholders to collectively provide incentives to encourage drivers to perform better***

- ✓ Raise awareness among car drivers
- ✓ Monitor driver performance
- ✓ ***Collaborate with ordering institutions and service providers to organize a system of rewards for eco-driving (insurance bonuses, vouchers, etc.)***

- ✓ Integrate embarked eco-driving software into any newly manufactured vehicle
- ✓ Integrate eco-driving training into all driving license training courses
- ✓ Provide information on the reduced CO_2 emissions/ costs to drivers depending on their driving style
- ✓ ***Collaborate with ordering institutions to raise awareness and integrate incentives into the embarked software***

Co-benefits

Environment and well-being

As a result of smoother driving with more even acceleration, eco-driving contributes to reducing congestion, thus improving air quality in urban areas. By providing information on the driving environment and enhancing awareness, eco-driving technologies and training are also likely to improve road safety.

Economic gains for all stakeholders

For public authorities and car manufacturers, the cost of eco-driving programs depends on the resources allocated to the implementation of the programs. The costs may be modest for general marketing and education materials, but will be higher for programs that include dedicated driver training. These costs should however be offset by the environmental and socio-economic benefits resulting from less congestion, fewer car accidents and reduced air pollution.
For car manufacturers, client satisfaction is likely to increase as a result of improved car durability, which is enhanced by smoother driving. In addition, overall additional costs could be progressively transferred to the sale price, and would be compensated for by the fuel savings for drivers.
For car drivers, the cost of eco-driving technologies is initially included in the price of the vehicle and largely offset by the economic benefits resulting from fuel savings. Mobile device applications are available for free or at a modest cost and provide cheap access to eco-driving apps for smartphone users.

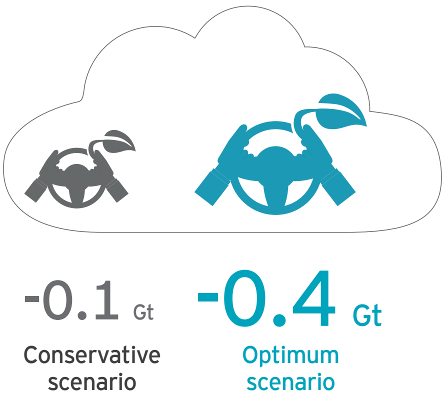
GHG abatement potential contributing to the "beyond 2°C" objective

Eco-driving has been evaluated mostly in Europe, and the results suggest that potential savings increase with the level of delegation and assistance provided by the vehicle:

- With embarked software providing real-time information and allowing drivers to regulate their driving style, savings amount to 6% compared to a standard vehicle without such an information system.
- With the integration of rewards and gaming into eco-driving technologies, it is possible to reduce fuel consumption by up to 15%.
- Finally, eco-driving training and "coach vehicles" could make it possible to reduce fuel consumption by as much as 24%.

For light road passenger transport in OECD member countries, the large-scale deployment of embarked eco-driving software could lead to saving 0.10 $GtCO_2e$ in 2030, and up to 0.39 $GtCO_2e$ if eco-driving training and "coach-vehicles" could lead to saving from 0.1 $GtCO_2e$ (in a conservative scenario) to 0.4 $GtCO_2e$ (in an optimum scenario) by 2030, compared to a business-as-usual scenario. This represents 3% to 11% of the necessary abatement to be in line with the IEA's "beyond 2°C" scenario by 2030.

GHG abatement potential of eco-driving technologies and training programs in OECD member countries for passenger transport
(by 2030, compared to a business-as-usual scenario)



OECD | CHINA | NON-OECD
URBAN | PERIURBAN | RURAL
FREIGHT | **PASSENGER**
ROAD | AIR | MARITIME

CASE STUDY 3

3 PROMOTING SHORT-DISTANCE CAR-POOLING APPLICATIONS AND THE SHARING ECONOMY IN FREIGHT TRANSPORT TO ADDRESS CONGESTION: SHARING TO OPTIMIZE THE USE OF TRANSPORT INFRASTRUCTURE

Sharing as a response to congestion

With the high population growth in urban areas and limited space for transport infrastructure, cities will not be able to continue responding to mobility demand with ever-increasing space for cars, leading to major congestion challenges. In addition, the average use and occupancy rate of vehicles in OECD countries is rather low, leading to inefficient use of the rolling stock of vehicles. Connected private transportation, building on the growth of the sharing economy, has the potential to respond to congestion issues by optimizing the use of the rolling stock of vehicles for both passenger and freight transport.

Connected private transportation: a cost-effective solution towards contributing to the "beyond 2°C" target

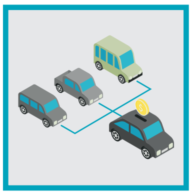
Connected private transportation involves car-sharing, when a fleet of vehicles is shared amongst a large number of users who pay a usage fee instead of owning a vehicle; and car-pooling, when car-owners connect together to use one car for several individuals instead of using several cars for the same amount of people. Sharing can also be applied to freight transportation, by optimizing the use of space in warehouses and truck loads.

These solutions do not require heavy capital investment and build on new behaviors and organizational structures that are already being adopted in the market: sharing is facilitated by the development of smartphone apps, new ICTs and smart use of data, and by wide access to internet, which facilitates connection between individuals and companies. The development of these apps is an opportunity for public policy-makers to limit the stock of rolling vehicles and encourage commuters and freight transporters to prefer a sharing option by providing the right incentives and support for the sharing economy.

Shared transportation makes it possible to:

REDUCE THE NUMBER OF ROLLING VEHICLES AND OPTIMIZE THE CURRENT FLEET

by improving the ratio of users or goods per rolling vehicle;



PROVIDE ALTERNATIVES TO CAR-OWNERSHIP

and promote less systematic use of individual cars in the case of private transportation.

This case study will focus more specifically on car-pooling for private transportation, which combines the benefits of reducing emissions by sharing trips and reducing congestion. Further details are provided on applications of sharing to freight transport.

Examples of successful projects

Car-pooling is rapidly developing for long-distance journeys, with the example of the French application Blablacar, which registers trips averaging 330km. It is however used less for daily commutes and short distances and makes a more limited contribution to reducing congestion in peak hours than short-distance car-pooling. A few examples can however be noted:

- Karos, a car-pooling start-up, specializes in short journeys (an average of 21km), and has developed a partnership with the public transport regulation authority for the Paris area, granting two free trips per day for holders of the Paris transportation pass (Navigo). The start-up is financed by the transport regulation authority for each trip made using the app.
- In Cape Town, South Africa, uGoMyWay connects drivers and passengers to share their daily commutes within the city. The app promotes "liftclubs", which are communities for daily commutes.
- A recent study led by the MIT's Computer Science and Artificial Intelligence Laboratory showed that the 14,000 taxis in New York City could be replaced by only 3,000 passenger cars if the use of the latter was optimized via car-pooling services. Using taxi data, the researchers developed an algorithm to optimize car journeys in real time in order to increase their occupancy rate.

KEY SUCCESS FACTORS

Integrating car-pooling into the local mobility system

A key advantage of car-pooling is that it relies on technologies and networks that are already operational and widespread among the public. The smart use of data and ICTs is a strong driver for optimizing the link between supply and demand, providing commuters with real-time information on shared, less costly, low-carbon alternatives to meet their needs.

To enhance the attractiveness of car-pooling compared to the easiness of using one's private car, technology and infrastructure should offer the opportunity to conveniently combine the shared trip with other transport options. Car-pooling apps should enable users to visualize how to extend a shared route using public transport, in particular in rural areas and urban peripheries where car-pooling alternatives may be less numerous, less direct and less tailored to users' needs. It is also critical to provide the right parking and connection infrastructure so that drivers and passengers can meet at convenient spots and leave their cars in secure parking facilities at no additional cost while they share the main commute.

To maximize the practicality of using car-pooling alternatives, policy-makers and car-pooling service providers can work towards interlinking car-pooling systems with public transportation, both in terms of infrastructure, data management and financial modelling.

Providing the right positive incentives and financing car-pooling as a collective transport service

While the global development of smartphones and ICTs could enable the large-scale adoption of car-pooling practices, cultural behaviors may impede their development in some countries. Short-distance car-pooling still struggles to become a widespread option, mostly because of long-term habits and the convenience of using one's own car. In addition, commuters share the cost of the ride, but usually have to pay a service fee to the car-pooling service provider. This extra cost may be prohibitive and public authorities should work towards making the overall cost of car-pooling very attractive.

Public policy-makers could consider providing financial incentives or advantages (free parking, toll reductions, subsidize car-pooling service fees, etc.) to commuters who use car-pooling. This is an alternative to significant capital investment in infrastructure, resulting in substantial savings for local governments.

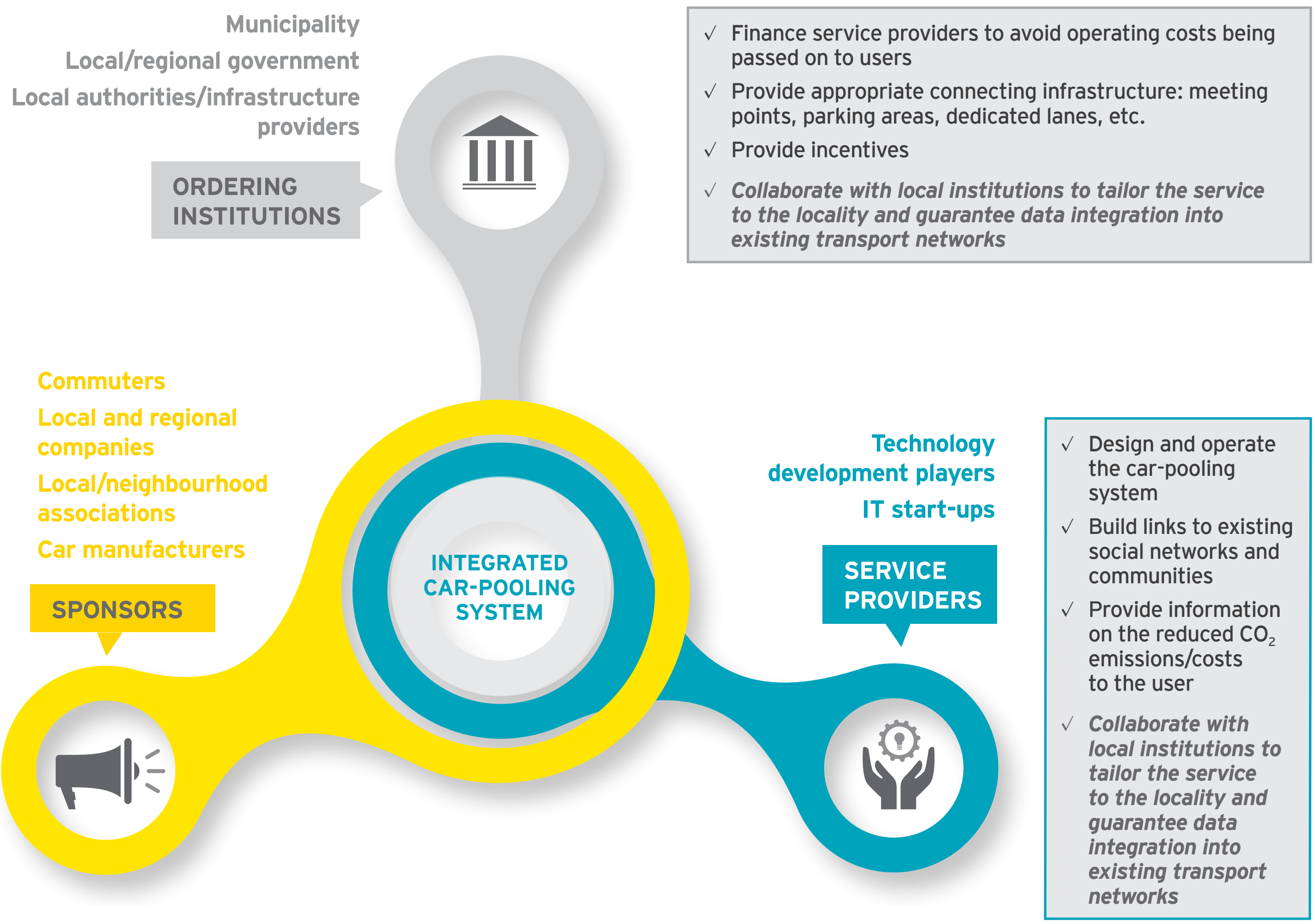
Organizing the car-pooling community

The success of a car-pooling service ultimately depends on how many alternative trips are provided and how easy it is to connect commuters for a given trip. The commitment of major local employers, including the local private sector, will be crucial to organizing the pooling network and providing the right platform to connect commuters. They can also contribute to awareness-raising and offer their employees incentives and flexibility to maximize the uptake of car-pooling.

The local private sector can contribute to supporting the widespread development of car-pooling by organizing a community of car-poolers and providing a platform to connect commuters within a company.

- √ Organize communities with high potential for sharing rides
- √ Raise awareness among peers
- √ ***Collaborate with service providers to build relevant sub-communities***
- √ ***Collaborate with service providers to integrate car-pooling software into vehicle software/control panel (for car manufacturers)***

STAKEHOLDER ECOSYSTEM AND KEY LEVERS



ENCOURAGING SHARED MOBILITY WITH BLABLACAR AND KAROS, BY TOTAL

Mobility is evolving and new practices are emerging. Total commits to finding appropriate solutions to climate issues while taking into account changes in customs and services. Car-pooling is one of the solutions Total supports through two partnerships:

Total has teamed up with Blablacar and offers a fuel card or a Total Wash card for the first trip made by a car-pooler. In 2017, more than 400,000 fuel cards and nearly 50,000 wash cards were distributed.

Total employees were encouraged to use the Karos app as a short-trip solution to facilitate commuting during the summers of 2016 and 2017. Since August 2016, more than 300 employees from the Paris area have registered.*

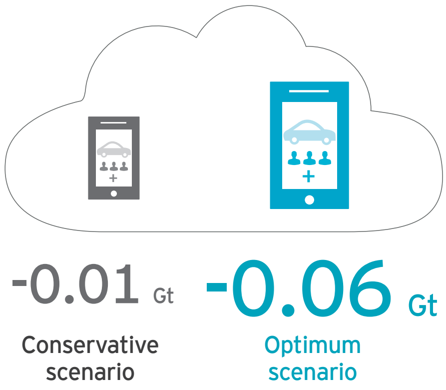
**figure as of February 1st, 2017*

GHG abatement potential contributing to the "beyond 2°C" objective

The level of deployment of car-pooling and the resulting reduction in GHG emissions will be determined by the implementation of these key success factors and may vary depending on local specificities. **The widespread development of short-distance car-pooling in OECD countries could lead to saving from 0.01 GtCO$_2$e (in a conservative scenario) to 0.06 GtCO$_2$e (in an optimum scenario) by 2030, compared to a business-as-usual scenario. This represents up to 3% of current total CO_2 emissions resulting from road passenger transport in OECD countries.**

In freight transport, highly integrated vehicle and depot sharing could lead to a reduction of 20% and is yet to be taken up in the case of at least 85% of commercial vehicle kilometers, according to the WBCSD's Road Freight Lab.

GHG abatement potential of short-distance car-pooling applications in OECD member countries for passenger transport
(by 2030, compared to a business-as-usual scenario)



Co-benefits

Financial savings for individuals

Car-pooling and car-sharing can reduce the costs associated with using a car, as the latter are shared by several users instead of being the responsibility of the car owner alone. In addition, the need to own a vehicle could also decrease, resulting in substantial savings for individuals who would shift from owning a car to sharing with others. According to the GeSI SMARTer2030, connected private transportation, which includes car-pooling, car-sharing and intermodal transport, could translate into $611 billion of avoided costs, including fuel costs.

Community building and social well-being

Car-pooling has the potential to foster social relationships between individuals that would not exist otherwise and could contribute to making the daily commute a more social and enjoyable moment. While commuting can be perceived as an inconvenience, car-pooling has the potential to improve well-being and social links, in particular among individuals of the same community (neighborhood, company, etc.).

NEW BUSINESS MODELS TO INTEGRATE THE SHARING ECONOMY INTO PUBLIC SERVICE OPERATIONS, BY EGIS

The sharing economy and the service economy are not yet sufficiently integrated into urban policies. However, better use of existing infrastructure and the rolling stock of vehicles would result in significant reductions in the overall carbon footprint (including infrastructure construction and lifespan footprint) and deserves the attention of decision-makers.

Egis recommends that metropolitan areas should set up high-level service bus lines by converting and securing the emergency stop lane on urban highways (such as the "freeway Bus Rapid Transit" in Grenoble or in Ile-de-France), together with the construction of Park and Ride facilities in the suburbs. This new lane could be created within a short timeframe, without major investment, and could also be accessible to car-pooling commuters.

Car-pooling for daily commuting is difficult to implement despite the development of smartphone apps. As soon as the passenger and the driver are "paired", they often leave the application that put them in contact with each other in the first place. Start-ups are therefore looking for a model that retains users and secures income. Employers or the public authorities responsible for transportation can subsidize the app service fee, thereby funding the connection between car-poolers for short trips, as an integrated solution to metropolitan transport systems. The French start-up Karos minimizes user input as much as possible by using big data and artificial intelligence to understand each user's travel habits. The app then optimizes the journey without any planning by the users.

RETHINKING LOGISTICS IN THE SHARING ECONOMY, BY DHL

Today, the tremendous scale of digital sharing platforms and crowd-based access to already existing assets is redefining the concept of 'sharing' and reshaping the future of logistics, bringing great financial and productivity benefits.

Sharing could be applied across all parts of the logistics value chain to improve or change logistics operations – as well as create new businesses. For example, according to research, one in four trucks on US and EU roads drives empty or often only half-loaded. Digital platforms provide an instant snapshot of availability and the ability to access spare capacity in almost any truck, including smaller delivery vehicles or even privately owned cars on a day-to-day basis. With its recently launched Saloodo! real-time freight brokerage platform, DHL is already tackling the inefficiencies of unused capacity. Saloodo! uses the global network of smartphone users and real-time communications to reach a greater audience of shippers to take advantage of excess capacity.

This promising opportunity for new business creation does not come without challenges. The pace of technological innovation and social change, which often outpace regulatory frameworks is one of the challenges. On top of that, different parties have a role to play. "Working in an ecosystem with reliable partners across the value chain is a key success factor to ensuring sustainable development in the long run," points out Manoella Wilbaut (Head of Commercial Developments – Sustainability).

ON KEY TECHNOLOGICAL SOLUTIONS

1. Sustainable biofuels: a key component of the "beyond 2°C" roadmap
2. Towards mass adoption of electric mobility
3. Natural gas vehicles, more than a transitional solution, a key player in decarbonizing transport
4. The potential of the hydrogen-based fuel cell electric vehicles: the vehicle of the 21st century?

These globally impactful solutions rely on technologies and infrastructure that require considerable capital investment and that will reach large-scale development in the medium or long term.

The development of the vehicle charging and refueling infrastructure, production cost reductions, purchase incentives, and a safe and accessible supply of low-carbon fuels will be critical to ensuring the large-scale deployment of these solutions. Collective transportation and public vehicle fleets are on a scale that is appropriate for these solutions to start being deployed, so as to prove the business case and thus trigger significant emission reductions in urban areas.

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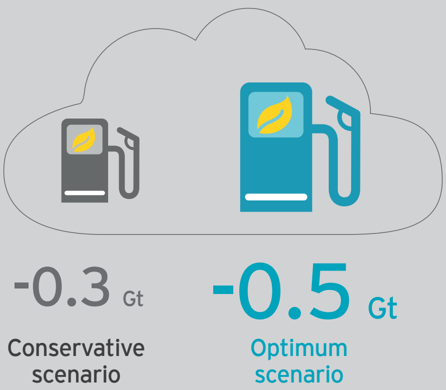
Sustainable biofuels: a key component of the "beyond 2°C" roadmap

How can sustainable biofuels contribute to the "beyond 2°C" scenario?

Biofuels are produced through biological and thermo-chemical processes, such as the fermentation of sugar or esterification of vegetable oils. Their key advantage is that they can be used in low percentage with the current engines and by using the current gasoline infrastructure. They are contributing to reducing the carbon footprint of the current rolling stock. While efforts are being pursued in the development of new forms of biofuels, the production and commercialization of biofuels is already a key contributor to the achievement of the "beyond 2°C scenario". Biofuels already represent 3.5% of the energy used in road transportation worldwide. Their development depends on the mobilization of sustainable feedstock, and should therefore be thought of as complementary to other solutions.

On a global scale, assuming that the current share of biofuels in worldwide fuel production is doubled, the use of biofuels could lead to saving from 0.3 $GtCO_2e$ (in a conservative scenario) to 0.5 $GtCO_2e$ (in an optimum scenario) by 2030, in passenger and freight road transportation.



GHG abatement potential of sustainable biofuels worldwide for freight and passenger transport
(by 2030, compared to a business-as-usual scenario)

- **Current biofuel technologies** include esters derived from vegetable oils, and ethanol derived from sugar and starch crops. The efficient use of arable land and forests to produce food, fiber or biomass will become a critical challenge. According to IRENA, substantial potential exists to expand the supply of both sustainable food and fuel, provided that policies are set up to encourage higher farm yields and sustainable forestry.

- **New biofuel technologies** rely on progress made in biochemical and thermochemical processes. New types of molecules allowing cleaner burning, drop-in fuels that can be blended without blending limits, are already available on the market (e.g. HVO, Hydrogenated Vegetable Oils). Current developments are targeting the use of all types of available biomasses (lignocelluloses, wastes and residues), or using non-arable land (algae), thus complementing the biofuel offer.

Increased interest in new types of biofuels

New biofuel technologies are reaching the market phase, supported by regulations and years of R&D development: for instance, Total plans to open a 500 kT biorefinery in France in 2018, based on the use of a variety of fuels, all lipid-based.

New biofuels are either emerging technologies, or at the research and development (R&D), pilot, demonstration or flagship phase. Projects will need strong support from governments to achieve commercial maturity by 2030 and make their contribution to the "beyond 2°C" scenario.

- BioTfueL, a collaborative project involving six companies (Avril, Axens, the French Commission for Atomic Energy, IFP Energies Nouvelles, Thyssenkrupp and Total) aims to develop a process chain for the production of biodiesel and biokerosene from lignocellulosic biomass (straw and wood from agriculture and forestry).
- The cellulosic ethanol industry is at a critical development stage. Technology development players are taking stock of the lessons learnt during the development of their first flagship plants, and several others are building or planning their first industrial plant. There are currently around seven major technology development entities globally, focusing on commercial cellulosic ethanol production. Examples include the ST1 Cellunolix® ethanol plant in Finland based on sawdust, the Beta Renewables BioCrescentino plant in Italy producing cellulosic ethanol based on agriculture residues (wheat and rice straw), the POET/DSM Project Liberty in the US (Iowa) producing cellulosic ethanol based on corn crop residues and Raizen (a joint venture between Cosan and Shell) in Brazil, which produces cellulosic ethanol from bagasse.

SUSTAINABLE BIOFUELS AS A KEY COMPONENT OF OUR STRATEGY, BY TOTAL

Total's biofuels are one of the key drivers in achieving the reduction of CO_2 emissions from fuels. Biofuels are produced from biomass that has absorbed CO_2 during its growth. The European Commission requires that the share of renewable energy in the transportation sector will be 10% by 2020. In this context, Total is launching the first French bio-refinery for the global market in La Mède. With a production start announced for 2018, Total evaluates its production at 500 kt / year of HVO (hydrogenated vegetable oils)

THE IMPORTANCE OF COLLECTIVE ACTION TO GROW THE GLOBAL MARKETS FOR LOW CARBON FUELS: THE BELOW50 INITIATIVE, BY NOVOZYMES

Below50 is a global collaboration that brings together the entire value-chain for sustainable liquid fuels – that is, fuels that produce at least 50% less CO_2 emissions than conventional fossil fuels. Below50 is creating global campaign for local action, taking a global strategy and implementing solutions at a local level. The aim is to create demand for these fuels and scale up their deployment by:

- Increasing the number of companies choosing below50 fuels
- Creating inter-sectoral B2B opportunities across supply chains from consumer-facing businesses with fleets of vehicles and planes to fuel suppliers
- Demonstrating that below50 fuels makes good economic, social and environmental sense
- Addressing legislative and financial barriers to sourcing below50 fuels

www.below50.org

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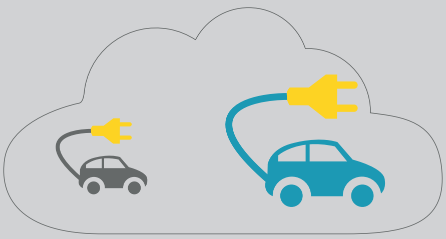
Towards mass adoption of electric mobility

The business case for battery electric vehicles is increasingly attractive...

Electric vehicles are particularly relevant to reducing the environmental externalities of the mobility sector as they emit almost no CO_2 (tank-to-wheel) and few atmospheric pollutants and are almost silent. In OECD countries, battery electric vehicles (BEVs) are starting to take off in the market, boosted by owners and operators of captive vehicle fleets for car-sharing services and in the freight industry. Cities are suffering more and more from atmospheric pollution and a number of regulations have been enacted to progressively ban the most polluting vehicles from city centers. BEVs will become increasingly popular in this context, all the more so as their cost will become progressively more competitive. According to a recent study by the French Commission for Sustainable Development (Commissariat Général au Développement Durable, CGDD), BEVs will be economically competitive by 2020 in dense urban areas. They remain relevant primarily in urban areas, given their battery range and the need for the appropriate charging infrastructure for longer distances. When purchase, maintenance and usage costs are factored in, BEVs would be approximately €700 less expensive for the user over their whole usage cycle than thermal engines by 2020. Between 2020 and 2030, this economic gain could increase to €5,000.

In addition, the potential for developing energy services based on energy storage and redistribution to the grid will enhance the business case for BEVs. Such services could contribute to the further integration of renewable energies into the energy mix, making it possible to compensate for the intermittency of renewable energies and enhance the stability of the network through storage and redistribution via vehicle-to-grid technologies.



-0.1 Gt
Conservative scenario

-0.2 Gt
Optimum scenario

GHG abatement potential of battery electric vehicles in OECD member countries and China for passenger transport
(by 2030, compared to a business-as-usual scenario)

... but support on infrastructure developments is still required to achieve mass adoption

Several technical improvements will further enhance the attractiveness of BEVs, notably the improvement of battery performance and battery life cycle, charging infrastructure and charging time. While decision-makers support the roll-out of BEVs and their adoption by consumers, significant efforts must be made to allow BEVs to reach large-scale development. For example, in 2015, the French government passed the law for energy transition (Loi de Transition Energétique) aiming to deploy seven million BEV charging stations by 2030, but only 13,000 have been installed to date. The development of the vehicle charging infrastructure will be critical to facilitating the use of BEVs and progressively enabling the shift from thermal engines to BEVs, while maintaining the same quality of service.

In terms of economic competitiveness, the CGDD study showed that thermal vehicles remain the most competitive in non-urban areas and for long distances, with BEVs being largely used as a secondary vehicle for short urban trips. As the battery (lithium-ion technology) represents 30% of the BEV retail price, lower battery prices will be an important driver of mass-market adoption. A technological breakthrough is expected to bring the costs down (to $200/kWh by 2020 and $150/kWh by 2025). The expected take-off of the electric vehicles markets over the next decade will increase demand on some specific materials related to batteries. Specific actions are therefore needed: active cooperation with suppliers, investment in R&D to adapt the chemical roadmap to limit the need for critical materials, support to recycling and close loop process to remain owner of the raw materials, etc.

The expected decarbonization of the global energy mix will be supportive of mass adoption.

Electricity supply must be low carbon for BEVs to achieve their potential in reducing GHG emission levels. The IEA showed that given the current energy mix of electricity production in China, hybrid vehicles would be less GHG-intensive over their whole lifecycle than BEVs.
The electricity production mix is therefore an indicator of the relevance of BEVs in a given region. In France, where the electricity generation mix is dominated by nuclear energy (75%), and in Sweden, where it is dominated by renewable energies (60%), electric mobility is particularly relevant, with respectively 9.72 and 3.48 gCO_2e/km (well-to-wheel). In Germany, fossil fuels dominate the electricity mix (66%), leading to significantly higher well-to-wheel emissions (68.24 gCO_2e/km).

Combined with smart management of the electricity load the development of storage capacities, and optimal management of energy consumption (efficiency and sobriety), electromobility could significantly support the energy transition, the development of renewable energies and a progressive phase out of fossil fuels energy. This is a major field for collective thinking, dialogue and collaboration between stakeholders across the value chain.

A recent study conducted by the Fondation pour la Nature et l'Homme (FNH) and the European Climate Foundation highlights two co-benefits related to BEVs:

- Vehicle-to-grid, allowing BEVs to become a flexible supporting device for the network while being parked;
- Second-life for EV Batteries, ie. the reuse of batteries as storage units.

Public authorities therefore need to consider electric mobility and the decarbonization of power generation simultaneously, to ensure that the massive scale-up of BEVs truly contributes to the GHG mitigation objective. The FNH study shows that BEV's global warming potential over their whole life cycle could be 2 to 3 times lower than that of thermal vehicles in 2030 (from 19.6 tCO_2e for an internal combustion engine LDV to 8.1 tCO_2e for an electric LDV in France) if French public authorities meet their objective of 32% of renewable energy in the energy mix by 2030.

Assuming an average worldwide emission factor of 67 gCO_2e /km for a small city battery electric car and a penetration rate of 7% to 12% of the vehicle stock in the OECD and China by 2030, the CO_2 emission abatement potential could reach 0.1 Gt (in a conservative scenario) to 0.2 Gt (in an optimum scenario), or 3% to 5% of the necessary abatement to be in line with the IEA's "beyond 2°C" scenario by 2030. The deployment of BEVs would also significantly contribute to improving air quality and reducing noise pollution.

THE HUGE POTENTIAL OF ELECTRIC VEHICLES FOR URBAN DELIVERY, BY DHL

Deutsche Post DHL Group continues to focus consistently on electro-mobility and its self-developed StreetScooter electric van. "The new StreetScooter WORK XL is the perfect vehicle for parcel deliveries in major cities and large urban areas, and will enable us to cope with the rising parcel volumes in an even more environmentally friendly and quiet manner." Says Jürgen Gerdes, Member of the Board of Management Post Parcel at DHL Group. Each WORK XL could save around five tonnes of CO_2 and 1,900 litres of diesel each year. With 2,300 vehicles in service as planned, this could result in a total saving of 11,500 tonnes of CO_2 and 4.4 million liters of fuel each year. The company is now also selling its own electric vehicles to third parties. Deutsche Post DHL Group sees municipal authorities, strategic partners and large fleet customers in Germany and the rest of Europe in particular as potential buyers to start with.

RENAULT ENERGY SERVICES : KEY TO REINFORCING RENAULT'S LEAD IN THE EUROPEAN ELECTRIC VEHICLE MARKET AND ACCELERATING THE EV INDUSTRY'S SCALE-UP, BY GROUPE RENAULT

Groupe Renault, Europe's number one manufacturer of electric vehicles*, created Renault Energy Services. The aim of this new subsidiary is to have an active presence in the energy and smart grid sectors, which are both critical to the expansion of electric mobility.

Renault Energy Services will focus on the development of smart charging, vehicle-to-grid interaction and second-life batteries. Connected to smart grids, Renault electric vehicles will benefit from more economical and low-carbon electricity. In addition to supporting the development of smart charging, smart grids favour both interaction between electric vehicles and electricity networks (vehicle to grid) and projects involving second-life batteries:

** Groupe Renault sold more than 29,000 electric vehicles worldwide in 2016 (96% of these sales were in Europe).*

OECD | **CHINA** | NON-OECD
URBAN | PERIURBAN | RURAL
FREIGHT | PASSENGER
ROAD | AIR | **MARITIME**

Natural gas vehicles (NGVs), more than a transitional solution, a key player in decarbonizing transport

Natural gas and biomethane can achieve significant CO_2 emission reductions

-0.02 Gt
Conservative scenario

-0.06 Gt
Optimum scenario

GHG abatement potential of natural gas vehicles in China for freight and passenger transport
(by 2030, compared to a business-as-usual scenario)

Low-carbon fuels are an important part of the effort to decarbonize the transport sector. Many technologies are being investigated to shift from conventional fuels to alternative low-carbon fuels: fuel-cell electric vehicles, vehicle-to-grid, traction batteries, etc. While many of these technologies are still emergent or in their growth stages, it is necessary to start transitioning from conventional fuels, using fuels that are less intensive in terms of CO_2 emissions and for which the business model is already mature.

Natural gas vehicles (NGVs) use compressed natural gas (CNG) or liquefied natural gas (LNG) as a cleaner alternative to conventional fuels. These vehicles are even cleaner when they use low-carbon gas such as gas mixed with biomethane. NGVs offer a high level of CO_2 abatement potential, with light engine adaptation and almost no change in transport uses: their autonomy is similar to vehicles using conventional fuel. NGVs are particularly relevant as medium and heavy duty vehicles for the transport of goods and passengers using captive fleets: buses, trucks, utility vehicles, etc.

As passenger cars, NGVs generate 23% less CO_2 emissions than petrol vehicles and 7% less than diesel; the reduction is from 80% to 95% if biomethane is used. With 20% of its heavy duty freight vehicles being NGV, China could save up to 0.042 $GtCO_2e$ in freight transportation, i.e. 4.6% of the total CO_2 emissions in Asian freight road transport. With 5% of its light duty passenger vehicles, China could save up to 0.016 $GtCO_2e$ in passenger transport, i.e. 2% of the total CO_2 emissions in Asian passenger road transport.

The NGV market is experiencing sharp growth in markets with strong support from public authorities

Public authorities can play an important role in supporting the development of NGVs. Over the last decade, China, Iran, India and Pakistan have actively promoted NGVs thanks to incentives such as consumption or import tax exemptions, purchase incentives for buyers, easier access to city centers, etc. By the end of 2016, there were more than 24 million NGVs on the roads worldwide, with more than two thirds of the stock in these four countries, including more than 25% in China. In the first months of 2017, sales of natural gas heavy duty vehicles increased by 540% in China, driven by the ban on the use of diesel for trucks over 40 tons to transport coal in the northern provinces and Tianjin. Thanks to the government's incentives, the number of refueling stations is in line with the growing number of NGVs: China accounts for 90% of LNG refueling stations worldwide (2,300 stations).

However, the availability of refueling stations is still curbing the scale-up of NGVs in other markets and costs of NGV motorization will continue to be prohibitive with regard to democratization of NGVs, unless strong fiscal incentives are implemented by public authorities. The retail price of an NGV is $4,000 to $8,000 higher than a comparable petrol vehicle.

Decision-makers worldwide must provide sufficient fiscal incentives and implement regulations to foster the large-scale development of NGVs, especially for freight transport. They should also guarantee a steady supply of natural gas and promote the development of renewable-based sources. In its Horizon 2020 "Smart, green and integrated transport" R&D program, the European Union aims to foster investments in natural gas, as an innovative solution to be scaled up to replace diesel for heavy duty vehicles.

NATURAL GAS: ONE OF THE ALTERNATIVE ENERGIES FOR PASSENGERS AND FREIGHT ROAD TRANSPORT AS PART OF OUR COMMITMENT TO A SUSTAINABLE ENERGY MIX, BY TOTAL

Acting for sustainable mobility also means that Total offers its customers alternatives to conventional fuels. Natural gas is a credible, viable and available solution, in particular for trucks and commercial vehicles. From a health standpoint, the levels of atmospheric pollutants (such as NOx and fine particulate matter) emitted by NGVs are lower than the Euro VI regulatory limits, with no additional cost linked to the installation of depollution systems. Another major advantage is that noise pollution from NGVs is two times lower than noise pollution caused by equivalent gasoline-powered vehicles.

Under current tax and energy price conditions (in France for example) the Total Cost of Ownership (TCO) for a NGV can be lower than that of an equivalent diesel-powered vehicle, for an annual mileage over 50,000 miles (80,000 kilometers), and despite a purchase price that is up to 30% higher.

This fuel is now available at more than 450 Total NGV stations in Asia, Africa and Europe. The Group's objective is to develop a network of more than 700 stations worldwide as early as 2022, including 350 sites operated in Europe, and to become the NGV distribution leader in Europe.

THE NEED TO DEVELOP THE NGV CHARGING INFRASTRUCTURE IN THE NETWORK, BY GEODIS

GEODIS was one of the first groups to adopt natural gas vehicles. As a result of the significant technological progress made over the past few years, NGVs are very well suited technically to freight transportation. From an economic standpoint, NGVs are more costly in terms of capital investment than conventional thermal trucks, but natural gas is cheaper than gasoline and the NGV truck total cost of ownership (TCO) is lower than the TCO of diesel trucks for high annual mileage. In addition, NGVs are more efficient than diesel trucks over long distances, which further supports the business case for them. However, the charging infrastructure is still underdeveloped on the road network, limiting the number of trips that can be covered by NGVs, despite the efforts made by the European Commission with the Blue Corridor project. There is a need for decision-makers to further support the development of the infrastructure on the road network to enable the extensive uptake of NGCs in freight transport fleets. Negative incentives and regulatory constraints on diesel will further foster the use of NGVs, in particular in urban areas.

TOWARDS LOW EMISSION LOGISTICS WITH NATURAL GAS AND BIO-NATURAL GAS AS CLEAN FUELS, BY ENGIE

At ENGIE, we are making it possible for transport companies in France to run on these cleaner fuels through our existing network of 140 fueling stations and 20 new fueling stations to be opened by the end of 2018. One of our customers – Carrefour, a major French retail company – is committing further by fostering the circular economy and setting up a low-emission sustainable transport system. The idea is to use biodegradable waste to fuel the trucks that deliver goods to its stores around the country. The waste, some of which is taken from its own stores, is transformed into bio-methane gas – a form of biogas-and subsequently used to power a fleet of nearly 500 trucks in France.

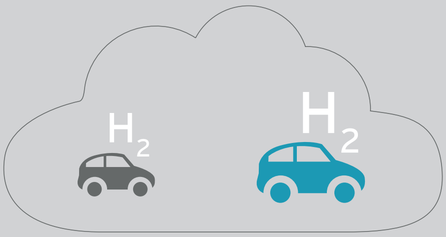
This bio-NGV fuel is therefore derived from biodegradable waste, making it a model of low-consumption and efficiency. From formation right through to consumption, the process recycles waste, the fuel emits very few fine particles and NOx-thereby reducing CO_2 emissions by 95%, plus the trucks involved make half the noise of those with diesel engines. We opened our first fueling station fueled with Bio-NGV at La Courneuve in the Paris area near a number of major motorways. Open 24/7, it provides not only fuels for all types of Bio-NGV vehicles but can also supply refrigerated trucks with liquid nitrogen, a greener alternative to using diesel for generating the cold necessary for cold storage. 100 metric tons of CO_2 can be saved by every refrigerated truck per year thanks to the use of liquid nitrogen.

At ENGIE, we are setting up innovative and clean solutions to help our customers contribute to reducing their GHG emissions and improving the air quality of our cities and regions.

OECD | CHINA | NON-OECD
URBAN | PERIURBAN | RURAL
FREIGHT | PASSENGER
ROAD | AIR | MARITIME

The potential of the hydrogen-based fuel cell electric vehicles (FCEV): the vehicle of the 21st century?

The need to find an alternative to thermal engines



-0.008 Gt
Conservative scenario

-0.04 Gt
Optimum scenario

GHG abatement potential of hydrogen-based fuel cell electric vehicles in OECD member countries and China for passenger transport
(by 2030, compared to a business-as-usual scenario)

Several countries in Europe, as well as India and China (the world's biggest vehicle market), recently announced their intention to ban the production and sale of petrol and diesel cars in the coming decades. This is an incentive for car manufacturers to develop new clean-energy vehicles that can provide a service equivalent to thermal engines while emitting less or no CO_2 and fewer or no pollutants. Battery electric vehicles are technologically mature but are still struggling to reach large-scale commercialization, due to higher purchase costs and use constraints such as charging time and battery range. They are however expected to become financially competitive in urban areas by 2020, due to very low maintenance and usage costs and the decrease in battery prices. For long distances, there is a need to develop alternative solutions to thermal and diesel cars that are economically unchallenged. Beyond road transport, it is also necessary to develop alternative fuels that will allow air and maritime transport to reduce their carbon footprint.

FCEVs could contribute up to 6% of the necessary reductions in transport-related carbon emissions in the "beyond 2°C" scenario...

Fuel-cell electric vehicles (FCEVs) store clean hydrogen in a tank, which is used as a fuel to produce electricity within the fuel cell and power an electric engine. FCEVs offer advantages in use comparable to thermal engines both in terms of driving range and refill time, as well as promising perspectives in terms of global GHG emissions abatement provided they reach large-scale commercialization. If all political commitments made to date are respected, the stock of rolling FCEVs could reach nearly 8 million, or nearly 0.5% of the rolling stock by 2030 and represent up to 25% of the rolling stock of private vehicles by 2050 (according to the IEA's projections), assuming sales ramp up quickly. **By 2030, the active deployment of FCEVs in the OECD and China could contribute to saving from 0.008 $GtCO_2e$ (in a conservative scenario) to 0.04 $GtCO_2e$ (in an optimum scenario) by 2030, compared to a business-as-usual scenario. This deployment would also significantly contribute to reducing air and noise pollution in urban centers and also contribute to improving air quality and reducing noise pollution.**

... but the FCEV market faces many uncertainties that could be addressed by public authorities

Hydrogen and fuel-cell technologies used in FCEVs are technologically mature but today their use is limited to niche markets and demonstration projects due to high production costs and an underdeveloped charging infrastructure. Production costs and purchase prices are still too high to make FCEVs attractive for mass markets: the current price of a low duty vehicle is around $60,000, and up to $1 million for buses.

Around 4,000 FCEVs – with more than 70% in Japan-and 150 H_2 buses have been sold worldwide as of 2017. FCEVs currently represent less than 0.001% of the global vehicle stock, but the market could grow rapidly, if driven by political incentives and economies of scale on production costs.

The price of hydrogen is not stabilized, mainly because the transport and distribution infrastructure has yet to be developed, which will require considerable upfront capital investment from both public and private investors. In addition, the long-term development of the FCEV market depends on the availability of low-cost excess electricity produced from renewable energy, or the development of carbon capture, usage and storage technologies coupled with conventional hydrogen production processes.

Public authorities can play an important role in developing captive fleets (public buses, car-sharing, etc.) to test and prove the business case for hydrogen. This will constitute a first step towards the development of the supporting infrastructure. Most importantly, support for the integration of renewable energy into electricity grids should be a priority for the development of FCEVs. The large-scale development of hydrogen mobility should be conditioned by the availability of electricity from renewable sources to produce "green hydrogen" via electrolysis. The use of conventional hydrogen should be conditioned by the availability of carbon capture utilization and storage technologies in the supply chain.

The need to support cross-sectoral synergies in the development of hydrogen mobility

Hydrogen is also a relevant alternative energy source for air and maritime transport and stakeholders across all sectors are investigating opportunities to use hydrogen as an alternative fuel. The deployment of a large-scale hydrogen refueling infrastructure should therefore integrate these transport modes, take into account the specific needs of air and maritime mobility and explore synergies across all transport modes. As an example the regional government of the Occitanie region in France is developing the HYPORT project, aiming to develop a region-wide hydrogen infrastructure, which would integrate urban and rural mobility systems, as well as airports and seaports within the region.

H_2 APPLICATIONS IN THE AVIATION INDUSTRY, BY DASSAULT AVIATION

The air transport community has always sought technological progress that will optimize both the economic, operational performance of aircraft, and its environmental footprint. Today, the aeronautics community is looking for new breakthroughs to face the challenge of sustainable growth in the aviation sector and the growing desire for flexible, efficient transportation with little or no impact to the environment.

Scientists and engineers are already working on new, innovative technologies for the future generations of aircraft. Some very major initiatives (like Clean Sky in Europe and Cleen in the U.S.) are joining the aeronautics research forces to prepare the next generation of aircraft. In the context of a continuous increase in the demand for power on board aircraft and growing regulatory pressure to reduce polluting emissions from aeronautical activities, the More Electric Aircraft (MEA) is one of the potential technological routes towards tomorrow's aircraft.

The inherent characteristics of fuel cells make them uniquely suitable for addressing the environmental, societal and economical concerns associated with the generation of conventional fossil fuel-based electric power. Fuel-cell systems can thus play an important role in the development of the MEA concept, as unique solutions for highly efficient on-board power generation.

Several applications for fuel cells on aircraft have been identified. They could power basic functions (such as cabin and hotel loads, power sources for medical equipment/systems or for galleys), or essential functions on-board (such as emergency power or replacement of the Auxiliary Power Unit - APU) and even full aircraft propulsion in general aviation. Besides commercial air transport and general aviation, electrical unmanned aerial vehicles (UAV) have also shown interest for fuel cells as a key means to offering an improved endurance and range mission capability.

In addition, airports have been identified as relevant locations to deploy a hydrogen infrastructure, by allowing the co-existence of captive fleets of vehicles moving on the tarmac and on-board aircraft use.

OUR AMBITION TO BECOME A LEADING SUPPLIER OF FUEL CELL TECHNOLOGY, BY FAURECIA

By 2035, Faurecia estimates that 5 million vehicles equipped with fuel cell technology could be in production.

Patrick Koller, CEO of Faurecia: "Faurecia has the ambition to become a leading supplier of fuel cell technology. We believe in this new energy vehicle alternative which has increased autonomy and rapid refueling time. In addition, hydrogen can be produced locally using sustainable technology."

In 2017, Faurecia has successively sealed strategic partnerships with STELIA Aerospace Composites to develop high pressure Hydrogen Tank and with the CEA to collaborate in a research and development program of fuel cell stack technologies. The partnerships complements the investment that Faurecia recently made in Ad-Venta, a specialist in pressure valves for efficient and safe hydrogen storage.

TOWARDS ZERO EMISSIONS TRANSPORT WITH H_2 AS A CLEAN FUEL, BY ENGIE

At ENGIE, we are setting up innovative, clean solutions to help our customers contribute to reducing their GHG emissions and improving the air quality of our cities and regions. As collective passenger transportation contributes to GHG and pollutant emissions, public transport companies are willing to operate with greener - and possibly 'carbon neutral' – fuels such as biogas and hydrogen. According to the Hydrogen Council, "hydrogen is a central pillar of the energy transformation required to limit global warming to two degrees. To achieve the 2°C scenario, the world will need to make dramatic changes year after year and decrease energy-related CO_2 emissions by 60% until 2050". In the transportation sector, hydrogen-powered fuel-cell electric vehicles (FCEVs) will complement battery electric vehicles (BEVs) for the profound decarbonization of the sector.

At ENGIE, we are thus making it possible for transport operators in France to run on these cleaner fuels, and are innovating with the use of hydrogen for mobility. One of our customers – SMTU-PPP (Syndicat Mixte des Transports Urbains Pau Porte des Pyrénées) – is committing further by fostering the development of local renewable energy sources and setting up a sustainable zero emissions transport system. Powered by hydrogen from renewable sources, eight buses for rapid transit will be running in the Pau city center within the next two years, as part of a project where we are partnering with SMTU-PPP, Van Hool and ITM Power. Features of these hydrogen buses will include a driving range of more than three hundred kilometers and fast charging in less than 10 minutes, placing them at the highest level of operational availability and productivity for a bus operator. In addition, the BRT lines are characterized by increased attention to comfort, passenger safety and information, and a dedicated bus lane.

We will be in charge of the construction and operation of the hydrogen refueling station for these buses. Hydrogen will be produced on site by an electrolyzer from ITM Power, with electricity being produced locally from a renewable energy source. This will therefore ensure a carbon-free energy supply for propulsion.

HYDROGEN, A KEY TECHNOLOGY FOR CARBON-FREE TRANSPORT, BY MICHELIN

Hydrogen ticks all the boxes in terms of Michelin's vision of sustainable mobility: it eliminates emissions of CO_2, improves air quality and promotes energy transition, whilst adapting to every type of usage. Michelin has set ambitious objectives with the aim of becoming a global leader in sustainable mobility, and constantly innovates in its products and services to boost mobility today and invent the mobility of tomorrow. It is because of these characteristics that we have been working on this energy source for over 15 years. Moreover, we work with Symbio FCell, an innovative French SMB that created the first hydrogen range extender and of which Michelin has been a shareholder since 2014.

MARITIME TRANSPORTATION: ZERO EMISSION SOLUTIONS ARE BEING INTRODUCED, BY MICHELIN

While emission regulations have been in force in road transport for more than two decades, heavy fuel oil and high sulphur diesel are still largely used in maritime transport. In cities with major harbors, maritime transport currently contributes significantly to air pollution. A first generation of pure battery electric ships has been introduced in recent years. However, such ships have a limited range, long charging times and require a high-capacity grid connection. In that respect hydrogen and FC technology are promising options.

The port of La Rochelle has been a pioneer in France in promoting sustainable mobility, not only in terrestrial transport. As a major port, hosting world-class maritime events, La Rochelle decided to be a role model in zero emission maritime applications. The city started with electric battery boats, known as the "sea bus". The boats are used as passenger shuttles in the harbor area. YELO H_2 makes it possible to add a hydrogen fuel-cell range extender to an existing sea bus. YELO H_2, which went into service in October 2017, is the first French experimentation of a hydrogen sea bus in a marine environment.

Michelin has provided the global hydrogen solution, fuel-cell and hydrogen high pressure storage. A hydrogen refilling station, supplied by HP systems, is installed on the harbor site. The goal is to demonstrate the capacity of fuel-cell solutions to increase the range of an electric boat and therefore its operational efficiency, significantly decrease the recharging time (compared to a battery operated boat) and improve the availability of the boat.

DELIVERY IN URBAN AREAS: ZERO EMISSIONS MADE POSSIBLE FOR ALL PROFESSIONALS, BY SYMBIO

Low and ultra-low emission zones, labels such as the Crit'air in Paris, new taxes, etc., in a context where more and more cities are tackling air pollution and carbon emissions, a dedicated solution is required for certain categories of drivers: those working for delivery companies or urban services, for instance, who do at least 100 km a day and are always chasing after time. For those professionals, even if "zero emissions" is the trigger to complying with ongoing local regulations and potential additional constraints, battery electric vehicles are not adapted to their needs: their range is too low, their charging time too slow (from 20 minutes to 8 hours), and they are adversely impacted by cold and hot weather. Symbio, a 50-person company with Michelin and ENGIE among its shareholders, has developed a dedicated solution for these users: Symbio integrates a fuel-cell range extender into electric battery vehicles, thus doubling the number of kilometers they can do and enabling them to "refuel" with hydrogen in three minutes ... without doubling the price (the total cost of ownership is similar to that of hybrid versions). There are currently more than 200 vehicles equipped by Symbio – mostly the Renault Kangoo ZE H_2 for now –on European roads. They belong to companies such as DHL, CETUP, La Poste, ENGIE Cofely, etc., and to local authorities.

OUR COMMITMENT TO INTENSIFY INVESTMENT IN THE DEVELOPMENT AND COMMERCIALIZATION OF HYDROGEN, BY TOTAL

Total is involved in the development of alternative energies and has been investing in Research & Development in hydrogen mobility pilot projects for nearly 15 years. Total aims to identify the best technologies for producing green hydrogen, reducing production costs, and identifying different means of transport, storage and distribution of hydrogen.

For the past two years, Total has been part of the "H_2 Mobility" joint venture with five other partners. The objective of this JV is to develop the hydrogen distribution infrastructure in Germany so as to provide nationwide coverage, with 100 stations by early 2019 and 400 at the end of the project.

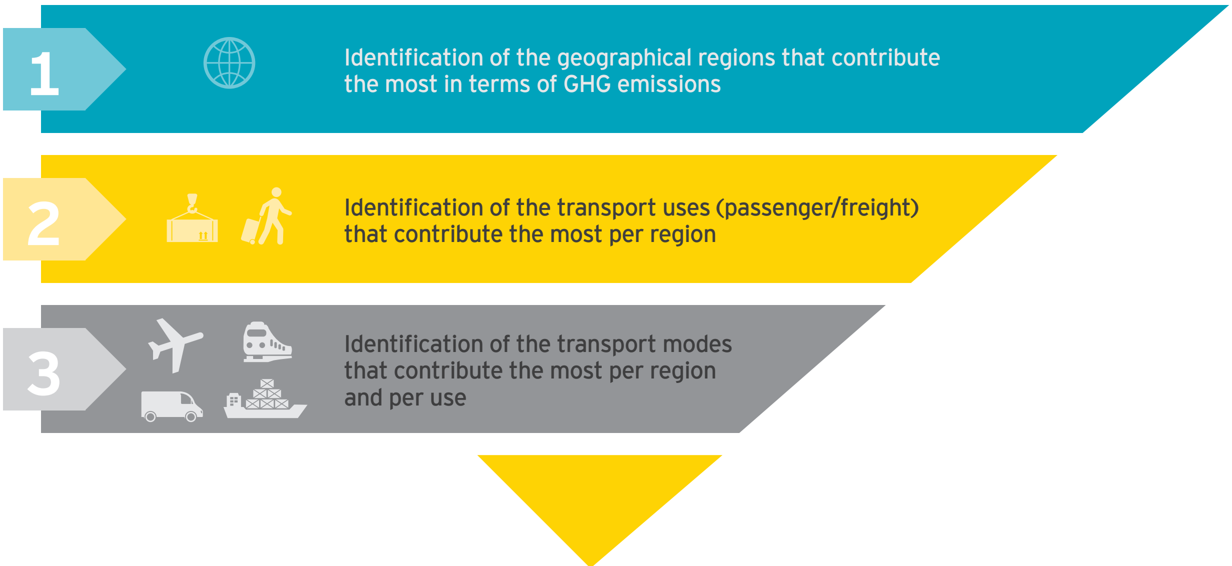
Hydrogen is promising as a key solution to accelerating the energy transition. With this in mind, Total, along with 12 other players in the energy, transportation and industry sectors, launched the Hydrogen Council, in parallel to the Davos World Economic Forum in January 2017. The Hydrogen Council is a first-of-its-kind global initiative, whose members have stated their decision to intensify their investment in the development and commercialization of hydrogen and fuel cells to limit global warming to 2°C, in compliance with the goal set by the Paris Climate Agreement in 2015.

METHODOLOGY

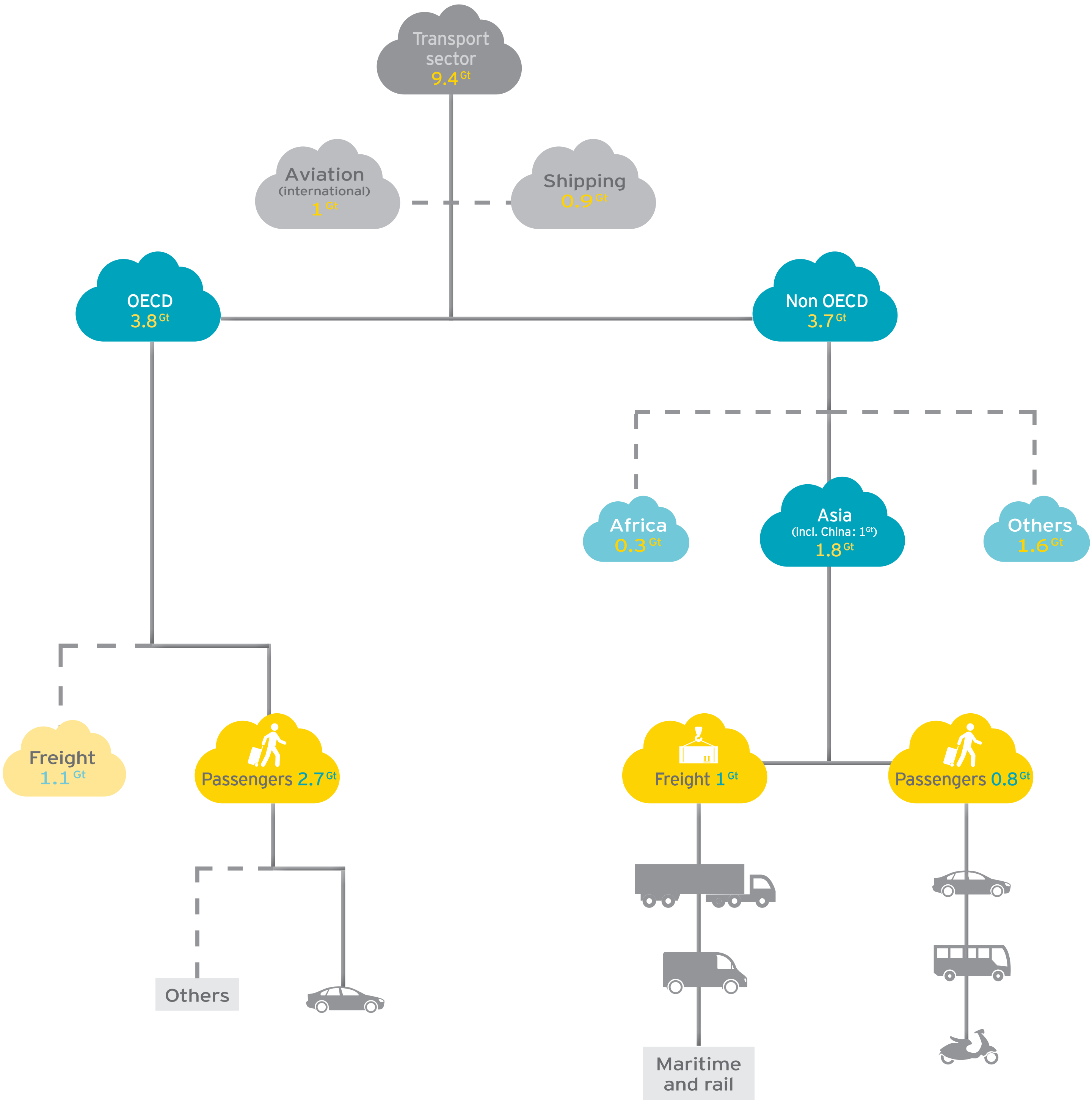
The methodology for the study was established based on the community's objectives and a consensus with its participants. The working group established a research approach to identify solutions that could contribute to the "beyond 2°C" scenario in the next decade.

IDENTIFYING THE MAJOR GLOBAL MOBILITY CHALLENGES IN TERMS OF CO_2 FOOTPRINT.

In order to identify relevant solutions for the short term, the community started by defining mobility stakes worldwide, based on the CO_2 footprint of mobility flows by region, use and transport mode.
This top-down approach was based on a thorough review of the literature, challenged and validated by the community participants.



- **Selection of the primary segments by region, use and transport mode**
- **The mobility solutions identified lined up with the primary segments selected**



Source:
EY from International Transport Forum 2017, International Transport Outlook and IEA (International Energy Agency), 2017, Energy Technology Perspectives 2017

INVENTORY AND MAPPING OF CLEAN MOBILITY SOLUTIONS

Along with the identification of major global mobility challenges, an exhaustive database on clean mobility solutions was established, based on a review of the literature and a series of interviews with experts throughout the community.

Over 20 solutions are listed in this database and classified depending on their contribution to clean mobility: demand reduction and modal shift, vehicle efficiency and low-carbon fuels. Each solution was evaluated based on three main criteria subject to the same weighting:

1. The GHG emission reduction potential of the solution directly expressed as a quantity of avoided GHG emissions (Gt) or as a percentage of reduction in comparison to the emissions of a conventional vehicle or a current transport situation.
2. The degree of technological and economic maturity of the solution categorized as emergent, growth or mature technology.
3. The barriers identified that still need to be overcome to enable the deployment of the solution on an impactful scale.

These criteria were used to select an initial pool of solutions based on their level of maturity and GHG emission abatement potential. The feasibility of the solutions selected in each region of interest in the next decade was then assessed, resulting in the selection of the solutions that are presented in this report that are deemed particularly relevant to tackling the main challenges identified. The large-scale deployment of these solutions seems realistic but needs active support from various stakeholders to achieve the necessary impact.

The community intentionally did not focus on the following solutions:

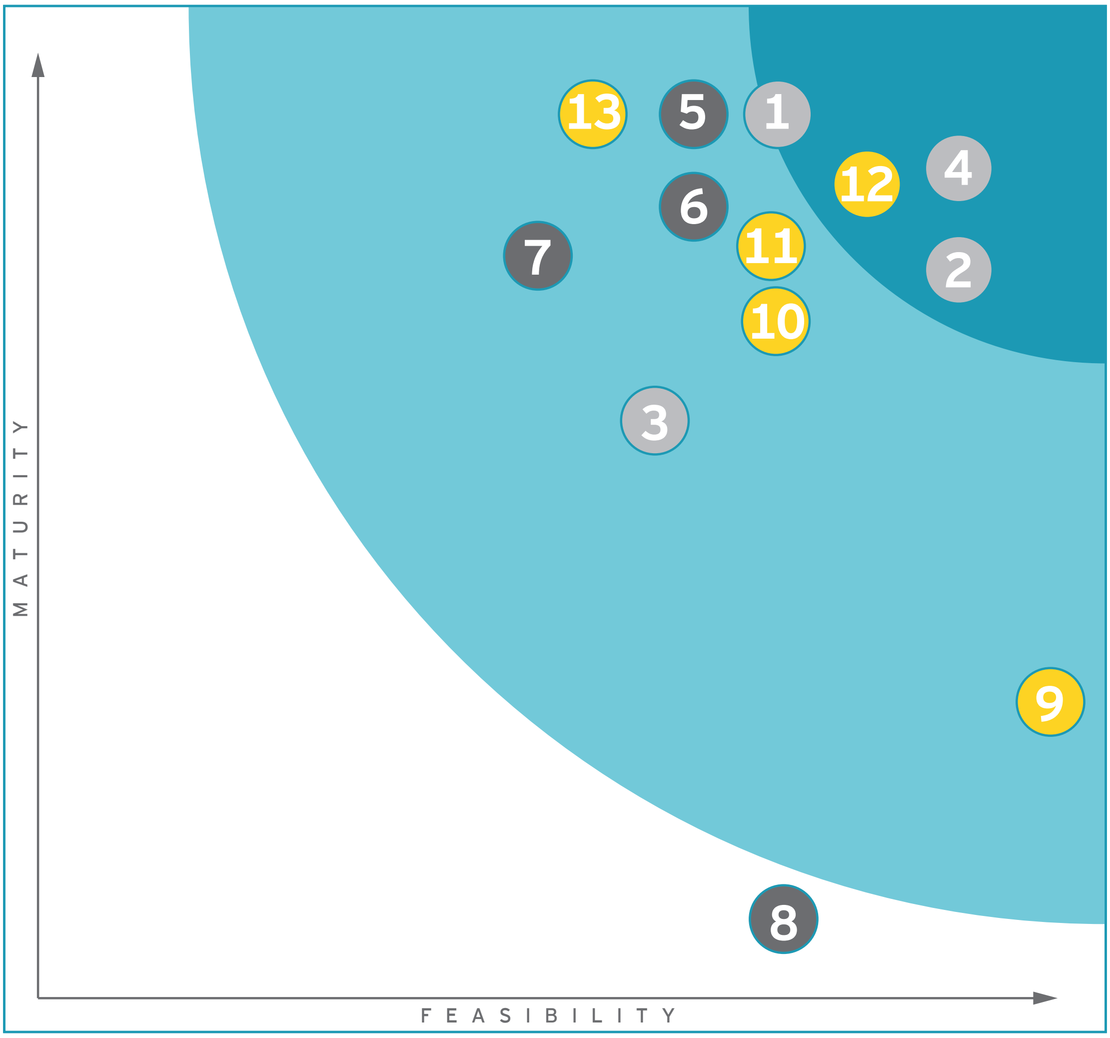
- Solutions considered as "naturally" acquired by the market are not part of the detailed study. For instance, the technical improvements in vehicle efficiency in OECD country markets are already systematically implemented by car manufacturers because of regulatory standards and market expectations.
- Solutions with a high potential for GHG emission mitigation but a low level of mass-market deployment by 2025, such as autonomous vehicles.

DETAILED CASE STUDIES AND FOCUS STUDIES ON KEY TECHNOLOGICAL SOLUTIONS

The detailed case studies in this report focus on solutions that rely on mature, available technologies that foster behavioral change through positive incentives. They are not highly capital intensive and can make a substantial contribution to reducing CO_2 emissions in a given municipality and trigger significant co-benefits (air quality, social well-being, etc.).

The focus studies on key technological solutions present solutions that are more capital intensive but that have very significant potential for reducing CO_2 emissions related to transportation world-wide. Their mass-market development could be more gradual than for the solutions presented in the case studies, but will achieve major CO_2 emission reductions in the long run.

Each detailed case study and focus is linked to a scope (geographical zone, use, transport modes) for which it is particularly relevant to foster the development of this solution in the short term.



Avoid & Shift:

1 Traffic control and optimization
2 Car-sharing and car-pooling
3 Smart logistics
4 Incentive and reward programs in favor of eco-mobility and modal transfers

Vehicle Efficiency:

5 Mechanical, technical and physical improvements to vehicles and engines
6 Hybrid propulsion
7 Eco-driving training and technologies
8 Connected and autonomous vehicles

Low-carbon fuels:

9 Hydrogen-based fuel cell electric vehicles
10 Sustainable biofuels
11 Natural gas and biogas
12 Battery electric vehicles
13 Improvements to conventional fossil fuels

METHODOLOGY AND HYPOTHESES USED FOR THE CALCULATIONS OF CO_2 EMISSION REDUCTION POTENTIAL

In line with the top-down approach used to select the solutions, the scope of calculation of the CO_2 emissions avoided corresponds to the geographical regions for which the large-scale deployment of each solution would be particularly relevant in the short and medium term. For most of the solutions, the avoided CO_2 emissions resulted from the difference between the estimations of the volume of emissions in two scenarios:

- A Business-As-Usual (BAU) scenario taking into account the current trends in the transport sector
- A "beyond 2°C" scenario based on the assumption of deployment of the solution by 2030. The deployment hypotheses range from a conservative to an optimum scenario.

Please note the following important details concerning the methodology:

All activity data was extracted from the IEA's Energy Technology Perspectives 2017, while emission factors were sourced from various databases: the DEFRA and ADEME databases, and lifecycle analysis studies.

- For simplification purposes, activity data and emission factors are assumed to be equal in both the BAU and the "beyond 2°C" scenarios.
- Hypotheses on vehicle occupancy rates were also used to convert the activity data (p.km and t.km) into travelled kilometers.
- Extrapolations were made when the data was only available for one country or city, to extend the calculation scope to a wider region.
- The calculation of CO_2 emissions avoided through the deployment of incentive programs was subject to a specific calculation methodology based on Eurostat statistics on commuting.

For each solution considered, the conservative scenario corresponds to a continuation of trends observed in the past years or decades, while the optimum scenario considers an acceleration of the deployment of the solution to reach a maximum market share by 2030. The hypotheses take into account existing feasibility constraints and deployment curves as well as the local context for each region considered. In each case, the conservative and optimum scenarios are based on a mix of hypotheses drawn from the literature and from expert estimates. The main information sources that were used are listed below. Specific sources for each solution are listed in the bibliography section. Detailed hypotheses for the two scenarios are available on demand.

Sources and key imputs for GHG mitigation potential estimations	Activity data source	Scope considered	Emission Factor	Occupancy rate
Case study: Incentive schemes	Eurostat	OECD|Passenger	Sétra	The Shift Project, 2017
Case study: Eco-driving	The Shift Project, 2017	OECD|Passenger	The Shift Project, 2017	
Case study: Car-pooling	IEA 2017, ETP 2017	OECD|Passenger	DEFRA database	European Environment Agency, IATSS Research, University of Michigan, Indian Institute of Technology
Focus: Biofuels Passenger	IEA 2017, ETP 2017	World | Passenger and Freight	ADEME database	
Focus: Biofuels Freight			ADEME database	
Focus: BEV	IEA 2017, ETP 2017	OECD and China|Passenger	MIROVA SRI Research	
Focus: NGV Passenger	IEA 2017, ETP 2017	China|Passenger and Freight	DEFRA database	
Focus: NGV Freight			DEFRA database	
Focus: FCEV	IEA 2017, ETP 2017	OECD and China|Passenger	ICCT	

Notes on bibliography:

- The bibliographical resources used for the identification of the solutions and their evaluation are numerous, ranging from academic research to studies by consulting firms and position papers by private transport companies.
- The identification of global mobility stakes is mostly based on reports by international agencies such as the Intergovernmental Panel on Climate Change (IPCC), the International Energy Agency (IEA), the Energy Information Administration (EIA) and the International Transport Forum (ITF).

SOURCES

General

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Car-pooling applications and the sharing economy in freight transport

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- European Commission, 2017, Horizon 2020 – Smart, green and integrated transport
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Sustainable biofuels

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Electric mobility

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Hydrogen-based fuel cell electric vehicles

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NOTES

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