T4<2° | Transport For Under Two Degrees

Transport for under two degrees – the way forward

10 key insights for the decarbonisation of the transport sector

A GLOBAL FORESIGHT STUDY

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Agora Verkehrswende

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Preface – Federal Foreign Office

Dear Readers,

by adopting the 2030 Climate Action Plan including a CO_2 pricing scheme for the transport sector, the Federal Government has paved the way for meeting its climate targets for 2030. Our long-term goal is to achieve carbon neutrality in line with the targets agreed under the Paris Agreement.

Germany has taken on a pioneering role in the global energy transition – which represents the efforts made and results achieved on renewable energy expansion and energy efficiency. The transition thus serves as the basis for a clean, secure and affordable energy supply, which is essential for all our lives. To achieve its climate targets, Germany will additionally advance the transformation of the industry, heat and the transport sector.

Besides establishing smart interlinkages between the said sectors and improving energy efficiency, we emphasise the aspect of a just transition in industrial and individual mobility. In addition to implementing national policies as stipulated by the national executive, it is also our responsibility to promote dialogue internationally. In this context it is important to note that our goal "T4<2°" – Transport for under two degrees – can only be achieved jointly within the international community.

In order to enhance international cooperation, the German Federal Foreign Office is delighted to present this comprehensive foresight study on the potentials and challenges regarding the decarbonisation process of the transport sector. However difficult this process may seem from an individual's perspective, without decarbonising the transport sector, a global energy transition cannot be achieved and our nationally determined contribution towards the Paris Agreement cannot be met either. Moreover, as the study underlines, decarbonisation of the transport sector is crucial and at the same time possible, given our technical advances and the international governance structure.

This study also offers important insight into fields where we can advance our joint efforts in cooperation with our international network. As another positive prospect, the global transport transition will create additional safe and sustainable workplaces, from which Germany and the international society as a whole will benefit. Therefore, the Federal Government is striving to bring forward the transition towards a decarbonised transport sector on the global stage.

Through the contribution of 346 renowned international experts from 59 countries, the study draws a global picture of the probable future of the transport sector's transformation. The diverse backgrounds of the experts, ranging from intergovernmental organisations, to non-governmental organisations, think tanks and the private sector, make each contribution adding to the richness of this study. The findings of this project provide relevant insights for the future of a decarbonised transport system and offer exciting impulses to bring a sustainable transformation of transportation forward as a joint international endeavour.

We wish you a pleasant and inspiring read.

Hinrich Thölken
Director for Energy and Climate Policy
Auswärtiges Amt (Federal Foreign Office)

Preface – Steering Committee

When we – Agora Verkehrswende, the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH and the World Economic Forum – started with the project "T4<2° – Transport for under two degrees" on behalf of the German Federal Foreign Office, it was eminent that fundamental changes in transport would lie ahead: The international community had committed itself to limiting the rise in the global average temperature to well below 2°C above the pre-industrial level, if possible, to 1.5°C. As a result, a complete reduction in emissions must be pursued by the middle of the 21st century. While the past few years have been marked by major global progress in decarbonising the energy industry itself, it has been clear, that the next step is to decarbonise the transport sector.

With this project we wanted to provide a systematic look at the changing framework conditions of the transport sector and necessary fields of action for foreign policy and international cooperation. Foreign policy and international cooperation have a special responsibility in creating the framework for a global transformation of the transport sector, beyond questions of technical and regulatory implementation of individual innovations.

Much has happened since then. As we wrote this final project report between April and July 2020, large parts of the world have experienced limitations of their social and economic activity in order to reduce the spread of Covid-19. Some countries are currently emerging from lockdown and slowly restarting their economy, whilst other countries are entering another phase of severe restrictions. These disruptions have had a pronounced impact on mobility behaviour and most transport modes. However, as the situation is still fluid, uncertain, and complex, it remains to be seen which medium- and long-term-effects on the mobility sector will endure. Responses to Covid-19 have however shown potential for systemic changes to the mobility sector. The recovery period moreover allows us to harmonise economic recovery and climate protection. It opens up the opportunity to align governance structures in the mobility sector towards a more sustainable, resilient, efficient and inclusive system.

The results of this study can provide the basis to formulate long-term strategies for the decarbonisation of transport and hence strengthen the resilience of the sector in general. Its findings give a clear account of what a decarbonised, sustainable and just transport system could look like. Moreover, it provides the necessary assessment on crucial changes, and essential action that needs to be considered on this path, while presenting related implications. These can guide policymakers and other stakeholders in taking the necessary steps to decarbonise transport as part of their long-term strategies. Hence, this study hopes to contribute to the global efforts in response to the current health crisis as well as the climates crisis with the aim of building a more resilient and sustainable future for all.

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Executive summary

The transport sector is the fastest growing source of greenhouse gas emissions at present. It accounts for approximately one quarter of global greenhouse gas emissions and hence figures prominently in efforts to transform the energy economy and protect the climate. Without a scaled-up global mitigation effort, it will not be possible to reach the climate targets of the Paris Agreement. A decarbonisation of the global transport sector is the next necessary step in the global energy transformation.

Since this study was commissioned, the surrounding circumstances have taken an unforeseeable turn on a global level. The Covid-19 pandemic has shown that there is potential for swift systemic change within the mobility sector whilst at the same time highlighting certain weaknesses of the transport system. This has underlined, that the transformation towards a decarbonised, socially and economically sustainable transport sector must start immediately, not only to tackle climate change but also to strengthen societal and economic resilience and prepare for future crises.

The main findings presented here could thus not be more relevant and urgent.

Germany's Federal Foreign Office has commissioned the project "T4<2° – Transport for under two degrees", a global foresight study on the decarbonisation and transformation of the transport sector. The study identifies challenges and opportunities for a sustainable, low-carbon transport sector and provides decision-makers with a clear vision and specific recommendations on how to achieve decarbonisation of the sector and orchestrate international efforts for a global transport system transformation.

To identify the necessary action for a full decarbonisation of transport, the study applied methods of strategic foresight[1]: In particular, these methods comprised context mapping in the form of a systematic literature review on international transport scenarios and 56 qualitative interviews with international senior experts primarily from the transport and energy sectors. Subsequently, a two-stage Delphi survey was conducted.
A Delphi survey is a structured, iterative group facilitation technique that has been developed as a systematic, interactive forecasting method. 290 international experts participated in the first round of the survey; 103 experts took part in round two. The project was implemented between March 2018 and February 2020.

The findings from the context mapping and Delphi survey have been synthesised and interpreted, thus deriving implications for policy and international cooperation.

1 Burchard, B., Greenblott, J., O'Farell, T., Olson, R. (September 2019): Strategic Foresight in the Federal Government: A Survey of Methods, Resources, and Institutional Arrangements. World Futures Review 2018 11:3, 245–266

The study provides 10 key insights:

1

A full decarbonisation of the transport sector requires higher ambition in order to reach the goals of the Paris agreement: A full decarbonisation must happen by 2050, as projections show[2]. This means that the current level of ambition in countries world-wide – as estimated by the experts in this study – has to be raised to achieve these goals. The study moreover concludes that developed as well as developing countries should work on the same timeline. This gives rise to the question whether the so far discussed differentiated timelines in the Paris Agreement are necessary or useful for the transport sector. The surveyed experts do not expect that the transformation will slow down economic growth – to the contrary, they estimate that it will create more jobs than it may eliminate. In order to ensure that the transport sector effectively contributes to overall sustainable development, its decarbonisation needs to be accompanied by policies fit to reduce social divides and global development gaps.

2

Energy and transport but also trade are the crucial fields of international governance that require more coherent and coordinated action: According to the surveyed experts, these three sectors need to be better integrated at an international level to achieve the decarbonisation of the transport sector. While the energy sector will have to provide sufficient renewable energy for the transport sector, governance of the trade sector will have to provide the frameworks for a level playing field and the reduction of overall transport demand. Within the transport sector, international governance should strive for coordinated and coherent policies regarding emissions reduction and low-carbon technologies. Among the international organisations, the European Union (EU) will play a leading role in these efforts, according to the experts.

3

Electricity from wind and solar will be the leading energy carrier for transport: Experts overwhelmingly agree that the transport sector will mainly be powered by electricity from renewable sources. For land-based passenger and freight transport, directly used electricity from renewable sources will be the dominating energy carrier. Aviation and maritime transport on the other hand are expected to require the highest ambition, as the currently available options in these sectors still oppose the goal of decarbonisation. Therefore, more action is required in these areas in order to replace fossil energy carriers with synthetic fuels based on renewable energy. The expansion of the production of electricity from wind and solar needs to be extended and accelerated accordingly to make the transport transformation a success.

2 See for example Partnership on Sustainable, Low Carbon Transport (SLoCaT). (2018). Transport and climate change. Retrieved from www.slocat.net/wp-content/uploads/legacy/slocat_transport-and-climate-change-2018-web.pdf

4

Public transport, active modes of transport, shared mobility services as well as sustainable urban planning will be the backbone of climate-friendly urban transport. Therefore, investments in public transport along with the promotion of cycling and walking have to be prioritized. To break the expected and continued dominance of the individually owned car, policies are needed to promote sharing and pooling. Sustainable city planning is essential to reduce transport demand in the first place and set the prerequisite for efficient and just mobility systems.

5

The development of alternative drive technologies demands increased attention in rural areas without ruling out new mobility options. While rural areas in developed countries are highly car-dependent, rural areas in developing countries are faced with a considerable lack of access to mobility. Experts expect that cars will still play an important role in rural transport in 2050. Alternative drive technologies will be crucial to meet this demand. At the same time, alternative mobility solutions are needed to reduce car dependency and reduce spending on new car infrastructure in favour of mobility systems that support decarbonisation and promote equal access.

6

Digitisation and autonomous driving need a comprehensive political framework in order to support the decarbonisation of the transport sector: The majority of experts see a potential for digitization to support the reduction of greenhouse gas emissions, even though this is expected to be linked to a significant increase in energy demand due to data processing. Thus, the exploitation of this potential must be linked to strong international governance. The majority of the experts see a significant role of autonomous vehicles (AVs) in road passenger transport, although there is no clear position that they will dominate the market by 2050. In general, the potentially negative effects through increased urban sprawl and transport volumes as well as higher energy demand are seen as relevant concerns which also proves the need for political governance.

7

The political task of promoting the successful structural change in the automotive and fossil fuel industry will require more efforts by policy makers. Vested interests of incumbent industries – particularly the automotive and fossil fuel industries – are by far the biggest challenge to the decarbonisation of the transport sector, as the study reveals. The defining task for policymakers is actively supporting the structural change in these industries in order to manage their transformation.

8

Countries with large incumbent industries, economic weight and political power have to play the key role in order to ensure the success of transport decarbonisation. Experts see China, the United States (US), Germany, India and the EU in general as the key players to drive the transition. While countries without fossil oil resources would greatly benefit from transport decarbonisation, those with a high dependency on fossil fuel exports or automotive industries must support a structural shift in order to secure their long-term market competitiveness. This affects Russia, Saudi Arabia and the US, but also China and Germany. Furthermore, the experts point out that a shift in demand from fossil fuels to scarce metals such as cobalt or lithium, as well as rare earths needed for the sector's electrification does not necessarily decrease the risk of geopolitical conflict related to the unequal distribution of resources.

9

New technologies and mobility solutions can only unfold their full potential for decarbonisation if policy makers also focus on a change in mobility behaviour. A lack of suitable technology is not expected to be a challenge. The success of the decarbonisation of transport will first and foremost depend on how the technology will be adopted. Most of the experts suggest that policy-makers should focus more on regulation of behaviour in addition to regulation of technology.

10

Decision-makers have to prioritise regulatory action over incentivisation and hereby provide a sound political framework, in order to ensure long-term investment security for public funding as well as private capital: A lack of regulation was identified as the second biggest challenge to the transformation of transport after vested interests of incumbent industries. Fuel pricing and a forced phase-out of vehicles with combustion engines are seen as the most effective measures to support transport decarbonisation. Regulation needs to be complemented with investment, especially in public transport. Experts expect that sufficient funds will be available for the transformation of the transport sector. A combination of public and private sector money will have to be mobilised. This requires national and local governments to provide the right framework to make investments in sustainable mobility attractive to private investors. Reorienting public money currently spent on fossil fuel subsidies is as urgent as providing cities with greater financial autonomy, and supporting developing countries with sustainability-oriented, policy-based lending.

Foreign policy and international cooperation could play a more vital role in supporting a systemic transformation of the transport sector. They will need to contribute to agenda setting and transforming transport coherently by strengthening governance across sectors, intensifying bi- and trilateral cooperation with key actors, and building political momentum for the necessary global decarbonisation of transport. Countries should make use of their diplomatic resources in international fora such as the EU, the United Nations (UN), the G7 and G20 to orchestrate international efforts for the global transformation of the transport sector.

List of abbreviations

ASEAN	Association of Southeast Asian Nations
AVs	autonomous vehicles
BEVs	Battery-electric vehicles
DAC/ODA-Countries	Official Development Assistance (ODA) recipient country as provided by the OECD Development Assistance Committee (DAC)
EBRD	European Bank for Reconstruction and Development
ECA	Economic Commission for Africa
ECLAC	Economic Commission for Latin America and the Caribbean
EIB	European Investment Bank
EITI	Extractive Industries Transparency Initiative
ESCAP	Economic and Social Commission for Asia and the Pacific
ESCWA	Economic and Social Commission for Western Asia
EU	European Union
EU ETS	European Union CO_2 Emission Trading System
FCEV	Fuel Cell Electric Vehicle
FCV	Fuel Cell Vehicle
GDP	Gross Domestic Product
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
G20	Group of Twenty
ICAO	International Civil Aviation Organization
ICLEI	Local Governments for Sustainability
IFIs	International Financial Institutions
IMO	International Maritime Organization
IPBES	Intergovernmental Science-Policy Platform
IRENA	International Renewable Energy Agency
NDCs	Nationally Determined Contributions
NGO	Non-Governmental Organisation
non-DAC/ODA-countries	Countries, which do not receive Official Development Assistance (ODA) as provided by the OECD Development Assistance Committee (DAC)
NUMP	National Urban Mobility Plans
OECD	Organisation for Economic Co-operation and Development
PHEV	Plug-in hybrid electric vehicle
R&D	Research and Development
SDG	Sustainable Development Goal
SLoCaT	Partnership on Sustainable Low-carbon Transport
SUMP	Sustainable Urban Development Plans
TUMI	Transformative Urban Mobility Initiative
T4<2°	Transport for under two degrees
UN	United Nations
UNDP	United Nations Development Programme
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UN-HLPF	United Nations – High-level Political Forum
US	United States
WEF	World Economic Forum
WWF	World Wildlife Fund

List of figures and tables

1 Objective and scope of the T4<2° global foresight study

The transport sector is currently the fastest growing source of greenhouse gas emissions. With its almost exclusive use of fossil fuels, it consumes approximately 2,600 Mt oil per year, which corresponds to two-thirds of global oil production[3]. Consequently, transport accounts for about a quarter of global energy-related greenhouse gas emissions.

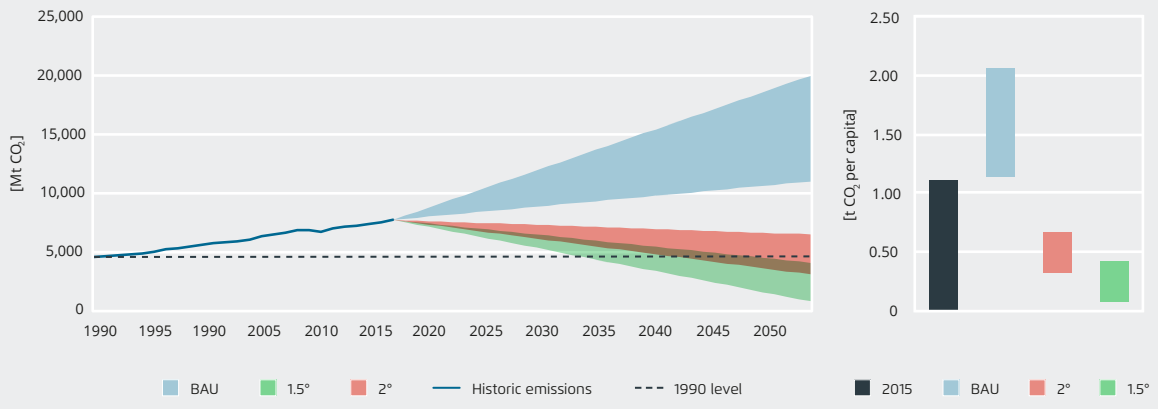
In recent years, emissions from transport have been more or less stable in Europe and North America, albeit at a high level. At the same time, the still comparably low per capita transport emissions in Asia, Africa and Central and South America are growing rapidly, along with the economic and social development of these regions. Projections show that the sector could more than double its global emissions by 2050, if business continues as usual. However, in order to achieve the objectives of the Paris Agreement and limit global warming to 1.5°C, or at least to below 2°C, the sector will have to bring down its emissions levels from around 8 Gt CO_2eq per year to around 3 Gt CO_2eq per year by 2050[4].

The current targets for the transport sector set by countries in their Nationally Determined Contributions (NDCs) under the Paris Agreement are not ambitious enough to limit global warming to

3 International Energy Agency (IEA) (August 2019). Data and Statistics. Oil products final consumption by sector, World 1990–2017. Retrieved from https://www.iea.org/data-and-statistics?country=WORLD&fuel=Oil&indicator=Oil%20products%20final%20consumption%20by%20sector

4 Partnership on Sustainable Low-carbon Transport (SLoCaT). (2016). Implications of 2DS and 1.5DS for Land Transport Carbon Emissions in 2050. Retrieved from www.ppmc-transport.org/wp-content/uploads/2016/11/SLoCaT-1.5DS-2050-Report-2016-11-07.pdf

Figure 01 | Transport sector emissions: business-as-usual development and required reductions under 2 °C and 1.5 °C scenarios



Note: Simplified illustration based on historic levels and projected 2050 levels. Individual scenarios are likely to peak around 2020 and then decrease emissions at higher rates afterwards.
Authors' figure, historic emissions based on data from IEA (2018), projections based on data from Gota, Medimorec, et al. (2018).

well below 2°C.[5] Without considerably stronger efforts and more effective actions, the Paris climate goals will not be achieved.

Thus, profound changes within transport need to take place. The sector's strong potential to improve social inclusion and economic performance moreover requires its decarbonisation to be integrated into an overall pathway for sustainable development, as stipulated by the United Nations' Agenda 2030.

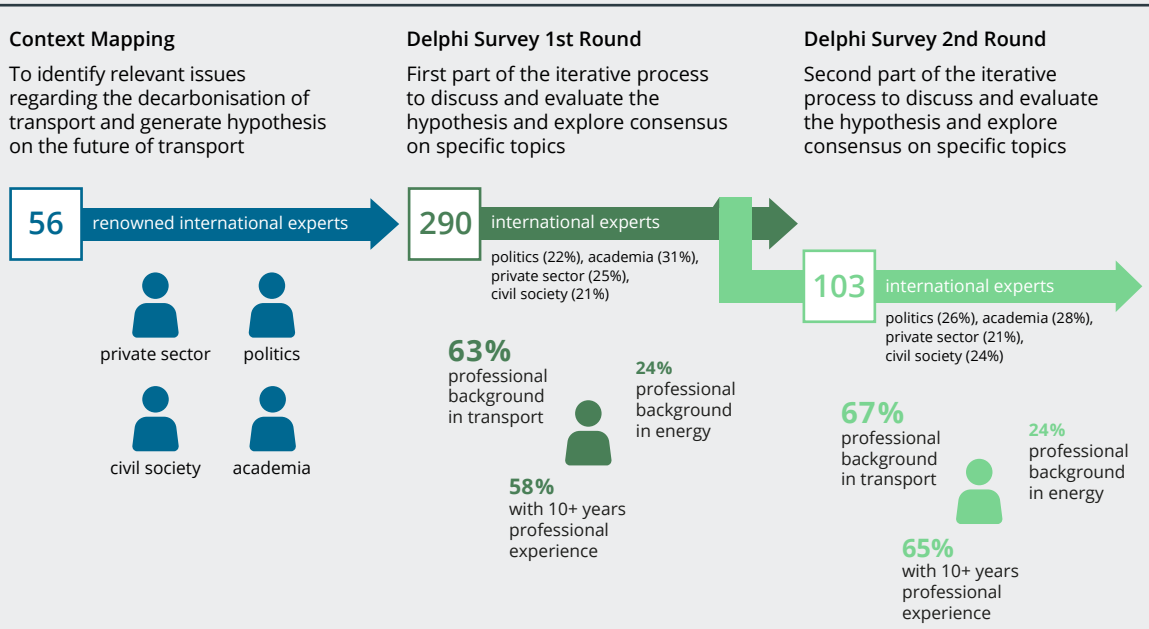
Germany's Federal Foreign Office has commissioned the project "T4<2° – Transport for under two degrees", an international study on the transformation of the transport sector. The study identifies challenges and opportunities for a sustainable, low-carbon transport sector and provides decision-makers with a clear vision and specific recommendations on how to achieve the decarbonisation of the sector by mid-century. To this end, the study applied methods of strategic foresight[6]. First was a context mapping exercise, which comprised a systematic literature review on international transport scenarios[7] and qualitative interviews with 56 renowned international experts. The objective was to identify relevant issues regarding the decarbonisation of transport and generate hypotheses on the future of transport. These hypotheses were subsequently discussed and evaluated by an international and interdisciplinary group of experts during a two-stage Delphi survey. The Delphi survey technique is a group facilitation method used for

5 See also Partnership on Sustainable, Low Carbon Transport (SLoCaT). (2018). Transport and climate change. Retrieved from www.slocat.net/wp-content/uploads/legacy/slocat_transport-and-climate-change-2018-web.pdf

6 Burchard, B., Greenblott, J., O'Farell, T., Olson, R. (September 2019): Strategic Foresight in the Federal Government: A Survey of Methods, Resources, and Institutional Arrangements. World Futures Review 2018 11:3, 245–266

7 A full list of the analysed literature can be found in table 1 of the appendix.

Figure 02 | The methodological design and expert background



Representation based on the results of the T4<2°-Delphi survey

systematic forecasting. During an iterative process of several rounds it is used to determine a range of opinions regarding future scenarios and to explore consensus on specific topics. During the first round of the survey from October to November 2019, 290 international experts participated, and during the second round in January and February 2020, 103 experts took part.

Starting with a short contextualisation of the project in the light of the Covid-19 pandemic, this report presents 10 key findings of the study and puts them into perspective in chapter 3. The chapter can serve as a basis and guideline for more effective action, from the global to the local level. Chapter 4 presents opportunities and implications for international cooperation and German foreign policy, which can be derived from the findings of the study. The methodology for the qualitative and quantitative survey is explained in the appendix in more detail.

The project was carried out by the Agora Verkehrswende Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and the World Economic Forum (WEF) between March 2018 and August 2020.

2 Foresight methods as a tool to prepare for future shocks and increase resilience: implications for the transport sector

With the Covid-19 pandemic, the world is facing the "biggest [economic] crisis since World War II", as many international leaders phrase it.[8] The measures taken by governments to contain the pandemic have led to a drastic slow-down of human and economic activity. In June 2020, the World Bank estimated that the global economy will shrink by 5.2% in 2020, with developed countries' economies being expected to shrink by up to 7%.[9]

The measures to contain the spread of the virus have had major impacts on transport demand and the transport sector. Supply chains across all modes of transport were slowed down or disrupted. Passenger air travel came to a halt; interurban passenger travel by rail or road was reduced or suspended. Lockdowns in cities led to a dramatic fall in urban movements.[10] How to move critical workers and deliver essential supplies (health and sanitary equipment, food) while providing the best health protection for staff and users were the most urgent challenges to be solved.[11],[12] In the urban context, with movements dropping sharply, we have almost experienced car-free cities, with minimal air and noise pollution from motorised vehicles, less congestion and fewer road accidents. People have shifted to cycling, micro-modes and walking – and some cities have adapted quickly in providing more space for these modes. Home delivery and digital services became economic and physical lifelines for many. The decline of transport activity – and of fossil fuel-based industrial production – has led to improved urban air quality and a fall in greenhouse gas emissions. On the downside, public transport and other shared modes have lost passenger numbers due to the fear of contagion. Many commuters have returned to their cars as lockdowns have been lifted, putting even more pressure on cities than before the crisis[13]. Areas and social groups with less access to digital and home delivery services found themselves highly disadvantaged. Whether these effects will have a lasting impact on emissions is not yet clear. Most likely, positive changes will only be implemented if recovery efforts are accompanied by the necessary systemic changes.

Global pandemics are not unprecedented. Thus, the economic and social risks related to them are not totally unexpected in terms of science

8 BBC News. (April 1, 2020). Coronavirus: Greatest test since World War Two, says UN chief. Retrieved from www.bbc.com/news/world-52114829

9 World Bank. (June 8, 2020). COVID-19 to Plunge Global Economy into Worst Recession since World War II. Retrieved from www.worldbank.org/en/news/press-release/2020/06/08/covid-19-to-plunge-global-economy-into-worst-recession-since-world-war-ii

10 Partnership on Sustainable, Low Carbon Transport (SLoCaT). (2020). Impacts of COVID-19 on Mobility – Preliminary analysis of regional trends on urban mobility. Retrieved from slocat.net/covid-19-impact-mobility/

11 Transformative Urban Mobility Initiative (TUMI) & Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. (May 2020). COVID-19 and Sustainable Mobility. Retrieved from www.transformative-mobility.org/assets/publications/2020_05_TUMI_COVID-19-and-Sustainable-Mobility.pdf

12 UITP. (2020). Public transport and COVID-19. Retrieved from www.uitp.org/public-transport-and-covid-19

13 Apple (July 2020): Apple Maps mobility trends report. Retrieved from https://www.apple.com/covid19/mobility

and policy. However, as politicians are faced with an increasing number of hypothetical risks, it is an enormous task to prioritise them, and to prepare appropriately and at the right time with available resources. Often the probability of occurrence and the associated extent of damage are misjudged, and consequently the preparation for future shocks is sometimes prioritised ineffectively.

In general, the Covid-19 crisis seems to be a reminder for governments to increase preparation efforts for future shocks and unforeseeable crises. Because of the climate crisis such shocks are likely to happen more regularly and with increasing severity due to rising environmental degradation, increasing inequality in societies and an interconnected world(-economy).

The pandemic has highlighted that the resilience of our systems must be strengthened, and contingency plans developed, considering the complexities and interconnectedness of our systems. Policymakers must generally be enabled to take the right (preventive) measures to ensure system resilience.

This study follows a similar approach. Its findings give a clear account of what a decarbonised, sustainable and just transport system could look like. Moreover, it provides the necessary assessment on crucial changes, and essential action that needs to be considered on this path, while presenting related implications. It can guide policymakers and other stakeholders in taking the necessary steps to decarbonise transport as part of their long-term strategies. Hence, this study hopes to contribute to the avoidance of unwanted shocks – whether economic, geopolitical, environmental or social.

3 Key findings: how to decarbonise transport and transform mobility by mid-century?

3.1 A full decarbonisation of the transport sector requires higher ambition in order to reach the goals of the Paris agreement

The transport sector currently emits about 8 Gt of CO_2eq greenhouse gases. With its expected growth rate in a business-as-usual scenario – both freight and passenger transport demand could triple by 2050[14] – its emissions would rise to at least 12 Gt. To limit global warming to well below 2°C as set out in the Paris Agreement, global emissions across all sectors must be limited to a maximum of 8 Gt. This means transport sector emissions have to be reduced to at least 4.7 Gt CO_2 to reach the target of 2°C. To limit global warming to 1.5°C, transport emissions must be reduced to as little as 2 Gt CO_2eq.[15]

Consequently, the question is not if the transport sector will have to be largely decarbonised, but how fast its decarbonisation can and must happen, as has been underlined by the experts participating in this study. A vast majority of 92% of survey participants agree that the decarbonisation of the transport sector will happen. However, the majority – 59% – believes that the current level of ambition is not enough to decarbonise the transport sector by 2050. This means that most do not expect the sector to be decarbonised in time to reach the goals of the Paris Agreement (see Figure 3).

Except for some singular voices and 4% of participating experts from DAC/ODA-Countries and 9% from Non-DAC/ODA-Countries in the Delphi, who believe that the sector's decarbonisation will never happen, experts underline that it must happen if we are to prevent the dramatic consequences of further increasing greenhouse gas emissions. In the context mapping, some experts stressed that decarbonisation must happen well before the middle of the century, and that we have already waited too long.

The Paris Agreement distinguishes between developed and developing countries and allows for differentiated timelines. However, the expectations of experts from developing and developed countries match on when the decarbonisation of the transport sector will be achieved. This gives rise to the question of whether the differentiated timelines under discussion by the Paris Agreement parties are necessary or useful for the transport sector.

Even though experts believe that decarbonisation of the transport sector can be achieved at the same time, they agree that the pathways and challenges for countries will differ.

Our interviewees pointed out that developing countries have the opportunity to avoid lock-in of unsustainable systems, certain costly infrastructure projects and stranded assets, and to immediately leapfrog to more sustainable solutions.

14 International Transport Forum. (2019). Transport demand set to triple, but sector faces potential disruptions. Retrieved from www.itf-oecd.org/transport-demand-set-triple-sector-faces-potential-disruptions

15 Partnership on Sustainable Low-carbon Transport (SLoCaT). (2016). Implications of 2DS and 1.5DS for Land Transport Carbon Emissions in 2050. Retrieved from www.ppmc-transport.org/wp-content/uploads/2016/11/SLoCaT-1.5DS-2050-Report-2016-11-07.pdf

> **"Fast growing low- and middle-income countries need to be integrated [into the transition] right in the beginning. We have a narrow window of opportunity to achieve an impact there."**
>
> (Senior Professional, Global Environmental Policy Organisation)

In response to the question of how this decarbonisation can be implemented successfully, interviewees pointed to the need for a clear, long-term vision for sustainable mobility and infrastructure, supported by a roadmap that formulates intermediate steps and goals on the way to 2050.

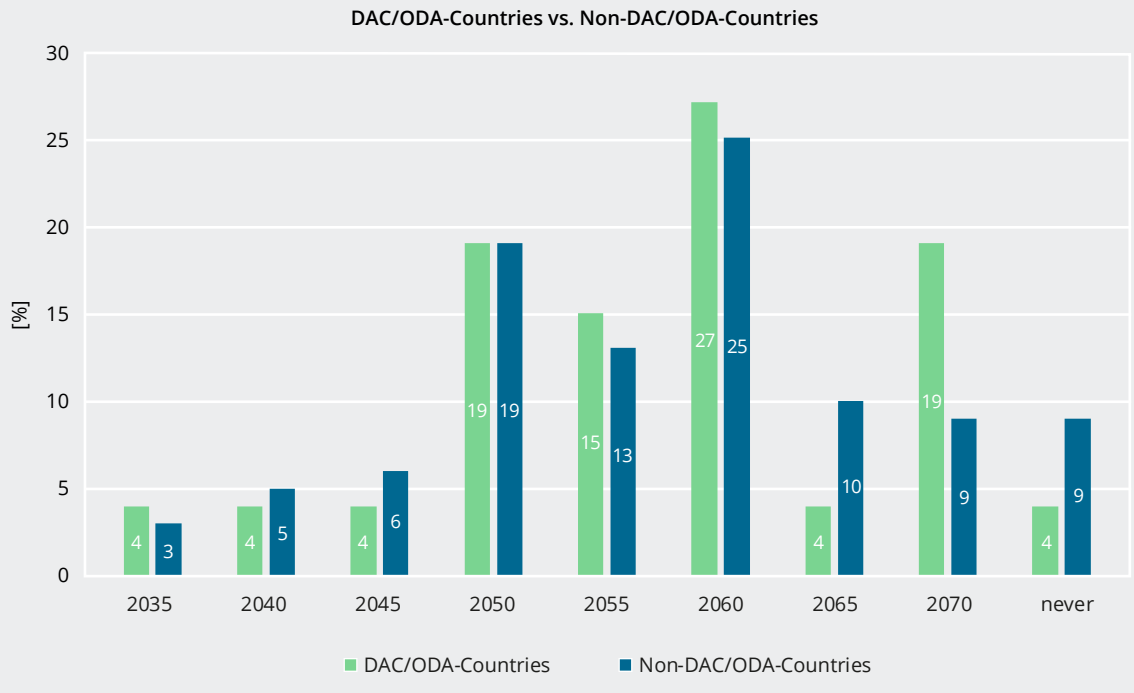
In order to facilitate the transition and generate political momentum, experts see more regional and global exchange as a critical factor to support the exchange of experiences, the broader adoption of successful practices, and the international collaboration towards the adoption of a common framework.

Also, a broad participation of different stakeholders well beyond the transport sector must be facilitated, including public and private actors as well as civil society in order to allow for a successful transformation.

3.1.1 Transport sector decarbonisation will create more jobs

In the public debate on climate action in general and the transformation of transport in particular, decarbonising transport is often associated with a potential loss of jobs. Experts however assess the creation of additional jobs through the sector's decarbonisation very positively: two-thirds

Figure 03 | By when will the transport sector be decarbonised?



Representation based on the results of the T4<2°-Delphi survey

of international experts believe that the transition in the transport sector will create more jobs than it will eliminate. Only 22% disagree with this statement.

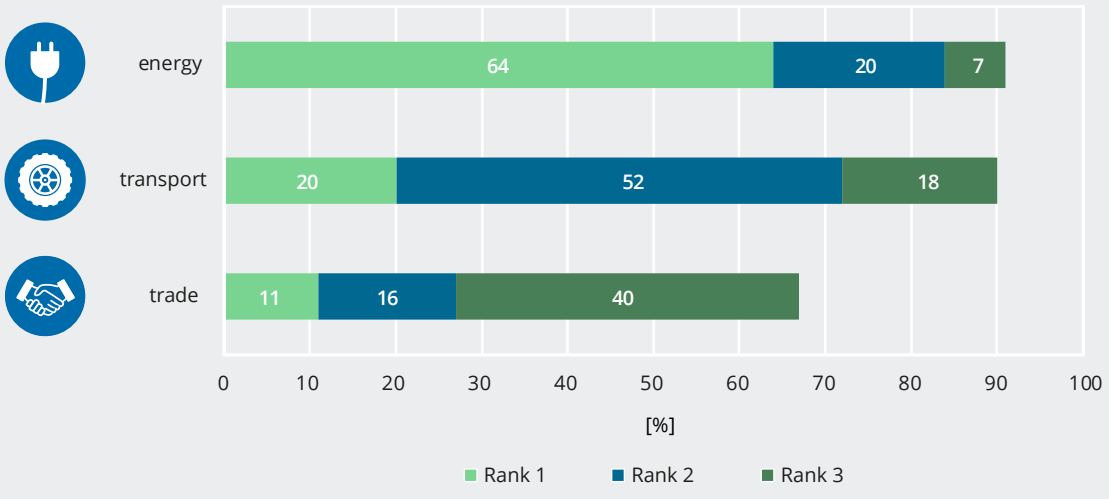
Experts acknowledge that a shift of jobs will have to take place, and that this shift towards new industries and fields of occupancy requires a guided and structured transition.

> **"[I]t is a flaw of the environmental community to think naively that we could deal with climate change [...] and not also have a holistic approach to what that means for jobs and economic development. The Green New Deal [...] looks at it from a standpoint of transformation of the whole society."**
>
> (Executive Director, NPO for Clean Transportation Research)

As the experts and other research suggest, new jobs are expected to be created within the transport sector not only locally, such as public and private transport services, but also on an industrial scale, such as electric battery production and recycling as well as the development of new technologies for vehicles and the transport system in general. The transport sector's transition is also expected to create jobs in other areas such as renewable energy production and digital services; small local businesses and tourism-related activities are expected to experience growth, mainly propelled by the transformation of city centres.[16]

16 See also: International Labour Organization & United Nations. (2020). Jobs in green and healthy transport: Making the green shift. Retrieved from www.ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/---publ/documents/publication/wcms_745151.pdf and World Health Organization. (2014). Unlocking new opportunities: Jobs in green and healthy transport. Retrieved from thepep.unece.org/sites/default/files/2017-05/Unlocking-new-opportunities-jobs-in-green-and-health-transport-Eng.pdf

Figure 04 | Ranking of the top three fields of international governance that require the most action in order to enable a transport transformation



Representation based on the results of the T4<2°-Delphi survey

In that regard, experts do not see transport sector decarbonisation negatively impacting overall economic growth.

As part of the Delphi survey, experts were asked to assess the significance of seven challenges to the decarbonisation of the transport sector. These were identified during the context mapping: vested interests of incumbent industries, a lack of regulatory action, a lack of international coordination and cooperation, a lack of public acceptance, a lack of suitable technologies, slowing economic growth and high infrastructure investment costs.

Of the experts from developed countries, 48% evaluated a slowdown of economic growth as least significant. Another 25% placed it in the second-last position. For experts from developing countries, a slowdown of economic growth as a potential consequence of the transport sector transformation ranks second to last, with 27% ranking it 7th and 23% 6th. Only a lack of suitable technologies ranks lower on average (see also 3.7).

3.1.2 Reducing social divides requires more than transport's transformation

Transport's transformation is not just an environmental necessity. The sector's strong potential to improve social inclusion and economic performance requires its decarbonisation to be integrated into an overall pathway of sustainable development, as stipulated by the United Nations' Agenda 2030.

In order to deliver on sustainable development as a whole, policies within and beyond the transport sector need to combine economic, ecological and social aspects to cater for sustainable development.

> **"The transport transformation holds the possibility to decrease all the divides … But it highly depends on the pathways chosen and the implemented policy regulations. Policies on transport transformation should always take into account which effects they might have on social structures and be designed in a way that social inequalities are decreased. I do not see this happening right now, as we are in a very technical approach."**
>
> (Expert contribution during Delphi Study)

Hence, experts do not assume an inherent decrease of social, gender, racial divides with the decarbonisation of the sector. Experts made clear that current inequalities and divides must specifically be considered and dismantled when transforming and decarbonising the transport sector. In the interviews, many experts expressed their concern that countries were currently not making use of the sector's transformation potential to reduce inequalities, and that more comprehensive policies are needed.

3.2 Energy and transport but also trade are the crucial fields of international governance that require more coherent and coordinated action

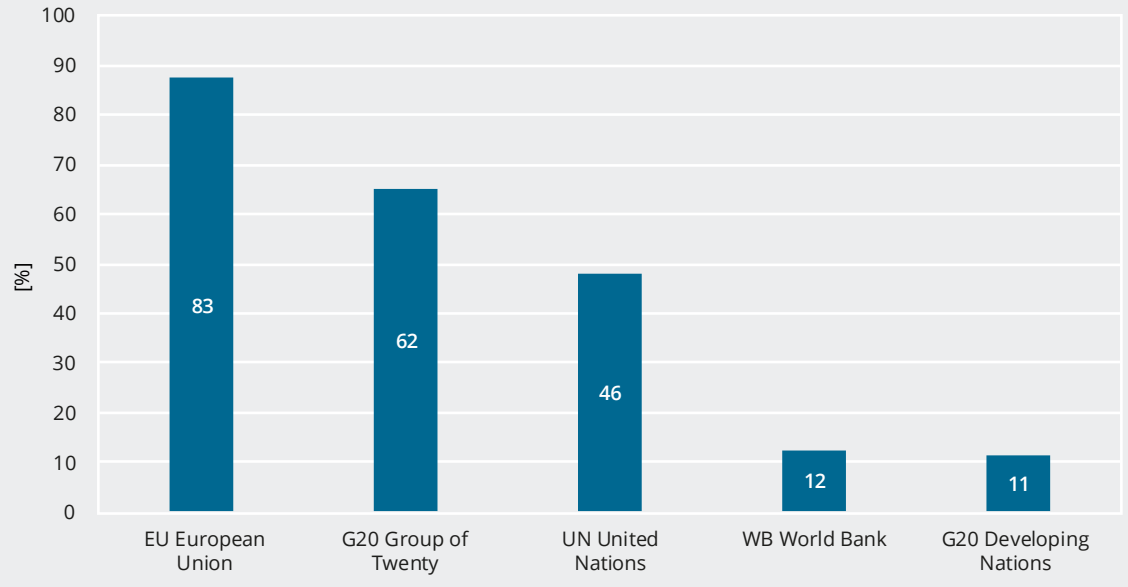
3.2.1 A strong cross-sectoral, integrated and international approach is necessary in order to decarbonise transport

The transport sector satisfies a demand that is driven by other sector policies. Freight transport for example is largely being determined by economic, trade and industry policies. The availability of renewable energy to be provided by the energy sector will massively influence the ability to decarbonise mobility. Without changes in these sectors, the transport sector by itself is unlikely to achieve the necessary transformation. Thus, a strong cross-sectoral, integrated and international approach is crucial to achieve the critical decarbonisation of transport.

This need has been emphasised by the experts participating in the study. They see energy, transport and trade as the areas of activity where most action in international governance is required to make transport decarbonisation possible. Energy in this regard is considered the most important field of international coordination that needs to be strengthened. Cross-cutting fields of action such as development cooperation, international standardisation, security and the regulation of transnational communication were assessed as less significant areas for international governance in this regard.

In their view, stronger international governance in the energy sector will not only have to support its own decarbonisation but will also have to make clean energy available to the transport sector. Hence, communication and coordination

Figure 05 | The most influencial international organisations for the success of the global transport transformation



Representation based on the results of the T4<2°-Delphi survey

between the two sectors becomes essential: the transport sector will need to understand and communicate its energy demands; and at the same time, the energy sector will need to understand and communicate how transport can contribute to reliable capacity planning, grid flexibility and the integration of more renewable energy. A strong integration of the two sectors will be key for a successful transformation of transport.

As for trade, stronger international governance would lead to more equal conditions in trade, especially when it comes to climate, environmental and social standards that influence pricing of goods and services through the integration of externalities, as experts pointed out. The border adjustment taxes currently discussed under the European Green Deal are an important signal but must also be seen as a regional response to the lack of international governance in the trade sector: if emissions regulation and CO_2 pricing were the same across countries, an adjustment mechanism to avoid carbon leakage and to ensure fair market conditions would not be necessary.

Also, while free trade agreements are important to link economies, they should take into account aspects of sustainability, push value chains towards better efficiency and disincentivise the movement of unnecessary goods.

Regarding more international governance in the transport sector, the majority of experts suggest that it would need to strengthen the coordination and coherence of policies, set minimum standards for emissions and the use of low-carbon technologies, and facilitate the adoption of compatible emissions trading schemes and CO_2 pricing for transport (see also 3.10) – all interventions that will drive the sector's decarbonisation consistently and on a global level.

3.2.2 The EU could lead international efforts towards a decarbonised transport sector

Beyond the need for international governance in the three sectors of energy, transport and trade, many experts also see a need for more coordination and cooperation regarding decarbonisation as a common task. Out of seven major challenges on the way to achieving transport's transformation, a lack of coordination and cooperation was ranked as the 3rd and 4th most important challenge by 57% of experts from developed countries, and as 4th and 5th most important by 50% of experts from developing countries.

When asked which organisation they believe would be most influential to help overcome the lack of coordination and to drive the transport sector's decarbonisation, 83% of experts stated the EU, among all major international institutions.

In fact, the EU has characteristics that would make it an ideal coordinator and facilitator. First, it can decide and implement legislation throughout its 27 member states, which constitutes a unique opportunity to define a common course towards decarbonisation. With its economic weight of 19 trillion USD gross domestic product (GDP), the EU is, after the US, the second largest integrated market in the world. If its members align, not only would their own contribution to decarbonisation be extremely significant, it would also build momentum to mobilise other countries through both economic relations and a strong voice in international fora.

Moreover, the EU has traditionally been a leader on policies to combat climate change, and played an instrumental role in the negotiation of the Paris Agreement. The EU's engagement in the transport sector's decarbonisation would be consistent with its previous achievements. Last but not least, as the largest provider of international

development assistance, the EU finds itself in the position to leverage its experience and provide guidance to other countries.

The Group of Twenty (G20) and the United Nations (UN) also have a key role to play, with experts perceiving them as second and third most influential.

While there are discussions on whether a dedicated UN body for transport should be created to take on this governance role, participating experts during the context mapping see the existing UN bodies for international aviation (ICAO) and international maritime transport (IMO) lacking ambition regarding the decarbonisation of the sector. A separate transport body within the UN system would, in their eyes, weaken the established, important integration of transport into the work of many UN agencies and bodies, for example the United Nations Development Programme (UNDP) and the United Nations Environment Programme (UNEP) as well as the regional economic commissions (UNECE, ECA, ESCAP, ECLAC, ESCWA, etc.). The question of whether the necessary international governance for the transport sector requires a constituent organisation or whether it could be facilitated through a counselling body still requires further analysis and discussion.

3.3 Electricity from wind and solar will be the leading energy carrier for transport

Achieving transport sector decarbonisation will require reducing both its overall energy consumption and the carbon footprint of its fuels. Along with avoiding unnecessary trips, shifting transport to more efficient modes and increasing vehicle load factors will be essential. When it comes to energy consumption per vehicle, the aim must be to develop and establish the most efficient technology for each mode of transport. Ultimately, for energy usage that cannot be avoided, sufficient zero-carbon and low-carbon energy carriers will have to be provided.

It cannot be denied that this is a fundamental challenge, even more so as, at the same time, access to mobility must further be improved, not limited. However, the design of energy-efficient road vehicles, aircraft, ships and trains with their respective drivetrain technologies as well as the provision of clean energy are, first and foremost, technological challenges that need to be – and can be – solved.

In the interviews and the survey, it became clear that there will not be a single technological solution powering all modes of transport by mid-century. Different modes of land-based passenger transport, freight transport as well as aviation and shipping have their specific challenges and will require customised solutions. Consequently, experts envisage a range of powertrain technologies and carriers of energy, depending on the type of mode, vehicle and its usage. The general opinion was to stay open-minded on the technology itself, but not on the standard – which should be zero emissions.

Electricity from renewable sources is seen as the most promising energy carrier for a decarbonised transport sector. If used as a direct source of power, as in the case of battery-electric vehicles or electric rail transport, it has the highest rate of electrical efficiency compared to any other drivetrain technology. Also, electricity that is used indirectly to generate hydrogen or synthetic fuels has a (near) zero-carbon footprint, if generated through renewable sources. However, the necessary conversion from electricity to hydrogen or synthetic fuels leads to a lower efficiency and therefore, electricity should be used directly – whenever possible. Other negative impacts, such as increased water usage, need to be considered.

In order to allow for this use of electricity with (almost) zero-carbon emissions in the transport sector, the decarbonisation of the energy sector must be pursued – and achieved.

> **"The current worldwide capacity of renewables is insufficient to fit the targets of electrification of transport; the development of further renewables is key."**
>
> (Senior Leader, Global Forum for Energy)

86% of experts agree that it will require a substantial extension of renewable energy production, and, at the same time, an increase in grid flexibility and storage to ensure electricity supply can be provided for transport, where and when needed.

They also consider new technologies such as high-capacity energy batteries as extremely relevant – and are certain that technologies will be available (see 3.9) – followed by the need for development of hydrogen production from renewable sources as well as power-to-X technologies.

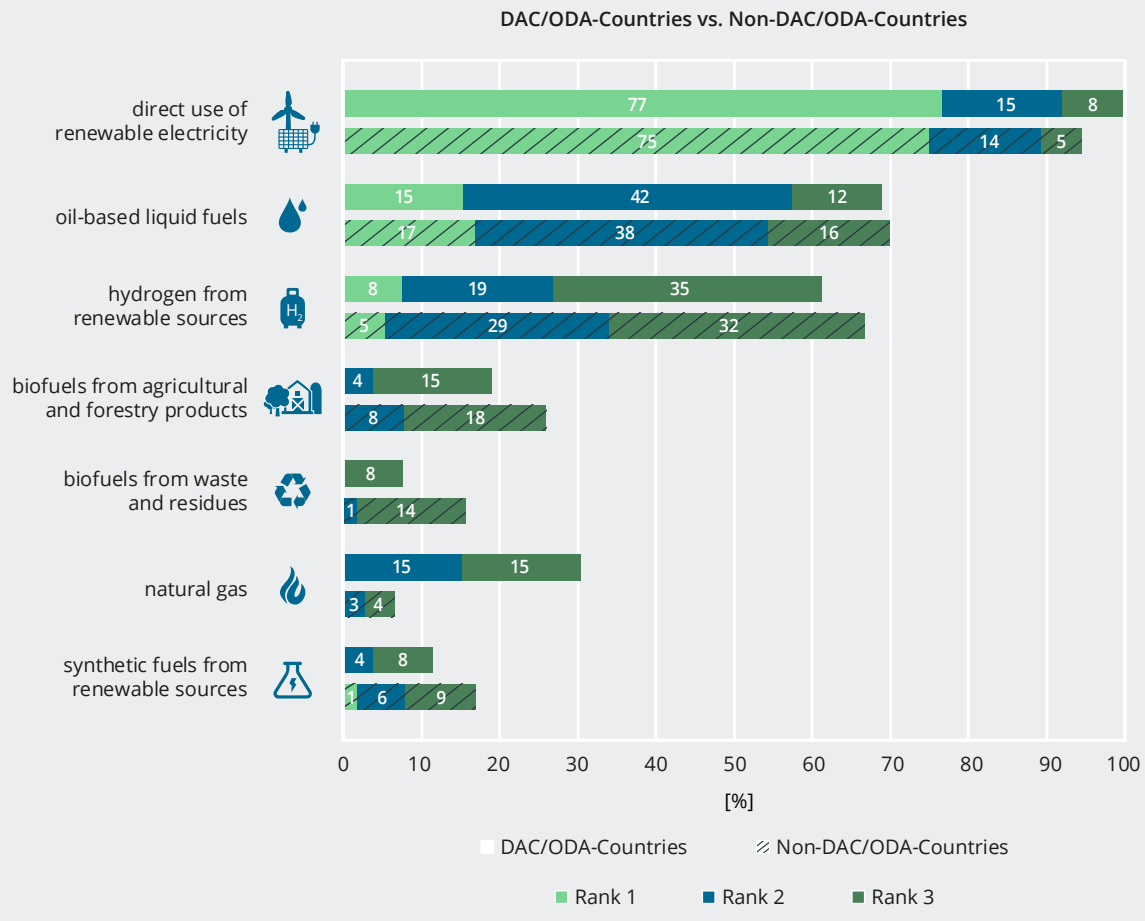
3.3.1 Directly used electricity will dominate land-based passenger and freight transport …

Experts see electricity as the most relevant energy carrier for both land-based passenger and freight transport. When asked which three types of fuels will have the biggest share, international experts ranked direct use of renewable electricity first, with a clear majority of 76% of experts from both groups in the case of passenger transport, and 47% of experts across both groups in the case of freight transport.

Hydrogen from renewable sources, for use in fuel cell vehicles, came in third on average, with experts from developed countries seeing it as somewhat more relevant for both passenger and freight transport than experts from developing countries. Due to its lower efficiency, hydrogen should only be used where direct electrification is not feasible.

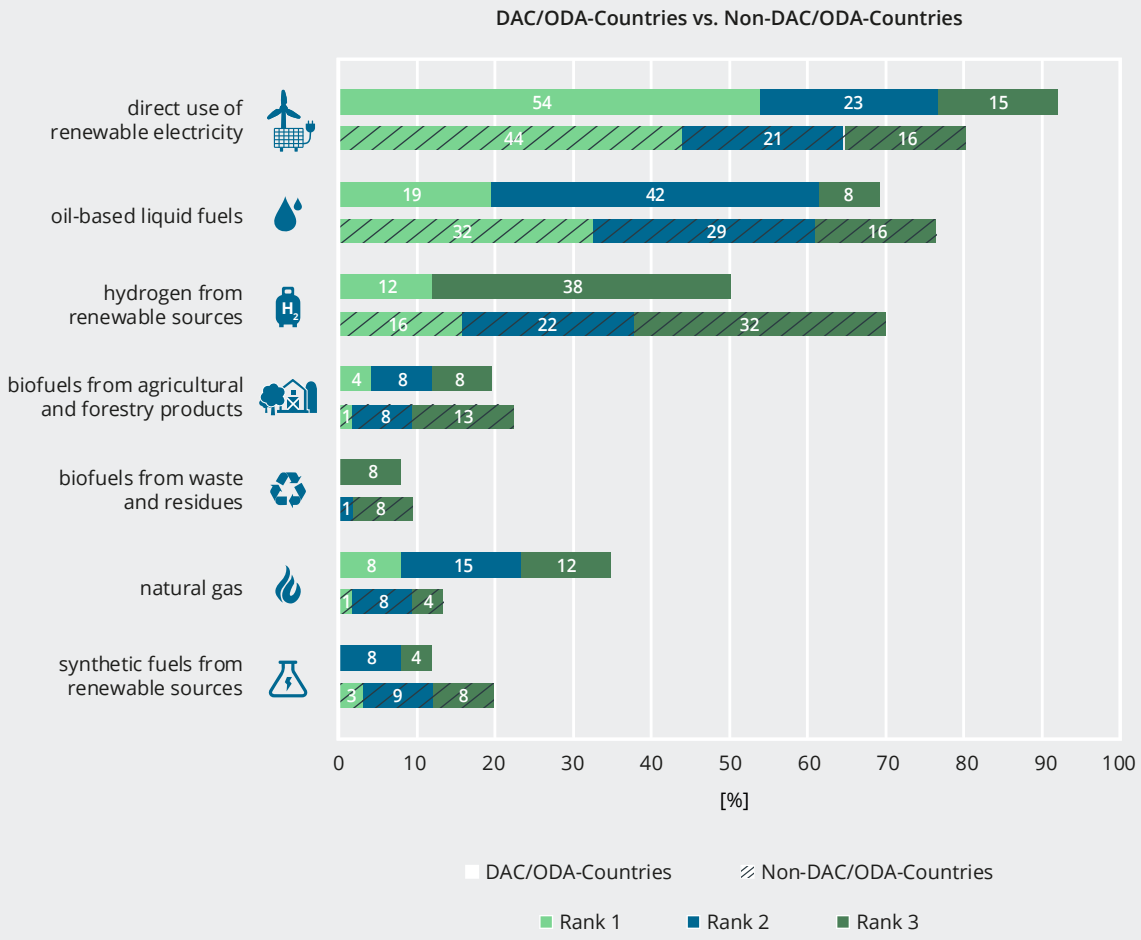
Nevertheless, experts assume that, until the transport sector is expected to have been decarbonised in the middle of the 21st century, oil-based liquid fuels will still have a role to play and

Figure 06 | Ranking of types of fuel with the biggest share in land-based passenger transport by mid-century



Representation based on the results of the T4<2°-Delphi survey

Figure 07 | Ranking of types of fuel with the biggest share in land-based freight transport by mid-century



Representation based on the results of the T4<2°-Delphi survey

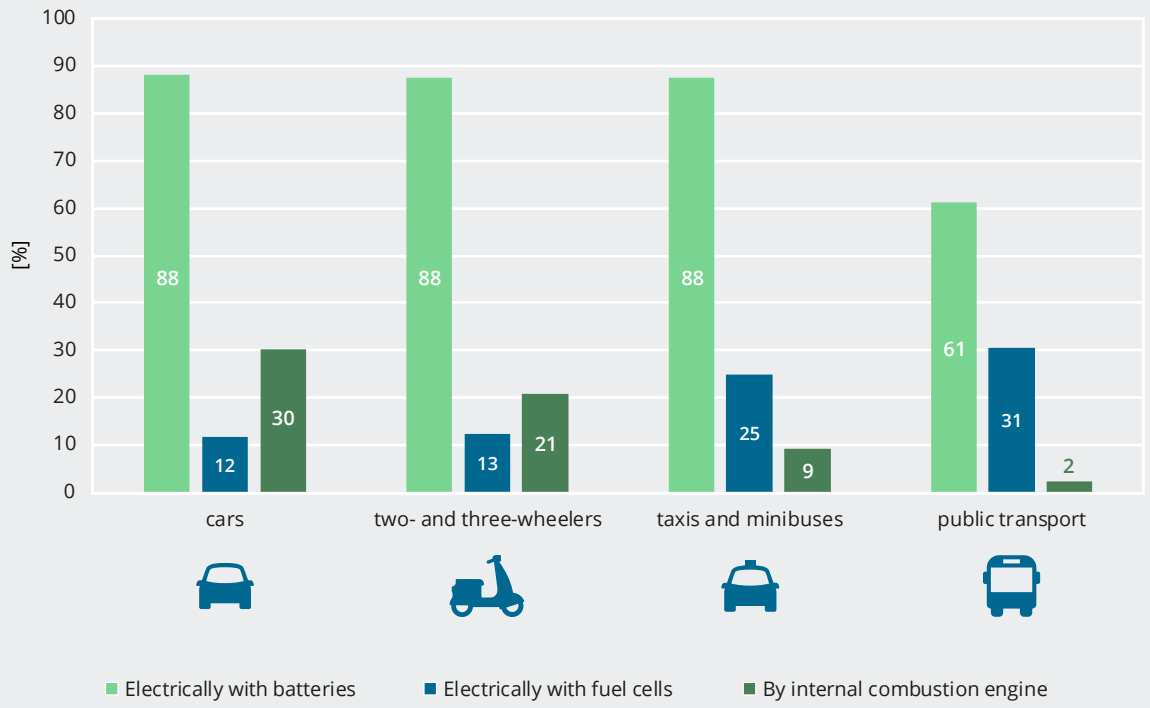
ranked it second across both groups. For land-based freight transport in particular, experts from developed countries see a more important role than experts from developing countries.

3.3.2 … in urban areas

In urban mobility, electricity is clearly seen as the most dominant power model across all modes, with public transport leading the field, followed by taxis and minibuses, two- and three-wheelers, and finally cars. This is not only due to electrified transport's contribution to the reduction of greenhouse gas emissions, but also in order to improve urban air quality.

When asked which of the two options for electrification will dominate – direct use via battery technology or indirect use as with fuel cell technology – experts were clear that battery technology is expected to take the lead.

Figure 08 | Power modes that will dominate urban transport by mid-century



Representation based on the results of the T4<2°-Delphi survey

Moreover, experts pointed out that different ownership and usage models of vehicles have varying potential and should be prioritised accordingly in the transition towards electricity-based urban mobility, with public transport, and taxis and minibuses being addressed primarily. For both segments, experts see almost no room left for internal combustion engines. Also, two- and three-wheelers are easy to convert to electricity as they do not necessarily require a public charging network but can also be charged domestically. Within the car segment, fleet vehicles in particular – as in the case of taxis and minibuses but also fleets owned by companies and administrations – have high potential due to their typically short trips within city limits on the one hand, and their high mileage use on the other hand, reducing total cost per kilometre driven. Additionally, this high mileage leads to a shorter lifetime of fleet vehicles along with a faster innovation cycle compared to private vehicles.

The expected vast deployment of electric battery technology in urban mobility goes back to cities' characteristics and urban mobility patterns: in densely populated urban areas, trips are rather short and at low average speeds. Hence, battery range and time spent on charging are less of a concern than in long-distance and inter-city trips. Also, the constant stop-and-go traffic plays in favour of electric drivetrains with their ability to accelerate very efficiently and recuperate energy under braking. Paired with the fact that an electric drivetrain produces zero local air pollution emissions and is low in noise, it represents the ideal technology for urban areas that are currently struggling with air- and noise pollution.

According to the experts, fuel cell technology will have a minor role to play in urban mobility, with somewhat more potential for public transport followed by taxis and minibuses. The fact that this technology is seen as less relevant in general, and particularly for cars, links to many uncertainties and concerns experts see regarding the production and cost of green hydrogen, and the cost of building widespread hydrogen infrastructure.

As in the overall energy mix for the transport sector, experts expect that – by mid-century – fossil fuel engines will still exist in urban mobility, most likely with cars (30%), to a lesser extent with two- and three-wheelers (21%).

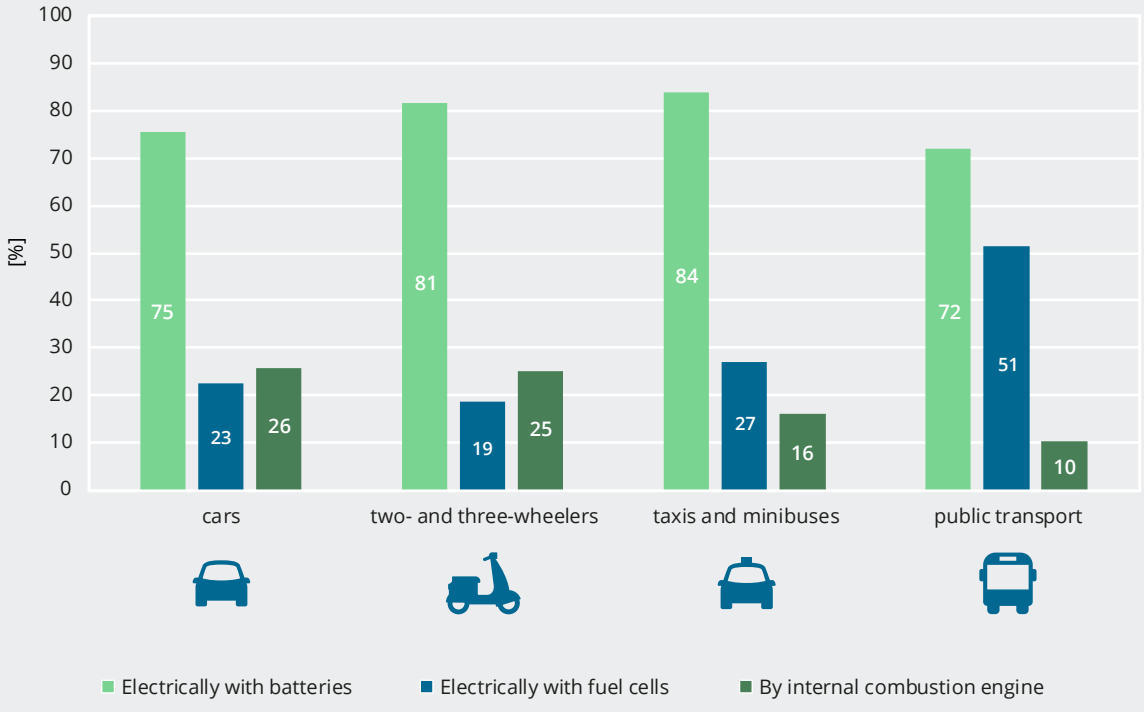
3.3.3 ... as well as in rural areas

For rural areas, experts expect that electricity-based passenger transport will be just as prevalent as in the urban setting.

Public transport in rural areas is also seen as having the strongest potential for conversion, followed by taxis and minibuses. Further, cars and two- and three-wheelers are expected to be electrified to almost the same level in rural areas as they will be in urban mobility.

When it comes to the different technologies for electrification, experts clearly see battery technology as the largely predominant solution. Yet, in rural areas, they expect a slightly bigger market share for fuel cell vehicles of all types, especially for public transport.

Figure 09 | Power modes that will dominate rural transport by mid-century



Representation based on the results of the T4<2°-Delphi survey

The somewhat more pronounced differing expectations regarding electric technology in rural areas link to the battery range and capacity, which still represents a challenge in the case of battery-electric vehicles (BEVs). In a rural environment, fuel cell vehicles have the advantage of a higher range capacity allowing for longer distances, and faster refilling, where the necessary new charging infrastructure is available.

In summary, these findings exemplify the need to deploy adequate infrastructure for electric mobility and the installation of necessary grid capacity in rural areas. With individual housing dominating in rural areas, some experts point out that the development of charging infrastructure can take a different path from urban areas and might need to focus more on decentralised energy production, for example through solar panels in individual homes.

3.3.4 Natural gas, biofuels and synthetic fuels will be of minor significance for land-based transport

The vast majority of the experts ranked natural gas, biofuels and synthetic fuels as less significant carriers of energy for land-based transport. Still, some experts from developing countries see a somewhat relevant role for natural gas in both passenger and freight transport. This links to the already existing use of gas in developing countries, particularly for long-distance transport through areas with no diesel supply. For experts from developed countries, where gas is insignificant, in 2050 it will not be a preferred source of power for land-based transport. These findings further encourage the current tendency of not introducing the widespread use of gas as an interim technology for particularly heavy-duty vehicles, but to move to electrification straight away.

In decarbonising land transport, biofuels from agriculture and forestry products, and – far behind – biofuels from waste and residue will be of minor importance, experts estimate. These expectations are shared almost equally by the interviewees from both developing and developed countries. At most, biofuels will play a supplementary role when added to fossil fuels in order to reduce their emissions impact. The reasons for this range from a lack of scalability and limited availability to concerns regarding the potentially negative sustainability impact of industrial-scale biofuel production. Many experts pointed out the adverse consequences of biofuel production on land use, food security and biodiversity. In order to mitigate these effects, ecological and ethical standards need to be defined and implemented on a global level.

Substituting fossil fuels by transforming electricity from renewable sources into liquid or gaseous energy carriers (power-to-liquid/power-to-gas) is also seen by the experts as less significant for land-based transport. The transformation of renewable electricity into these synthetic fuels results in high efficiency losses and costs compared to the direct use of electricity. Therefore, synthetic fuels will only be used if there is no other opportunity for powering a mode of transport, as might be the case for maritime freight transport or aviation.

IMPACTS OF ENERGY FROM AGRICULTURAL BIOMASS

Over the last decade, energy production from agricultural biomass has proved to have severe consequences in many parts of the world, particularly in developing countries. Large-scale deforestation in favour of biomass projects has led to a counterproductive loss of carbon sinks, and dramatically reduced biodiversity and resilience towards climate change.*, ** Use of land and water for energy instead of food production is exacerbating food insecurity and depriving small-scale farmers of income, even of their land. Hence, if not regulated, these fuels can be a potential threat to overall sustainable development.

* Curtis, P., Slay, C. M., Harris, N. L., Tyukavina, A., & Hansen, M. C. (September 14, 2018). Classifying drivers of global forest loss. Science, 361(6407), 1108–1111. doi: 10.1126/science.aau3445

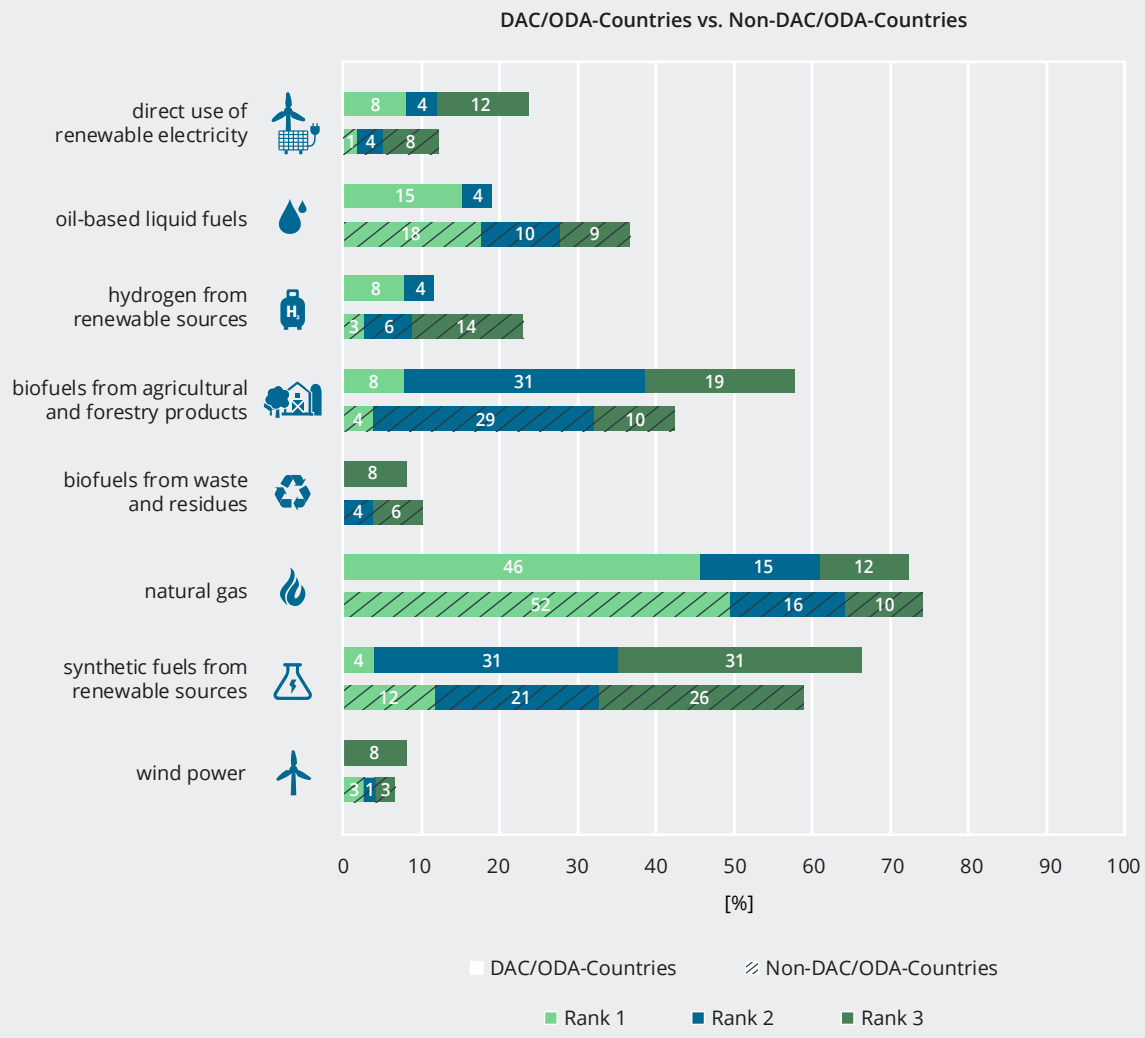
** Muzi, N., & Transport and Environment. (January 24, 2019). Palm oil and soy oil for biofuels linked to high rates of deforestation – new study. Retrieved from www.transportenvironment.org/press/palm-oil-and-soy-oil-biofuels-linked-high-rates-deforestation-new-study

For the following findings concerning the usage of fuel in maritime transport and aviation, it is important to add that the industry is currently working on various promising options to provide zero-carbon fuel for both the maritime and the aviation sector. The field of alternative fuels in a sector that relies on high-energy density and output is currently very dynamic and innovation-driven, making a reliable forecast on a leading energy carrier difficult. Thus, the statements made by the experts are to be interpreted in the context of the relevant options that are currently available, without ruling out that alternative zero-carbon solutions might become plausible in the near-future.

3.3.5 Opinions on how to decarbonise maritime transport are diverging

While the future clearly seems to be electric in land-based transport, experts were less united in their predictions for maritime transport. Many stated that they regard it as highly unlikely or even impossible to find a way – by mid-century – to power the massive and energy-demanding maritime vessels directly with renewable electricity, for example from wind power. Therefore, the aim must be to establish the most efficient standard possible for the remaining energy sources and drivetrain technologies. On the basis of the currently available options, most of the respondents see natural gas as the dominating

Figure 10 | Ranking of types of fuel with the biggest share in maritime transport by mid-century



Representation based on the results of the T4<2°-Delphi survey

source of energy for the shipping industry, with 46% of experts from developing and 52% of experts from developed countries ranking it first. Oil-based liquid fuels are still seen as the dominating power source by 17% of the experts.

Synthetic fuels from renewable energy sources and biofuels from agriculture and forestry are seen as second and third options to power maritime freight, even though a large share of experts remain sceptical about biofuels and synthetic fuels, as mentioned above.

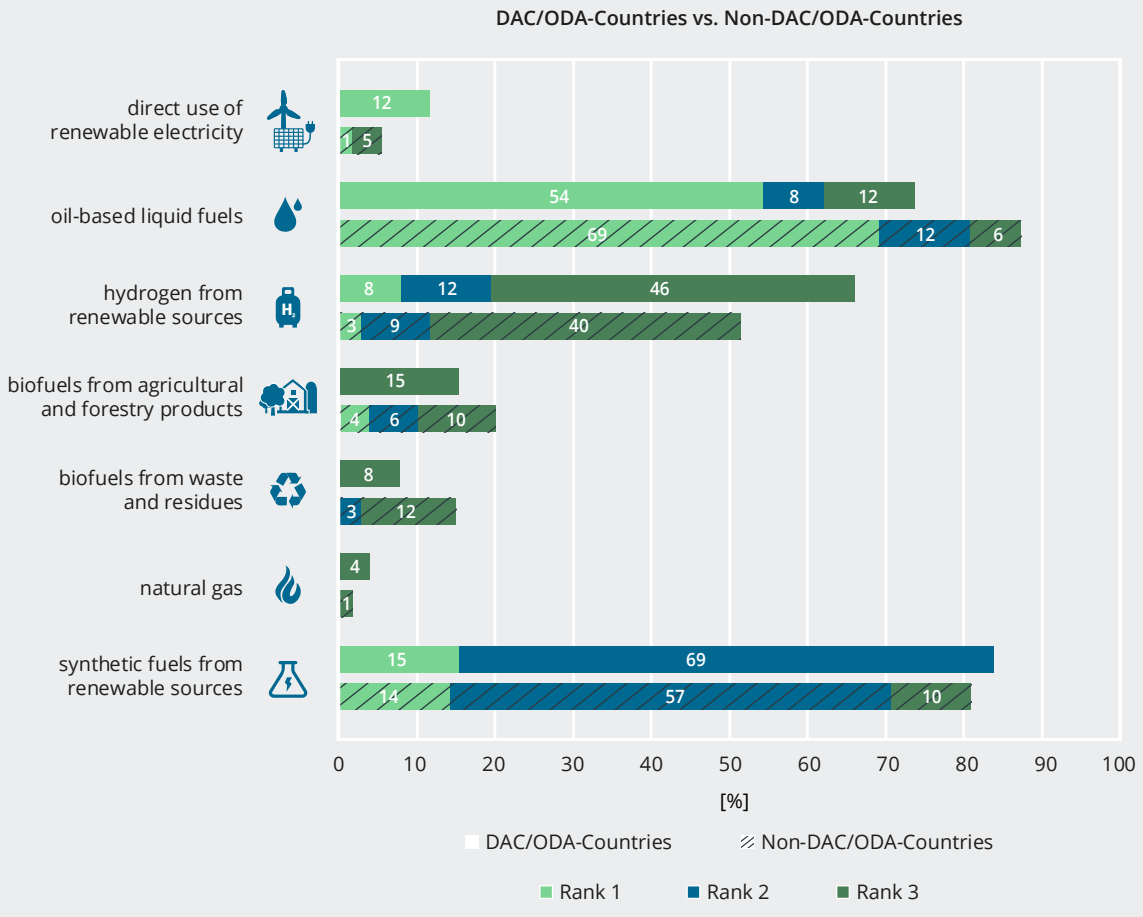
Just as with the direct use of electricity from wind power, hydrogen from renewable sources is seen as less significant in maritime freight.

3.3.6 Aviation will require the most ambition

It comes as no surprise that the aviation sector will be the biggest challenge in decarbonising the transport sector. This is first and foremost due to the high energy output and energy density needed to power large aircraft, which electric batteries most likely cannot provide in the foreseeable future.

Hence, the majority (65%) of international experts consider fossil oil-based liquid fuels still to be the major source of energy to power aviation by mid-century. Synthetic fuels from renewable sources closely follow, with 60% of experts across both groups ranking it second. Hydrogen based on renewable electricity comes in third, with an average of 42% of experts expecting it to dominate in aviation. Biofuels from agriculture and forestry come in fourth but far behind the first three. Direct use of renewable electricity is clearly seen as a minor solution for long-haul aviation due to the challenges of battery capacity and battery weight. With the ongoing development of battery-electric technology for short-haul planes, direct use of electricity may also have its contribution to make in aviation.

Figure 11 | Ranking of types of fuel with the biggest share in aviation by mid-century



Representation based on the results of the T4<2°-Delphi survey

As stated at the beginning of this chapter, energy efficiency is an important pillar for the decarbonisation of the transport sector. It cannot only be achieved through the improvement of fuels and vehicles; to a greater extent it needs to be achieved by configuring transport as a system and by avoiding energy consumption in the first place. For aviation, the high energy intensity and strong dependency on oil-based liquid fuel requires more debate on how much flying is actually necessary, and how much flying can be avoided through high-speed and night trains, and virtual meeting solutions.

3.4 Public transport, active modes of transport, shared mobility services as well as sustainable urban planning will be the backbone of climate-friendly urban transport

3.4.1 Cities are shaping the global transport climate

By 2050, 70% of a total population of 9 billion people[17] are expected to live in cities.[18] Already today, 40% of transport emissions are generated in cities. If urban mobility continued to be highly car- and fossil fuel dependent, expected urban growth would add another 26% to global CO_2 emissions.[19]

> **"We really need to re-embrace this idea that the city in itself is a transport solution."**
>
> (Executive Director,
> Research Institute for Economics and Political Science)

Cities' role in shaping mobility cannot be overestimated. They are already taking ambitious steps as the urban population suffers most from the negative effects of inefficient and unsustainable transport. Issues that need to be addressed are, for instance: pollution, congestion, accidents, inclusivity of transport systems and the allocation of public space. We are seeing a growing number of city governments regulating urban access for polluting vehicles through the introduction of low- and zero-emission zones, reducing space for cars, banning cars entirely, or prioritising more efficient modes of transport. As test beds for innovative projects including active modes of transport, forms of sharing and pooling, multimodal integration and last-mile delivery, they set examples and make valuable contributions, not only to their own mobility system, but to the transport sector's overall transformation.

> **"Transformation [of the transport sector] will be propelled by cities, regions and coalitions of cities."**
>
> (Expert contribution during Delphi Study)

Powerful city alliances are able to send strong signals internationally, building awareness and momentum for broader change. This explains why 80% of the surveyed experts ("agree" and "strongly agree" combined) see cities and coalitions of cities as main political actors shaping the future of transportation worldwide. Dedicated fora for discussions on transport amongst cities

17 United Nations. (2019, June 17). Growing at a slower pace, world population is expected to reach 9.7 billion in 2050 and could peak at nearly 11 billion around 2100. Retrieved from https://www.un.org/development/desa/en/news/population/world-population-prospects-2019.html

18 The World Bank Group. (n.d.). Inclusive Cities. Retrieved from https://www.worldbank.org/en/topic/inclusive-cities

19 International Transport Forum. (October 2018). Policy Priorities for Decarbonising Urban Passenger Transport. Retrieved from www.itf-oecd.org/sites/default/files/docs/policy-priorities-decarbonising-urban-passenger-transport_0.pdf

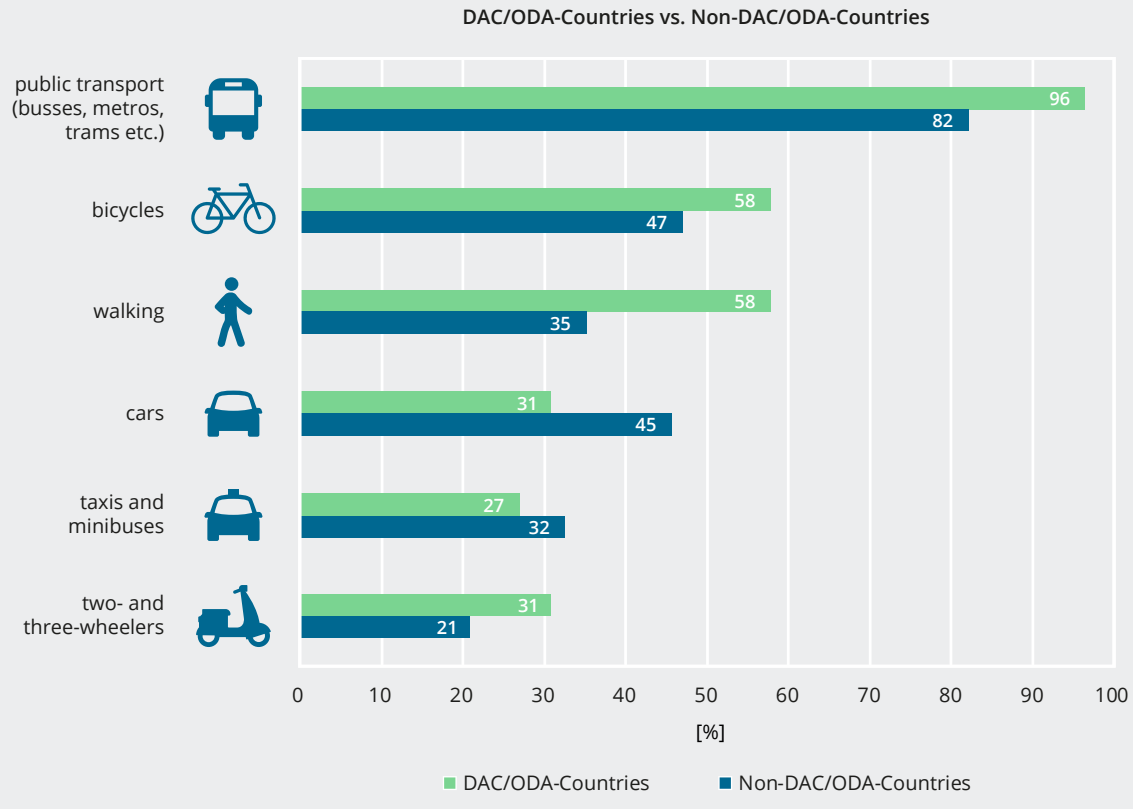
need to be further promoted so they can share their experiences and help accelerate the transformation of transport.

How cities shape their urban mobility systems will thus be essential, for the decarbonisation of the transport sector and for the sector's overall sustainable development. Four key elements will help to make urban mobility a pillar of transport's transition: public transport, active modes of transport, sharing and sustainable urban planning.

3.4.2 Public transport and active modes of transport will be the backbone of urban passenger mobility

Public transport has the best capacity to move a large number of people with low energy consumption, emissions and space use per capita. With its offer to be mobile without having to own a car, public transport makes mobility socially more inclusive. As it can be deployed most efficiently in densely populated areas, its planning needs to be integrated with city planning as a whole. Together with its great potential for electrification, public transport's vast deployment is a central pillar of the decarbonisation of the transport sector.

Figure 12 | Transport modes that will dominate urban transport by mid-century



Representation based on the results of the T4<2°-Delphi survey

As shown below, 82% of experts from developed countries and even 96% of experts from developing countries state that public transport will be the dominant mode in decarbonised urban mobility in 2050.

Active mobility is not only the most efficient in terms of energy consumption, emissions and use of space, it is also the most economically accessible form of mobility, allowing people to be mobile regardless of their income. This especially applies to walking – the poorest walk most. For sustainable urban mobility, walking and cycling are essential stand-alone modes for short and very short trips; but they are also key to providing access to public transport and will thus play a crucial role in an efficient multimodal mobility system.

In line with this, 50% of the experts expect cycling to be the dominant mode in future urban mobility, with even stronger support from experts from developing countries (58%) than experts from developed countries (47%). Walking is considered as important as cycling with experts from developing countries (58%), but less important with experts from developed countries (35%).

Beyond mobility, both cycling and walking offer great health benefits and can lower the societal cost of the so-called "lifestyle diseases", making a major contribution to sustainable development in general.

3.4.3 Urban mobility will have less room for motorised vehicles …

Individually used motorised vehicles come with a high energy consumption per capita, and – if powered by carbon fuels – with high emissions. Also, they occupy more space – in use and when parked – compared to public transport or active modes such as cycling or walking.

When the experts were asked which modes will dominate in a decarbonised urban mobility system, cars, taxis, and two- and three-wheelers were stated well behind public transport and active modes.

Regarding motorised two- and three-wheelers, 31% of experts from developing countries stated that they would become a dominant mode, compared to 21% of experts from developed countries. These differences most likely relate back to the fact that, already today, two- and three-wheelers are a large part of urban transport in developing countries, mainly because they are more affordable and quicker than cars – and because public transport is underdeveloped. Driven by internal combustion engines, two- and three-wheelers have proven to be a notable source of air and noise pollution in many cities in developing countries. These negative effects, however, can be overcome easily with electrification. Together with their affordability, comparably low energy consumption and efficient space use, two- and three-wheelers can still play a role in sustainable urban mobility in 2050.

Furthermore, 31% of international experts stated rather equally that taxis and minibuses will be a dominant mode in urban mobility. These modes of transport will, first and foremost, have to provide connectivity where public transport cannot be deployed efficiently. That is especially the case in smaller quarters, less densely populated areas and on the outskirts of cities.

Individually used cars are the least sustainable mode in terms of energy consumption, emissions (if powered by non-renewable fuels), space use, road safety and social equity. Nevertheless, a considerable share of experts expects them to be a dominant mode in decarbonised urban mobility in 2050: 45% of experts from developed countries and 31% of experts from developing countries. If this is a minor but still relatively big group, experts largely agree that the remaining cars will need to be shared.

3.4.4 … and will need to make more use of sharing

In European cities, cars have reached an average occupancy rate as low as 1.7[20] and are not used for about 85% of the time. However, most of the road space is usually dedicated to cars. In the urban context, the performance of cars in terms of sustainability is lowest in all dimensions – economically, environmentally and socially. As well as the need to reduce overall energy consumption, sustainable development in the transport sector is faced with the challenge of individual ownership and respective use of cars – even if they are electrified.

In line with the figures above, the interviewed experts made clear that vehicles, particularly the remaining cars, will have to be shared.

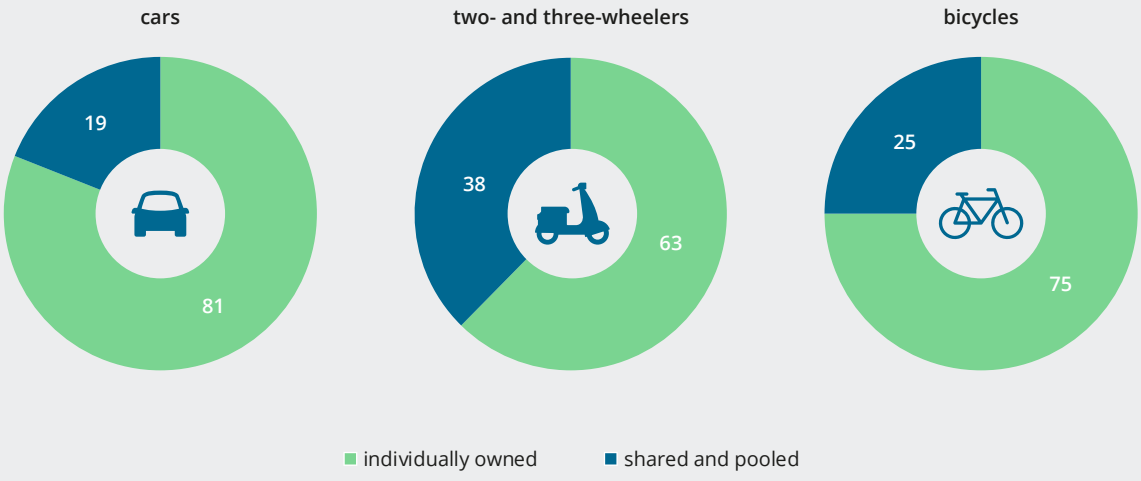
> **"New and shared mobility will be key. Without public regulation, this can be more attractive than public transport. It's good when it allows the first and last mile options to be more attractive or to replace cars by bicycles, scooters, or shared vehicles."**
>
> (Senior Professional, Global Research Organisation for Climate, Energy and Transport)

Despite this, the vast majority of experts (88% from developing countries; 80% from developed countries) expect that the remaining cars will be individually owned rather than shared or pooled.

These findings point to a major obstacle on the way to a decarbonised transport sector and call for policies and interventions that will make car sharing and pooling more likely to happen.

20 Fiorello, D., Martino, A., Zani, L., Christidis, P., & Navajas-Cawood, E. (2016). Mobility data across the EU 28 member states: results from an extensive CAWI survey. Transportation Research Procedia, 14, 1108.

Figure 13 | Ownership models for urban mobility



Representation based on the results of the T4<2°-Delphi survey

"We need policies that encourage pooling and sharing."

(Researcher at Transportation Sustainability Research Center)

The broader adoption of shared and pooled cars can be supported through the definition of legal and fiscal frameworks that incentivise the expansion of existing as well as the evolution of new sharing models. The goal should be to create comprehensive multimodal mobility networks, which form a link between public and private transport and enable users to determine an optimal combination of various mobility options without relying on vehicle ownership. These multimodal services require integrated trip planning and pricing, thus enabling seamless interconnection between public and private modes, similar to concepts of Mobility-as-a Service "MaaS". Ultimately, their usability will depend on whether they can be easily accessed and are available at the right time and in the right place.

Bicycles and two- and three-wheelers have a particularly high potential within these multimodal networks, as they are easy to integrate into sharing models and are an effective last-mile connector. Thus, for two- and three-wheelers, experts showed the strongest tendency towards a predominately shared use, with 50% of them from developing countries and 31% from developed countries.

THE ROLE OF PASSENGER AND FREIGHT DRONES

Drone technologies for freight and passengers are being increasingly tested and advertised. It is true that there is an important role for drones, especially in disaster relief and during times of crisis, when critical products have to be provided quickly and areas are too difficult to access. Also, they can be a solution to deliver goods to less developed and sparsely populated areas, where no other mode can be efficiently deployed.

Given their high energy consumption per unit or passenger carried, drones will – even if the many questions regarding security, use and regulation of urban air space were solved – most likely stay a niche technology. In this survey, only 9% of international experts expect cargo drones to become relevant in both urban and rural mobility. Only 6% believe that passenger drones will play an important role in urban mobility, and 2% in rural transport.

If drones are deployed, the majority of experts expect passenger and cargo drones to be 100% electric.

MICROMOBILITY

Micromobility refers to any very light-weight vehicle suitable for short-distance trips, mainly as part of an on-demand sharing concept and – if motorised – electrified. The term is usually used for bikes with various sharing schemes, with a docking station or dockless, for e-scooters and marginal vehicles like monowheels.

Particularly in urban mobility, micromobility can add to the mode choice and cover first- and last-mile connectivity as part of a flexible, multimodal and car-free transport system based on public transport. However, past experience has shown that it does not come without challenges; more assessment is required in order to understand and shape several elements. First, its impact on travel demand: does micromobility create trips that otherwise would not have been taken? Second, on mode choice: to what extent does micromobility replace more or even less energy- or carbon-intensive modes? Third, and in consequence of the first two, on its deployment: how can cities best regulate and integrate the use of micromobility as part of a multimodal transport system and car-free lifestyles? Often, a common language to classify these vehicles and services is still missing. This also contributes to vague or missing regulation*.

Micromobility, facilitated by mobile communication technologies, undoubtedly has a role to play. But ultimately, this role must be regulated to ensure it is integrated in the broader picture of urban mobility and shaped to contribute to the greater sustainability of the transport sector.

* Chang, A., Hawa, L., MacArthur, J. (January 2020): Micromobility needs a shared vocabulary. Retrieved from https://thecityfix.com/blog/micromobility-needs-shared-vocabulary-leila-hawa-annie-yj-chang-john-macarthur/

3.4.5 Urban planning in line with sustainability objectives is essential

Targeted urban planning is essential to limit urban sprawl and to reduce traffic volume. Mixed-use zoning blends residential, commercial and/or industrial uses in a single district and enables different modes of transport to coexist in the same public space.

Of the participating experts, 31% assessed mixed-used zoning as being most effective to achieve transport sector decarbonisation, especially experts from developing countries – 55% of them expressed strong support for mixed-use zoning.

Although the construction of urban areas in many low- and middle-income countries of the Global South is underway, it will not have been completed by 2050.[21] These areas in particular have the potential to shape their urban mobility based on integrated city planning that can offer attractive and sustainable urban lifestyles.

In developed countries, urban growth has slowed down and land use has largely been locked in over the past decades.[22] However, cities are under constant transformation and offer important opportunities to influence transport demand and mobility behaviour through the (re-)allocation of space and repurposing of buildings and areas.

> **"Much of the existing overbuilt capacity for motor vehicles can be refitted for more sustainable purposes."**
>
> (Professor of Science, Technology and Society)

Some cities around the globe have begun to reduce space for cars, both road and parking space, and to reallocate it to more efficient and sustainable modes. Examples show how the additional provision of infrastructure for public transport and active modes in combination with actively reduced attractiveness for the use of private cars could lead to shifts towards more efficient modes of transport, and improved access for all groups of society.

Among the many different types of urban vehicle access regulations, the implementation of low or zero emission zones as part of integrated city- and transport planning is an incremental step towards emission-free cities. In the survey, 36% of experts from developed countries and 46% of those from developing countries indicated that they consider zero-emission zones as one of the most effective tools towards transport decarbonisation. The chances that decision-makers will implement them are seen rather positively: 44% of experts from developed countries and 54% from developing countries expect them to be implemented – as we are already seeing today.

21 United Nations. (2019). World Urbanization Prospects: The 2018 Revision. p. xix. Retrieved from population.un.org/wup/Publications/Files/WUP2018-Report.pd

22 ibid. p. 23.

3.5 The development of alternative drive technologies demands increased attention in rural areas without ruling out new mobility options

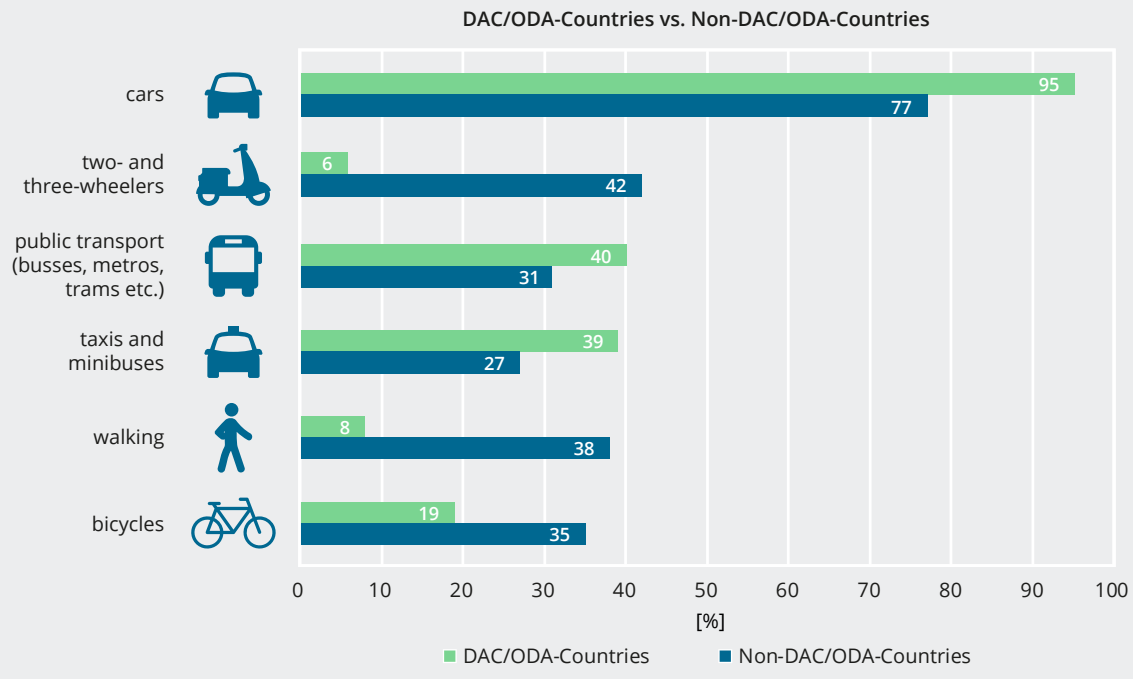
Just like urban spaces, rural areas have their challenges in mobility: low population density and scattered transport demand present challenges for traditional public transport systems. Furthermore, longer distances considerably limit the number of trips that can be done by bike or on foot.

With these prerequisites, and the prevailing car dependency in developed countries, 90% of experts – 77% in developing countries and 95% in developed countries – expect that cars will also be a dominant mode of transport in rural areas in 2050.

Public transport, and taxis and minibuses are considered as the dominant mode by 38% and 36% respectively, followed by cycling (23%), walking (16%) and two- and three-wheelers (16%). These assessments, however, differ substantially between developed and developing countries. In developing countries experts consider two- and three-wheelers (42%), walking (38%), bicycles (35%), public transport (31%), and taxis and minibuses (27%) more equally in terms of importance. In contrast, developed countries consider two- and three-wheelers (6%), walking (8%) and bicycles (19%) to be less prevalent, while public transport (40%), and taxis and minibuses (39%) are considered to have a more dominant role in rural transport.

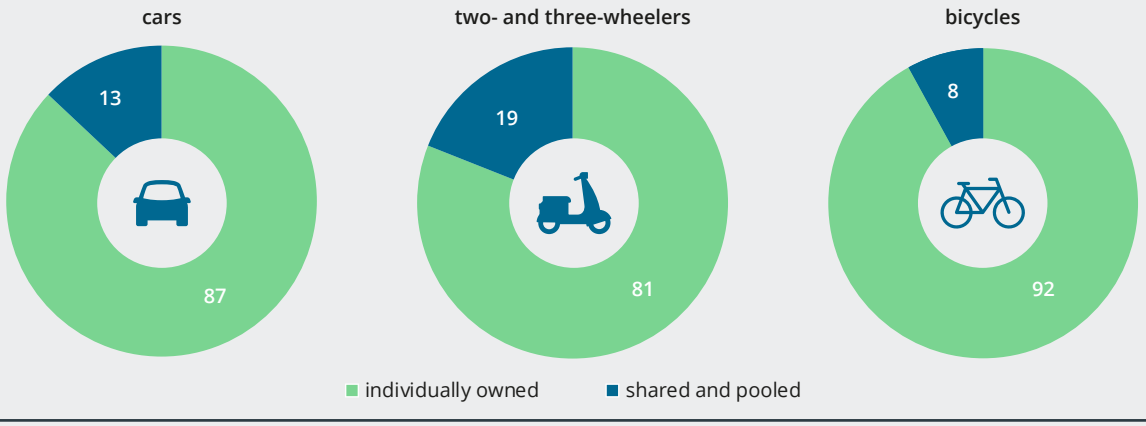
Furthermore, experts still expect a clear dominance of individually owned vehicles in rural areas by mid-century, whether bicycles, cars or two- and three-wheelers. However, (potential)

Figure 14 | Transport modes that will dominate rural transport by mid-century



Representation based on the results of the T4<2°-Delphi survey

Figure 15 | Ownership models for rural mobility



Representation based on the results of the T4<2°-Delphi survey

rural car dependency in both developing and developed countries deserves a closer look. While most developed countries have decent road networks in rural areas, mobility in rural areas in developing countries is still considerably limited through a lack of access to all-weather roads. For the transition towards a more sustainable transport sector, this lack presents challenges and opportunities at the same time: with little infrastructure in place, the design and construction of new roads must be conceived as one element of mobility, not as the only element. Just like urban mobility, rural mobility is to be developed as an integrated system that considers the actual transport demand of the local population and the adequate mode of transport. Plus, the local system needs to be integrated efficiently with regional and national passenger and trade flows.

With currently very low motorisation and limited supplies of fossil fuels in place, rural areas in developing countries also have the potential to leapfrog directly to the use of electricity from decentralised and renewable – most likely solar – sources, omitting the use of and dependency on fossil fuels.

Additionally, developed countries with an already established car dependency in rural areas are facing challenges that go beyond decarbonisation. Amongst these are limited access, especially for the elderly, children and physically or mentally challenged people; the requirement to invest in a second, even third vehicle to meet a household's transport demands; the negative impact on cities that receive large numbers of commuters from surrounding car-dependent rural areas, and thus additional congestion and pollution. Recently, an increasing number of smaller villages and regions have tested and adopted new solutions to strengthen rural mobility. These include community-based car-sharing models, sharing of the public fleet with citizens, transport-on-demand services operated jointly by several villages, low-capacity public transport to connect to larger transport hubs and autonomous shuttles providing last-mile connectivity.[23] Solutions exist in many areas; they just need adequate support in order to be deployed.

23 More examples on SMARTA. (2020). Smart Rural Transport Areas. Retrieved from: ruralsharedmobility.eu/

3.6 Digitisation and autonomous driving need a comprehensive political framework in order to support the decarbonisation of the transport sector

Digitisation in- and outside of the transport sector has the potential to contribute to the sector's transformation towards sustainability. It could help avoid unnecessary trips in the first place, reduce the need for car ownership, reduce per capita and per ton energy consumption, improve road safety, and it could lead to better access for marginalised groups such as children, the elderly, and physically and mentally challenged people.

Applications that could help to harvest these benefits range from the digitisation of public and private sector services, the integration of renewable energy systems and transport (smart grids, decentralised renewable energy production, vehicle2grid technologies), smart trip planning and seamless multimodal integration, capacity-induced pricing models, intelligent supply chain management and – potentially – the deployment of connected, shared and automated vehicles.

The current trend towards zero marginal costs and flat rates in the digital world is expected to propel the broad adoption of these digital technologies, giving them the potential to lead to disruptions inside and outside the transport sector.

However, the actual contribution of many digital technologies to a decarbonised and more sustainable transport sector remains uncertain. The majority of experts expect to see adverse effects resulting from an uncontrolled and increased use of digital technologies, which need to be avoided through adequate policy interventions and regulations.

> **"Digitisation certainly can help, but whether it will help – and how much – depends on how it unfolds."**
>
> (Expert contribution during Delphi Study)

Their biggest concern relates to data privacy. Of the international experts, 74% expect that digitisation in the transport sector will cause problems related to data privacy, while only 4% expect digitisation to cause few or no problems.

> **"We increasingly are seeing the loss of privacy through MDS [Mobility Data Specification], facial recognition, the use of cameras for many transportation related things. We are moments away from losing the right to anonymity on our streets. I believe there are many other ways we can achieve desired results without establishing a surveillance system."**
>
> (Expert contribution during Delphi Study)

The second concern is a significant rise in energy consumption from data processing. Of the participating experts, 58% expect this to happen whereas only 7% disagree (36% being unsure). This rise in energy consumption could even be exacerbated by the (unregulated) deployment of autonomous vehicles that would create additional kilometres travelled and hence increased energy consumption per capita.

As to whether digitisation will reduce the urban and rural divide or have a positive effect on social equity, 46% and 51% of experts respectively are unsure. While 19% expect that digitisation will reduce disparities between urban and rural areas, 34% have low expectations. Looking at the impact digitisation has on social equity, 29% of the respondents are not expecting to see positive changes, while 19% are more optimistic.

Figure 16 | Digitisation in the transport sector will ...

	not at all 1	2	3	4	5	6	7	8	9	10	very much 11
increase demand for international governance	1%	3%	2%	4%	2%	16%	23%	22%	16%	11%	0%
contribute to a decrease of greenhouse gas (GHG) emissions	0%	8%	6%	8%	10%	21%	18%	12%	13%	1%	2%
increase social equity	3%	6%	10%	10%	18%	20%	13%	12%	3%	1%	3%
close the urban-rural divide	4%	6%	8%	16%	13%	17%	16%	11%	5%	2%	1%
give rise to significant energy consumption in data processing and transmission	0%	0%	3%	4%	7%	15%	14%	18%	12%	19%	9%
cause problems related to data privacy concerns	1%	1%	1%	1%	2%	12%	9%	11%	22%	22%	19%

Representation based on the results of the T4<2°-Delphi survey

This complements the findings on the overall effect of decarbonisation of the transport sector on social equity. Without specific regulations, a more just system will not be achieved.

> **"Regulations need to ensure a social and just development of new [digital] services."**
>
> (Professor of Transport Planning and Economics)

Regarding the contribution of digitisation to a reduction in greenhouse gas emissions, the findings show a similar indecisiveness from the side of the experts. While 22% of respondents do not expect digitisation to play a role, 29% very much do. Almost half of the respondents (49%) are unsure.

In many cases, experts commented on their answers, stating that the contribution of digitisation will largely depend on how it will be used, what business models will be applied and what regulations will be implemented.

> **"Whether digitisation will lead to an increase or decrease in GHGs [greenhouse gases] depends on if we use it to increase or decrease vehicle miles travelled, vehicle occupancy or vehicle size."**
>
> (Expert contribution during Delphi Study)

In support of this need, 49% of responding experts expect an increased demand for international governance regarding digitisation in transport. Only 10% expect very limited or no need for more international policy frameworks.

In conclusion, digitisation has the potential to make the transport sector more sustainable.

To leverage this potential, however, clear policy frameworks ensuring a just and secure deployment of these technologies are needed, at both national and international levels. Policymakers will need to keep up to date with the rapidly changing digital world, analysing its potential impact on and value added to the sustainability of the transport sector.

However, two topics provoked debate and concern: autonomous vehicles and data governance. These will now be discussed in more detail.

3.6.1 Autonomous vehicles must be shared

Over recent years, industry has worked on developing and deploying vehicles with automated driving features, with the goal of eventually deploying fully autonomous, self-driving vehicles (AVs). These vehicles come with the promise to improve access and increase efficiency and road security. However, experts are rather unsure whether AVs will contribute to sustainable transport, considering them as both an opportunity and a risk. In their view, any actual benefit will largely depend on how they are deployed.

> **"The holy grail (...) is the completely autonomous vehicle and it can either be a chance for sustainability or turn out to be disadvantageous, depending on the decisions made now."**
>
> (Founder and CEO, Electronic Manufacturing Company)

When asked about the relevance of AVs in future mobility systems, 40% of experts expect them to play a significant role in road passenger transport. 48% expect them to neither play a significant nor insignificant role and 14% do not expect AVs to play a significant role. However, only 20% expect them to dominate the vehicle market. These results reflect the great uncertainty that is still associated with the development of autonomous vehicles.

Regarding the three key promises of AVs – access, efficiency, safety – interviewees raised doubts as to what extent these promises can be kept.

On the positive side, 46% of experts expect AVs to improve road safety. However, 41% are unsure and 15% are not expecting AVs to play a role in the reduction of road accidents.

In terms of the negative effects of AVs, 55% of experts anticipate an increased transport volume. Only 7% of the experts do not expect to see this. Furthermore, 41% expect to see an increased urban sprawl, while 50% are unsure and only 11% do not expect this. As passengers can make effective use of the travel time while being on board, and as riding an AV may be more appealing than public transport or active modes, distance and time becomes less of a factor in travel choices, leading to additional kilometres travelled. Ultimately, this would entail more congestion and higher energy consumption per capita through both vehicle powering and data processing, clearly offsetting other gains in efficiency, like optimal routing.

Moreover, there is a strong opinion amongst experts that the discussions around AVs is very much driven by industry's interests, not by the actual benefits that come with them. Conflicts of interest between industry and sustainable mobility were mentioned in several respects from some experts during the qualitative interviews. With the current business model of the automotive industry being the sale of cars – not mobility – its objectives cannot be aligned with transport transformation's objective of reducing the number of cars on the road and providing mobility without car ownership.

Figure 17 | By mid-century autonomous vehicles (AVs) will …

	not at all 1	2	3	4	5	6	7	8	9	10	very much 11
dominate the vehicle market	7%	4%	8%	11%	20%	22%	8%	8%	6%	2%	4%
play a significant role in road passenger transport	1%	2%	6%	5%	15%	14%	19%	15%	10%	6%	9%
have increased urban sprawl	2%	2%	3%	4%	10%	23%	17%	20%	10%	6%	5%
be all shared and pooled	7%	1%	6%	18%	13%	19%	11%	12%	8%	5%	1%
have increased transport volumes	1%	1%	1%	4%	5%	16%	18%	23%	16%	11%	5%
have narrowed the urban-rural divide	10%	9%	4%	14%	13%	25%	16%	7%	3%	0%	1%
have increased social participation of children, older people and disabled persons	3%	1%	2%	5%	6%	18%	29%	16%	13%	3%	5%
have increased social participation of economically disadvantaged persons	3%	9%	7%	10%	17%	23%	14%	10%	3%	2%	3%
have reduced road injuries and deaths	2%	1%	2%	10%	5%	17%	19%	14%	15%	10%	7%
be provided by the state rather than by private entities	17%	13%	17%	9%	9%	27%	1%	6%	2%	1%	0%

Representation based on the results of the T4<2°-Delphi survey

"The main thing is to get people out of the car, not just out of the driving seat."

(Professor of Transport and Economics)

A future business model might be to offer new digital services on board. However, it might then be of value to the industry to have passengers spend as much time as possible in a car, jeopardising the successful implementation of avoid (unnecessary trips) and shift (to more efficient modes) strategies.

"Many companies in the tech and auto sectors are striving hard to deliver a future of greater car dependence, greater time spent in cars [...] Probably far worse [than data privacy issues] is the mere profitability of the data generated, which will give companies every reason to induce people to spend more time in vehicles."

(Expert contribution during Delphi Study)

Another concern is that AVs could come at a price that will not be affordable for large parts of society, and thus increase social divides rather than improve access.

Some experts expressed their concern that the discussion on more sustainable transport systems is even being distracted by the car industry's communication efforts, and that more sustainable, socially equitable, low-tech and therefore less expensive alternatives may be overseen by decision-makers.

Key to mitigating AVs' potentially negative effects while harvesting their positive contribution to a more sustainable transport system, as experts emphasise, is their shared use. Only if deployed as shared and pooled fleets, not as private cars, will AVs play a part in achieving more sustainable mobility: when contributing to fewer cars on our roads, better access to mobility regardless of car ownership, and more efficient use of energy through higher load factors.

However, the experts are still undecided whether AVs will be shared and pooled in the future. They point to the currently absent, but urgently needed, policy dialogue that addresses autonomous vehicles beyond street testing permissions and still unresolved safety issues.

"Whether AVs will cause sprawl, or increase traffic volumes, be shared and pooled, these are all futures that are wholly in the hands of local and national policymakers. We can completely shape these outcomes. However, absent effort, the status quo definitely takes us to these worse possibilities."

(Expert contribution during Delphi Study)

3.6.2 Global standards for data privacy are necessary

The deployment of smart transport solutions undoubtedly requires the collection, use and exchange of data. With just a few companies dominating the digitisation of the sector and deploying their technology well beyond national borders, data security, dependency on foreign providers (e.g. mapping services, autonomous driving, digital infrastructure) and exchange of data have already proved to be of concern. Data privacy currently means different things to different countries, and cyber security still is a major intellectual and commercial challenge.

At the same time, a sustainable digitisation of the transport sector can only happen if the data of those using the services is not being abused, anonymous data is made publicly available and is not in the hands of a few companies, and if the distrust of those who refuse to use digital services can be reversed. Furthermore, digitisation must not become a barrier for those, who are incapable of using new services due to a lack of access or limited digital competence.

An increased digitisation of the transport sector will require stronger international coordination and ultimately rely on global standards for data privacy. In this field, Europe has shown strong engagement and could take the lead, defining standards for both digital services and digital infrastructure for its own markets, and driving negotiations at an international level.

Ultimately, digitisation deployment should not be driven by what is technologically possible, but by what is needed to achieve a more sustainable transport sector. Timely impact assessment and development of adequate policy frameworks will be essential.

3.7 The political task of promoting the successful structural change in the automotive and fossil fuel industry will require more efforts by policy makers

With the current configuration of the transport system – largely car dependent and almost entirely powered by fossil fuels – the automotive and oil industries have the strongest interest in maintaining the status quo. The growth of the transport sector in developing countries would open a market of an estimated additional 2 billion cars by 2050[24] without any changes to the current system – an increase of 200% compared to today, fully powered by fossil oil.

24 Fuel Freedom. (2019). What cars will we be driving in 2050? Retrieved from www.fuelfreedom.org/cars-in-2050/

The findings of this study emphasise that vested interests of incumbent industries are – by far – the biggest challenge to the decarbonisation of the transport sector. Out of a list of seven challenges, 73% of experts ranked industries' vested interests as most and second most significant, with 53% of those experts selecting it as the number one challenge.

> **"It needs strong political courage to rethink personal mobility and car-based transport. The biggest obstacle is not consumer preference, but vested interest in existing industries."**
>
> (Executive Director,
> Research Institute for Economics and Political Science)

SIZE OF THE AUTOMOTIVE AND OIL INDUSTRIES

Some 91 million cars were sold in 2019. In 2017, the global automotive industry created revenues of 5.3 trillion USD.* The same year, the world consumed about 3,900 Mt of oil, with two-thirds of it – 2,600 Mt – used for transport.** At an approximate 10-year average market price of 80 USD per barrel, the total oil market is worth 2.3 trillion USD; transport accounts for 1.5 trillion USD of this amount.***

* Wagner, I. (April 28, 2020). Revenue – automotive industry worldwide 2017–2030. Statista – The Statistics Portal. Retrieved from www.statista.com/statistics/574151/global-automotive-industry-revenue/

** International Energy Agency. (2017). Data and Statistics. Retrieved from www.iea.org/data-and-statistics/data-tables

*** Own calculation based on International Energy Agency. (2017). Data and Statistics. Retrieved from www.iea.org/data-and-statistics/data-tables

Some interviewees expressed their concern that corporate lobbying of governments is an obstacle: industries' efforts to maintain business as usual are seen as a dangerous distraction delaying the sector's transformation towards a transport system that is no longer car-centred and fossil fuel dependent but safer, more efficient, cleaner, cheaper and expected to create more jobs.

It is understandable that these industries will not change overnight, but their transformation needs to start now. Experts made clear that they do not expect to see industry to transition by itself – neither as comprehensively as necessary, nor at the required speed.

> **"Industries risk starting minor, more cosmetic changes only."**
>
> (Expert contribution during Delphi Study)

The challenge for policymakers is hence twofold: first, defining the guiding principles of the future mobility system; second, working with these industries to balance interests of past investors with the urgent need to transform the industries' business models to allow them to continue operations in a decarbonised world.

> **"Policies must be designed in a way that the current beneficiaries, who are running the system today, will still have a business case tomorrow."**
>
> (Senior Professional,
> Global Environmental Policy Organisation)

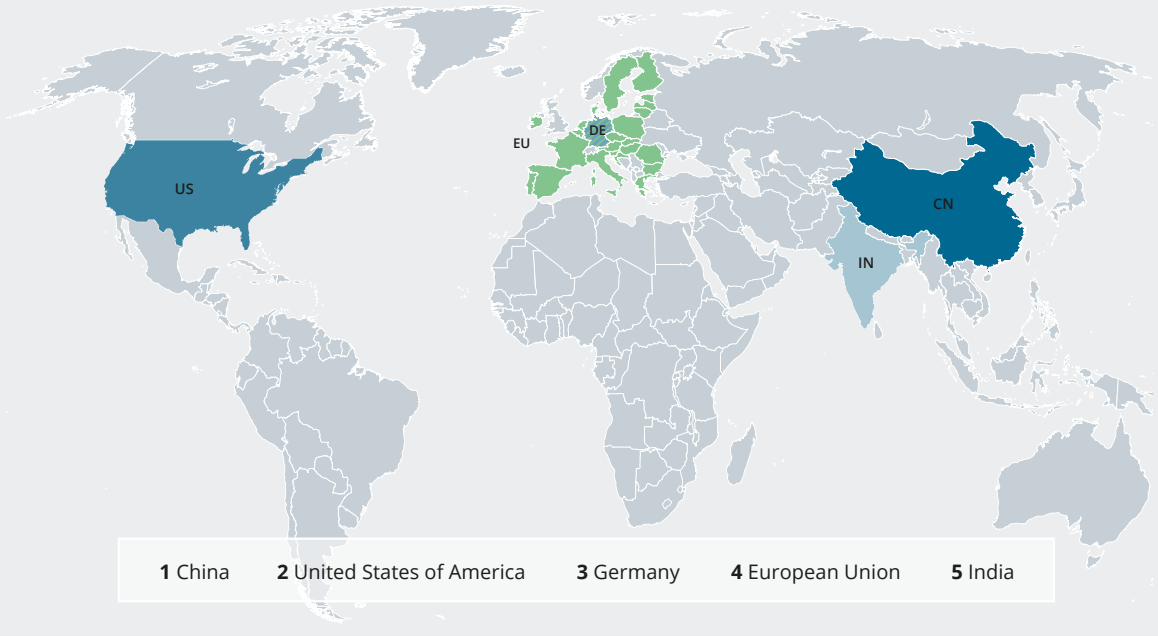
3.8 Countries with large incumbent industries, economic weight and political power have to play the key role in order to ensure the success of transport decarbonisation

3.8.1 China, the US, Germany, India and the EU will be most decisive

Countries with large incumbent industries combined with other elements, such as economic weight in general and international political power, will undoubtedly play an important role in the global decarbonisation of transport. According to the experts, China, the US, India and Germany, plus the EU as the largest single market in the world will be most decisive in transport's transformation. Of the experts, 88% stated that China will play a decisive role, followed by the US, with 78% of experts expecting them to be a key player; this expectation is equally shared amongst experts from developed and developing countries. Germany is expected to be decisive for the sector's decarbonisation by 55% of surveyed experts, with a larger share of experts from developing countries (62%) than those from developed countries (53%). The strong expectation of Germany persists if we exclude answers from German experts in the survey. For experts from developing countries India ranks fourth, and fifth for experts from developed countries. For experts from developed countries, the EU is seen by 28% as a key player for the sector's decarbonisation; for experts from developing countries, the EU is seen as less decisive.

Each of these countries has its own stakes and interests: China has become the largest car manufacturer globally with a still comparably low motorisation rate. It is the largest net importer

Figure 18 | The five most influential countries for the success of the global transport transformation



Representation based on the results of the T4<2°-Delphi survey

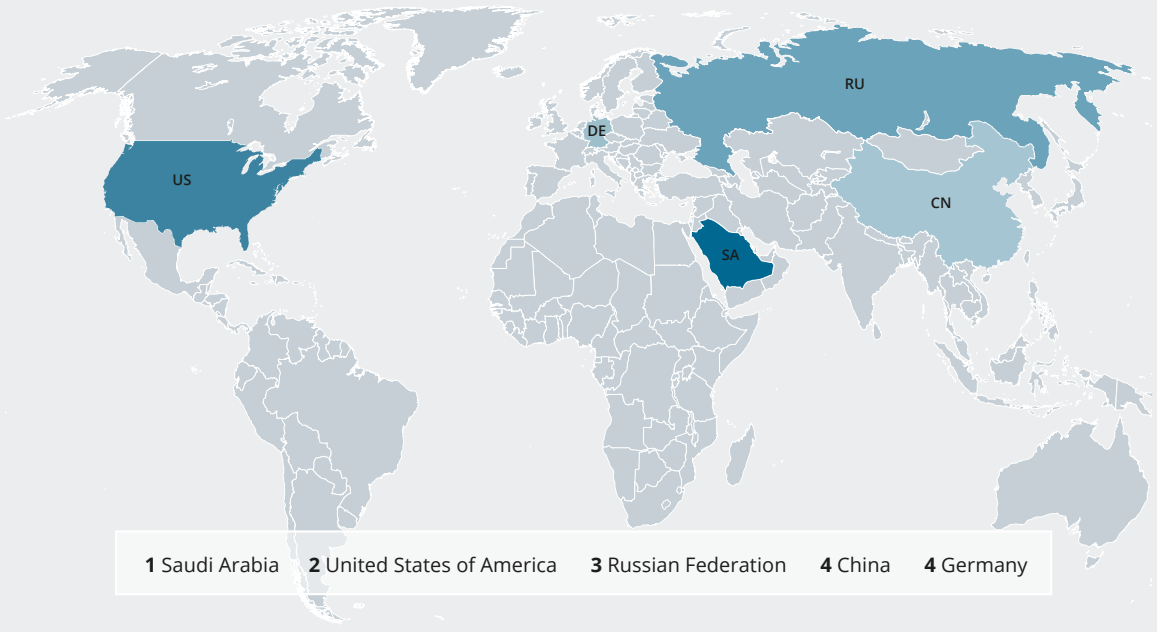
of oil, consequently being highly dependent on foreign markets to sustain its economic growth. At the same time, the country has become the largest manufacturer of electric vehicles and has taken over a leadership role in micromobility and autonomous vehicles. The US is characterised by a large automotive and fossil fuel industry catering primarily for its own energy demand. To decarbonise its transport sector its automotive industry has to transform, and the country's energy supply needs to be replaced with low-carbon alternatives. Germany's automotive industry accounts for 10% of its GDP yet the country is fully dependent on oil imports. India is characterised by a very low motorisation rate in relation to the size of its automotive industry. The country is the third largest consumer and net importer of oil. The EU is the single largest market area, producing 20% of global passenger cars, and is the second biggest consumer of oil, highly dependent on imports.

The ambition and speed of these countries in decarbonising their transport sectors – ideally as concerted efforts – will be decisive for the global transformation of transport.

3.8.2 Saudi Arabia, the US and Russia are expected to experience the most adverse consequences

With the decarbonisation of the transport sector, global energy flows are set to change. Experts strongly agree that countries with important fossil fuel industries in terms of contribution to GDP will experience the most adverse consequences from the decarbonisation of the transport sector. With 74% of experts' votes, Saudi Arabia features at the top of the list. It is closely followed by the US with 67% and Russia with 64% – each country

Figure 19 | These five countries will experience the most adverse consequences from the global transport transformation



Representation based on the results of the T4<2°-Delphi survey

facing its own challenges. Of the respondents, 10% assume that Germany and China will both experience the most adverse consequences, thus they rank equal 4th.

> **"Most adverse impacts will be on countries and regions dependent on fossil fuels for economic growth and development."**
>
> (Expert contribution during Delphi Study)

3.8.3 Countries without their own oil resources and net importers will most likely benefit

Today's fossil-fuel-centred transport system makes a large number of countries dependent on a few oil-exporting countries. The continued need to import oil puts economic pressure on countries without their own oil resources, particularly developing countries. With mobility being determined by access to fossil fuels, their governments and citizens are spending disproportionate amounts of their GDP, limited amounts of international currency and individual income on transport. The introduction of transport systems that are largely independent from fossil fuels will come with important advantages: financial resources are freed to be spent on more sustainable activities; renewable energy and even small electric vehicles can be produced or assembled in the country, creating local value; access to mobility will become more affordable and lead to more inclusive societies. Also, the need for sustainable energy sources and energy carriers for transport, such as electricity from renewables and hydrogen, open new economic opportunities for these countries: they will be able to develop their own energy industry and engage in new and growing international energy trade markets.

3.8.4 Increased demand for minerals and rare earth elements does not necessarily increase the risk of geopolitical conflicts

Powering the transport sector with electricity will increase the demand for minerals and rare earth elements for the production of battery and storage facilities. With a shifting demand from fossil fuels to these commodities, new actors will appear on the playing field while others will see their current market position weakening.

Of the experts, 63% estimate that the extraction and trading of commodities needed for electric mobility will not lead to a higher risk of geopolitical tensions; 30% of the experts still expect an increased risk. The expectation of a higher risk was stronger with experts from developed countries (32%) than with those from developing countries (23%). Experts from developing countries have a stronger tendency to expect no increase in the risk of conflicts (73%).

However, the increasing extraction of these raw materials needs to be regulated to avoid negative environmental and social impacts, as already being experienced by some countries. Similarly, battery reuse and recycling need a clear framework to ensure that raw materials are used in the most efficient way, and that extraction of new materials can be reduced as much as possible.

The shift from fossil fuels to minerals and rare earth elements will also shift global trading streams: while many countries are importers of oil today, only a few countries are likely to become importers of commodities for electric battery production.

3.9 New technologies and mobility solutions can only unfold their full potential for decarbonisation if policy makers also focus on a change in mobility behaviour

3.9.1 The provision of suitable technology will not be a challenge

The findings of this study provide a detailed account of the necessary technology to decarbonise transport in the next decades. While challenges such as the domination of incumbent industries will have to be overcome, experts are confident that the required technology will be available.

A lack of suitable technology is expected to be the least significant of all challenges to the transport sector's decarbonisation. Within the ranking of seven challenges, 80% of experts from developed countries rank a lack of suitable technology as 5th, 6th and 7th; experts from developing countries are almost as confident, with 73% ranking it in the last three.

With technological solutions being increasingly available in many areas, the success of the transport sector's transformation will depend on how we use them.

> **"The danger of technology is that it imparts power without wisdom. We must begin with values; or else technology will only propel us faster in the wrong direction."**
>
> (Professor of Science, Technology and Society)

3.9.2 Behaviour needs to be addressed

If technology is needed mainly to achieve energy efficiency and emission reductions through the improvement of fuels and vehicles, behaviour is decisive when it comes to transport's perfor-

SOME INNOVATIONS OUTSIDE THE TRANSPORT SECTOR WILL CONTRIBUTE – BUT LESS THAN EXPECTED

For a variety of relevant innovations outside the transport sector – for example 3D printing, e-commerce, virtual reality or home entertainment – experts do not expect a substantial positive impact on the transport sector's transformation. In some cases, experts point to the fact that innovation might increase demand, as has been the case with the increased use of e-commerce and the resulting increase in urban freight volume. Employee flexible working schemes and remote working, backed by advanced telecommunications, are considered more likely to contribute to decarbonisation.

Ultimately, experts regard a more sustainable lifestyle – including strengthened sharing options, the avoidance of unnecessary trips and increased regional consumption – as being most relevant to transport sector transformation.

mance as an entire system: avoiding unnecessary trips and a shift towards more efficient modes is largely determined by individual choices – thus behaviour. Hence, experts see a crucial role for behaviour change in achieving the sector's transformation and consider it much more of a challenge than the mere deployment of technologies.

> **"Changing behaviour on a global scale is much more a challenge [to the sector's decarbonisation] than technologies."**
>
> (Expert contribution during Delphi Study)

In this regard, when asked whether policy should influence behaviour or technology, a vast majority of our experts – 85% from developing countries and 79% from developed countries – stated that policy should mainly influence behaviour.

Opinions on whether this necessary change in behaviour will happen soon enough or take more time were diverging. Some experts in the context mapping were confident that the necessary behavioural changes can be achieved faster than we think; others expect that it will take several years to attain more sustainable mobility behaviour.

Regardless of the time scale, there is a strong opinion that behaviour change will not happen by itself but needs to be encouraged.

MARKETING BUDGETS OF THE AUTOMOTIVE SECTOR AND PUBLIC TRANSPORT – A COMPARISON

Automotive advertising expenditure across 14 key markets totalled 35.5 billion USD in 2018.* These markets comprise Australia, Brazil, Canada, China, France, Germany, India, Italy, Russia, South Korea, Spain, Switzerland, the UK and the US. The US auto market spent 18 billion USD. In China, ad spend has grown by 47% over the past six years, amounting to 6.3 billion USD, while India is the fastest growing auto ad market (an estimated 12.8% year-on-year growth between 2018 and 2020).

There are very limited accounts of the marketing spend by public transport organisations. The data that exists suggests that marketing departments – at least in the US – may be relatively small and subject to budgetary constraints.** This imbalance is very likely to affect consumer preference and thus mobility behaviour, and should be explored further.

* Zenith Media. (2019). Global intelligence: Automotive ad spend Forecasts. Retrieved from www.zenithmedia.com/wp-content/uploads/2019/03/Automotive-adspend-dorecasts-2019-executive-summary.pdf

** Cronin, J., & Hightower, R. (2004). An Evaluation of the Role of Marketing in Public Transit Organizations. Journal of Public Transportation, 7(2). Retrieved from citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.170.9420&rep=rep1&type=pdf

3.10 Decision-makers have to prioritise regulatory action over incentivisation and hereby provide a sound political framework, in order to ensure long-term investment security for public funding as well as private capital

3.10.1 Regulatory action is key to a successful transformation

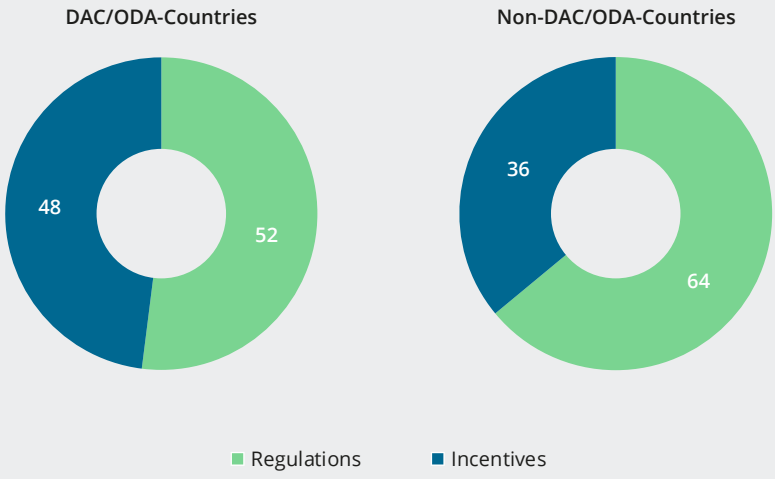
Both individual behaviour change and commercial and industrial interests can be addressed through policy and regulation. A lack of regulatory measures has, however, been assessed as the second most significant challenge by the panel of experts. The findings show experts are clearly asking decision-makers to take bolder action if they want to make the sector's decarbonisation happen.

The results slightly differ across the two groups, and the call for more regulatory action was more pronounced with experts from developed countries: 70% of them ranked it second (47%) or first (23%). Of the experts from developing countries, 69% ranked it second (31%) and third (38%); an additional 19% ranked it first.

Some experts expressed their concern that prevailing political uncertainties are a threat to transformative change, and that the legal and fiscal system is not yet fit to provide a favourable framework for transformation. The task of policymaking must thus be to shape conditions that drive both sustainable behaviour of the private sector and sustainable behaviour of consumers.

The need for regulation was also underlined by the experts, when they were asked which type of interventions policymakers should make use of. About two-thirds of the experts from developed countries agree that policymakers should use regulations, while one-third saw incentives as an

Figure 20 | Policy should make use of …



Representation based on the results of the T4<2°-Delphi survey

adequate policy intervention. Respondents from developing countries answered differently, with about half of the experts being in favour of regulations and the other half in favour of incentives.

In this regard, some experts pointed out that regional differences, as well as country- and culturally specific conditions, must be considered when choosing regulations or incentives.

3.10.2 Fuel pricing and a phase-out of vehicles with combustion engines are seen as the most effective regulatory measures

The experts were asked to assess the effectiveness of various policy instruments (from the categories regulation, incentives and information) by choosing the three instruments they deemed to be the most effective.

Of the different regulatory measures, 79% of the experts chose measures that influence the price of fuel, such as a carbon tax, as among the three most effective in the decarbonisation of

Figure 21 | Ranking of regulatory instruments

Representation based on the results of the T4<2°-Delphi survey

the transport sector. The call for a carbon tax or other measures of fuel pricing is stronger in developed countries (82%) than developing countries (69%).

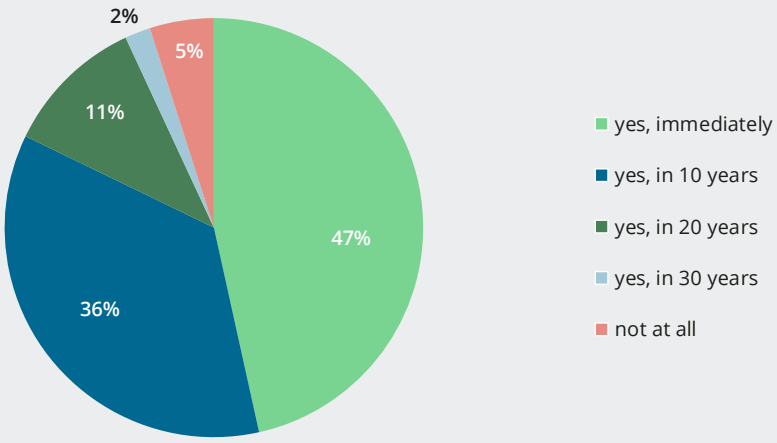
Putting a price on CO_2 – for example through a tax or a trading scheme – would help to accelerate the phase-out of fossil fuels such as petrol, diesel or natural gas. On the one hand, this would incentivise a shift towards more sustainable modes like public transport, cycling or walking. On the other hand, it would support the transition towards zero-emission vehicles and the use of clean energy for passenger and freight transport. Due to this comprehensive approach, it is seen as a very promising measure.

> **"We need to make unecological transportation options more expensive and inconvenient."**
>
> (Senior Director Mobility, Car Manufacturer)

Despite the largely shared consensus among experts regarding the need for fuel pricing, only 55% of experts from developed countries and 42% from developing countries believe that policymakers will actually adopt this measure. This is an indication of the challenge involved in adopting it and the difficulty in achieving a sufficient level of public acceptance of carbon pricing in the transport sector. Consequently, for this idea to be accepted a good communication strategy will be needed, together with the broad provision of alternative attractive mobility options.

Many experts in this study – 77% – believe that among the three most effective measures for decarbonising the transport sector is a forced phase-out of fossil-fuel-driven technologies. Of the experts interviewed, 47% believe that this process has to start immediately; more than one-third of the experts believe that it should start in 2030 by the latest. This means that 80% of the participating experts agree that a forced phase-out must start within 10 years. Only 5% believe that it is not necessary at all.

Figure 22 | A politically forced phase-out of incumbent and fossil fuel-driven technologies is needed in order to decarbonise the transport sector by mid-century



Representation based on the results of the T4<2°-Delphi survey

Several experts in this study suggest that a phase-out will require a comprehensive and lasting discussion with all stakeholders involved and should lead to a common but differentiated framework for different modes and types of vehicles. The phase-out of fossil fuels has gained increasing attention and support in recent years, particularly since several cities and countries have started announcing a ban on fossil-fuel-powered cars from between 2025 and 2050.[25] Yet, only 25% of the experts interviewed in this study believe that a forced phase-out is likely to be implemented to a sufficient extent, with an even smaller share of 19% of experts in developing countries.

The picture is very different when looking at the measures seen as most likely to be implemented. To begin with, the experts are less focused in their assessment, with a broader range of measures and lower percentages for the top-ranking ones. These are led by fuel economy standards, with 56% of the experts placing them among the three most likely measures, followed by a carbon tax or fuel pricing with 51% and zero-emission vehicle zones with 47%. It is notable that many experts do not seem to make a connection between the effectiveness of fuel economy standards and the phase-out of fossil-based technology, even though the recent experience with the EU fleet average CO_2 standards suggests that the former can act as a driving force for the latter. Only 26% expect the adoption of road pricing to be implemented. Compared to the measures of fuel pricing and a regulated phase-out of fossil fuels, fewer experts rate other regulatory measures such as road pricing – with 35% – and fuel economy standards – with 30% – as most effective. These ratings were largely shared across experts from both developed and developing countries.

25 Staufenberg, J. (June, 2016). Norway 'to completely ban petrol powered cars by 2025'. The Independent. Retrieved from www.independent.co.uk/environment/climate-change/norway-to-ban-the-sale-of-all-fossil-fuel-based-cars-by-2025-and-replace-with-electric-vehicles-a7065616.html

3.10.3 Investments, especially in public transport, need to complement regulatory measures

While regulatory action is seen as key to a successful decarbonisation of transport, these measures need to be complemented by investments that ensure availability of sustainable mobility options.

The incentive-based intervention valued by 80% of the experts as the most effective policy instrument to decarbonise the transport sector is investment in public transport. However, only 52% of experts rate this investment as the most likely instrument to be implemented. Decision-makers, on national and city levels, need to jointly mobilise resources for the extensive provision of public transport – if the decarbonisation of transport is to be achieved.

> **"Public transport continues to be the backbone [of mobility] and needs additional funding and development."**
>
> (Professor of Transport and Economics)

As to whether public transport should be offered for free as an additional incentive for users to adapt their behaviour in support of the sector's decarbonisation, opinions amongst experts differ: 35% of experts consider free public transport as an effective tool. However, only 8% believe that it is amongst the most likely tools to be implemented. With several cities around the globe currently testing the suspension of passenger fees, their experiences and findings should be shared widely and serve as a basis for a better-informed evaluation of its effectiveness.

Investments in active modes of transport are considered by 49% of the experts (62% from developing and 44% from developed countries) to be one of the three most effective measures, while

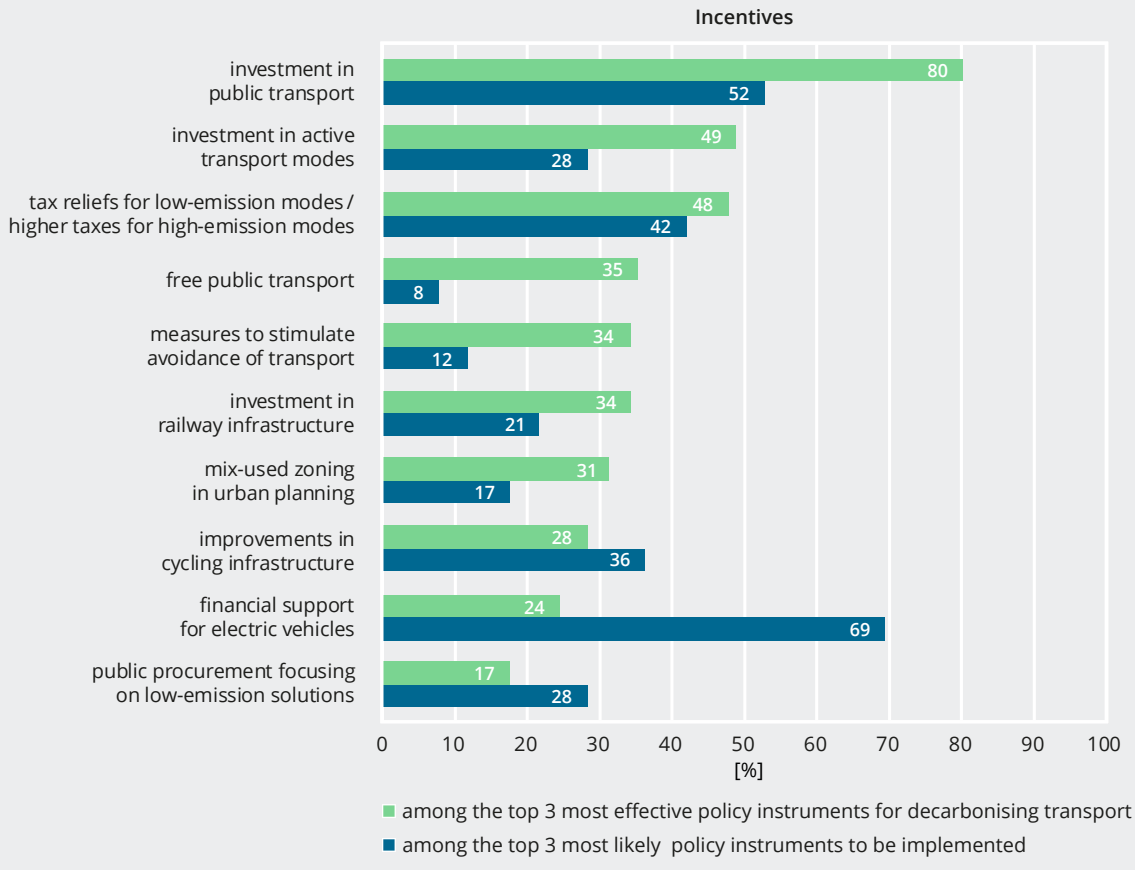
only 28% believe this is likely to happen. Improvements in cycling infrastructure were identified as most effective by 29% of the experts.

Tax incentives for low-emission modes and tax penalties for high-emission modes are, according to 48% of the experts – with support of 51% from developed and 38% from developing countries – an effective tool towards decarbonisation. Scores range from 38% of experts from developed countries to 54% of experts from developing countries expecting these measures to be implemented.

Investment in rail infrastructure as an important mode for freight and for inter-urban passenger transport receives stronger support from experts from developing countries (46%) than experts from developed countries (30%). This may well be explained by the fact that rail infrastructure is already more available in industrialised countries than in most developing countries. However, significantly fewer respondents consider these investments as likely to be realised (31% from developing and 18% from developed countries).

The experts are very clear that electricity is the future means for (land-based) transport. However, to decarbonise the sector, only an average of 24% of them believe that financial support granted for the acquisition of electric vehicles will be as effective as the measures of fuel pricing and a regulated fossil-fuel phase-out. There are

Figure 23 | Ranking of incentive-based policy instruments



Representation based on the results of the T4<2°-Delphi survey

decisive differences between the two groups of experts, with only 12% of those from developing countries stating that EV subsidies are as effective as fuel pricing and a regulated fossil fuel phase-out, compared to 29% from developed countries. However, 69% of experts from both groups believe that an incentive for electric vehicles will be the instrument of choice for policymakers.

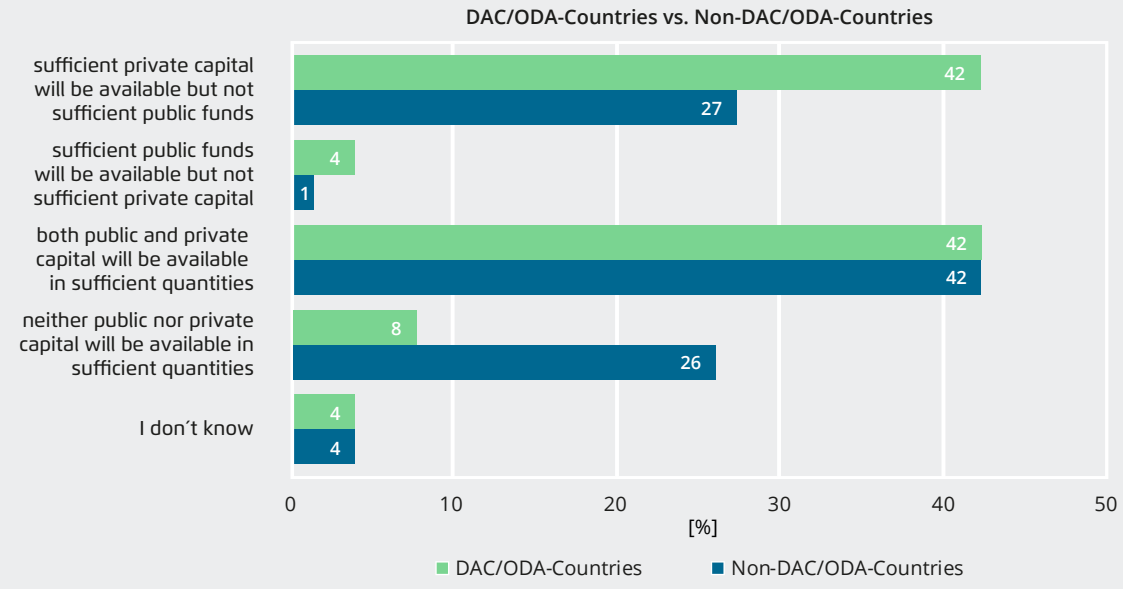
3.10.4 Governments have to provide a sound political framework to ensure long-term investment security for private capital as well as public funding

In the current debate, an often-used argument by the opponents of the transport sector's transformation is the cost allegedly linked to it. It is true that up-front investment will be required; but mid- and long-term savings in terms of reduced transport costs and reduced economic and social costs will be greater than the cost of the sector's transformation. Furthermore, non-action regarding the decarbonisation of transport will fail to limit global warming to well below two degrees. This will very likely come at a much higher cost.

> **"A recurring and dangerous distraction is that the transport transition is expensive. In absolute terms, it is expensive, but it is actually vastly cheaper than the prodigious efforts to perpetuate unsustainable mobility."**
>
> (Expert contribution during Delphi Study)

Looking at the means to finance the transport sector transformation, most experts expect that sufficient funds will be available. This view is strongly supported by experts from developing

Figure 24 | Sources of capital that will be available in due time in order to finance the global transport transformation



Representation based on the results of the T4<2°-Delphi survey

countries: 88% of them expressed confidence about the availability of the necessary capital, and only 8% expect that public and private money altogether will not be sufficient. In developed countries, 70% of experts are confident that money will not be lacking; 25% believe that resources will not be sufficient in any case.

In order to achieve the decarbonisation of transport, public money currently spent on fossil fuel subsidies needs to be consistently reoriented towards climate-friendly mobility and infrastructure. Furthermore, experts pointed out that cities which are playing a key role in transforming the transport sector need more autonomy and access to financial resources. However, experts from all regions agree that public funds alone will not be enough, and that private sector finance will have a significant role to play. To make investments in sustainable mobility attractive for private investors, national and local governments will have to provide a sound political framework and ensure long-term investment security for private as well as public capital. To date, experts have not seen sufficient economic incentives, hence the shortage of profitable projects for investors.

With regard to developing countries, more support regarding infrastructure development might be needed. Investments in transport infrastructure are expected to be one of the three most significant challenges (out of seven predefined challenges) to the sectors transformation by experts from developing countries, while this is only for 23% of experts from developed countries a considerable issue. Several experts pointed out that developing countries will need more support to build a sustainable transport sector and that development banks are playing a significant role in financing high capital expenditure transport infrastructure. Hence, their choices will continue to influence what type of investments will be made, and how their funds can leverage the use of private sector finance. Developing countries could be enabled to leapfrog carbon-intensive technologies to reduce the dependency on fossil fuels and prevent lock-in effects in unsustainable transport systems. Therefore, the assessment of transport system investments with regard to their contribution to a sustainable transport system, the provision of financing to integrated mobility solutions (e.g. infrastructure and services, multi-modal transport, transport and energy) and the de-risking and leveraging of private sector money needs to become a new focus of the development banks' funding activities.

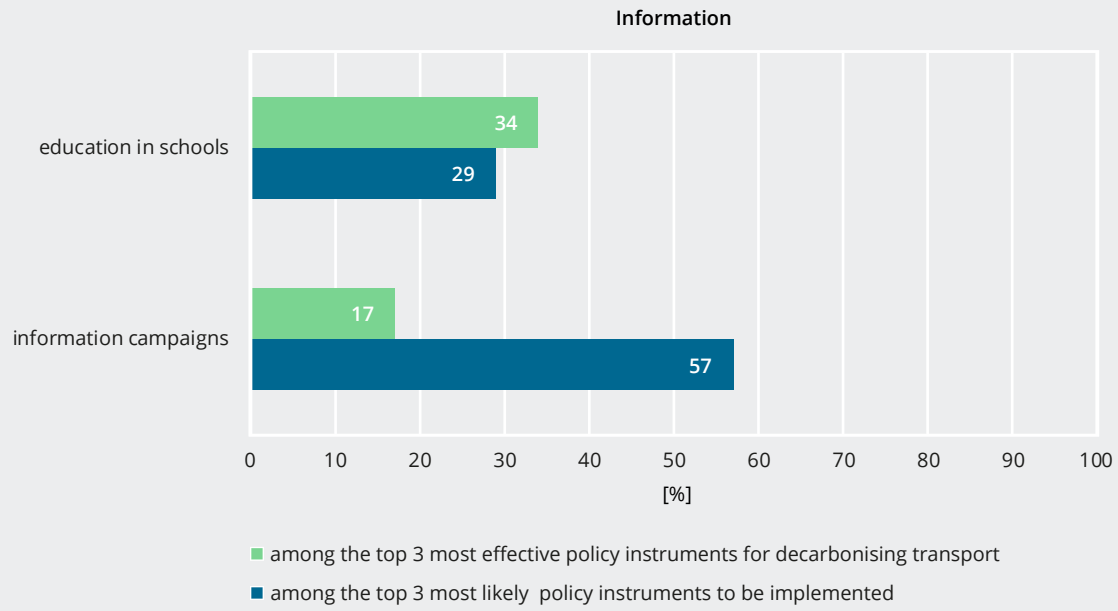
3.10.5 Information and transparent communication are not seen as the most effective measures but can help to increase public awareness

With behaviour change playing such a crucial role, public awareness for and acceptance of decarbonisation is a prerequisite for the transport sector's transition. When asked how they evaluate current public acceptance, experts were positive but also expressed differing opinions across regions. Experts from developed countries see public acceptance as a slightly bigger challenge than those from developing countries.

This can probably be best explained by the maturity of the sector. Moving away from a well-established car-centred system to people-centred mobility will require certain habits to change. In developing countries, the rate of motorisation is comparably low, and often people suffer from a lack of access. If decarbonising transport happens alongside increased access to mobility for large parts of society, acceptance will not be an issue.

During the context mapping, experts pointed out that acceptance and awareness can be influenced by transparent and targeted communication. In this, the experts see room for improvement for governments and authorities.

Figure 25 | Ranking of information-based policy instruments



Representation based on the results of the T4<2°-Delphi survey

> **"Government decisions are not communicated very well."**
>
> (Senior Leader, Global Research Organisation for Climate, Energy and Transport)

Education in schools is seen as one of the most effective measures for successful decarbonisation of the transport sector by 34% of the experts, and 17% think that this also applies to general information campaigns. While not being among the experts' top priorities in terms of efficiency, these measures can increase acceptance and awareness, and therefore support a successful implementation of regulation and incentives, while being likely to be adopted.

In their view, the framing of changes and decisions should focus less on what needs to be given up – car dependency. Instead it needs to highlight the expected gains on a personal level: increased individual mobility choices without having to own a car, less congestion and subsequently less time lost in traffic, clean air, improved health, safe streets and liveable neighbourhoods. And, for society as a whole: better social inclusion of marginalised groups, less tax money being spent on fossil fuel subsidies and car infrastructure, a more just allocation of external costs and of public space, and an overall less expensive transport system in the medium and long run.

> **"We need to do a better marketing job concerning these policies and communicate the benefits for society as a whole."**
>
> (Professor and Head of Department Civil and Environmental Engineering)

Moreover, many experts refer to the usefulness of pilot projects and the introduction of temporary measures when it comes to raising awareness and acceptance.

Their positive effects could already be proven with various examples, especially in cities, where temporary road closures or the reallocation of public space has led to a well-accepted and definite adoption of changes.

In this respect, local fora and citizen assemblies are also seen as an effective tool to increase participation by those who will be most affected – and who will benefit most – from changes in mobility on a local level.

Findings of this study show that the decarbonisation of transport needs bolder political action to be implemented than we have seen so far, and experts are rather timid in their expectations as to whether this will happen soon enough.

> **"It may need some more pressure to understand the emergency and the need to act."**
>
> (Expert contribution during Delphi Study)

To achieve the necessary transformation, sets of actions need to be chosen coherently and based on their effectiveness. Moreover, they need to be integrated into a long-term policy framework with clear pricing signals, to provide transparency for operators and users to prepare their investment and consumption choices.

Experts acknowledge that not all necessary interventions and regulations will easily be accepted. Therefore, they stress the need to combine less popular regulation with more popular incentives in packages that will lead to greater convenience, affordability and personal freedom through sustainable transport choices.

4 Outlook: Implications and opportunities for foreign policy and international cooperation

The findings of this foresight study provide a rich depiction of a possible future with a decarbonised transport system. The extensive material collected through context mapping and a Delphi survey indicates where global ambition is heading and where shortcomings need to be addressed. It also shows that foreign policy and international cooperation could play a vital role in decarbonising transport by

1. strengthening global governance in transport and across sectors,
2. intensifying bi- and trilateral cooperation with key actors,
3. building political momentum through dialogue on key topics.

In order to develop strategies for foreign policy and international cooperation, these fields of action should be analysed more carefully in future studies. The present study can help to outline some of the possibilities and opportunities.

Strengthen global governance

The study emphasises that a full decarbonisation of the transport sector requires higher ambition in order to achieve the goals of the Paris agreement. This will need all relevant actors to collaborate and a variety of ambitious measures to be implemented. Countries should strive for multilateral and regional agreements and frameworks. These can showcase positive effects, build up momentum and serve as a catalyst for broader action for others to follow. International cooperation and foreign policy will have to play a crucial part as facilitators of these actions.

Many levels, structures and organisations are already in place that are dealing with transport issues on an international level, from, for example, the European Union (EU), the G7, the G20 G20 and the United Nations (UN) to International financial Institutions (IFIs) as well as urban mobility policy and city networks. In order to achieve a coherent and coordinated international approach, a mapping of existing organisations would be necessary to analyse which actors are already focusing on decarbonising transport and to identify their focus area. Furthermore, it needs to be evaluated which role the decarbonisation of transport plays in the Sustainable Development Goals (SDGs). On this basis the question should be discussed whether a new clustering of tasks will be necessary within the existing organisations or whether new organisations will be needed for certain tasks (see for example the discussion about the foundation of a UN organisation for transport).

Intensify bi- and trilateral cooperation

The decarbonisation of the transport sector must become a cross-sectoral topic within economic and political partnerships on bi- and trilateral levels. Feasible solutions and benefits of action, joint projects and structural support in key areas should be highlighted to advance the dialogue for mutual benefit.

Particular attention should be given to:

- Dialogue with **fossil fuel exporting countries:** These countries will have to make profound changes to their economic systems. Modernisation initiatives should be encouraged.
- Partnerships with countries that have been assessed, besides Germany and the EU, as

the most decisive for the transformation of transport: **China,** the **US** and **India**.
- **Enabling less motorised countries** to leapfrog carbon-intensive technologies, thereby reducing the dependency on fossil fuels and preventing lock-in effects.
- **Promoting economic cooperation in the transport industry** by innovative industrial partnerships and networks for Research and Development (R&D) as well as the development and harmonization of industry standards, for example with regard to automotive industries, electric mobility, new mobility services, hydrogen and power-to-x-technologies, aviation and maritime industries.
- **Actively raising the issue** of transport transformation in bi- and trilateral cooperation.

Cooperation and dialogue that supports the transport transformation could focus on the following topics:

1. defining a strategy for a policy-driven **fossil fuel phase-out,**
2. redirecting **funding** towards low-carbon solutions,
3. implementing and harmonising **CO_2 pricing mechanisms,**
4. promoting the extension of **electricity production from renewable sources** for direct usage as well as for the production of hydrogen and other power-to-x fuels,
5. mitigating the negative effects of **biofuels,**
6. ensuring the availability and socially as well as ecologically responsible production of **scarce metals and rare earths** needed for zero-emission technologies such as traction batteries, particularly cobalt and lithium,
7. identifying options to reduce the **transport demand** caused by trade policies and supply chains, and
8. agreeing on suitable pathways for decarbonisation in **aviation and maritime transport.**

Finally, raising awareness for the necessity of a transport sector transformation and transparently communicating its advantages and the necessary changes is essential in order to promote acceptance and mobilise widespread stakeholder support. With embassies as multipliers, foreign policy has a strong network to disseminate information, stimulate national networks and get partners involved. Sharing national and local experiences will strengthen the dialogue on solutions for the future of transport as part of international advocacy work for the global transformation of the transport sector.

5 Appendix: Deploying strategic foresight methods to understand the future of transport[26]

The study applies methods of strategic foresight in order to answer the question *"how to decarbonise transport and transform mobility by mid-century?"*. In detail, it made use of the Delphi survey technique, a technique that has been widely adopted as a foresight method. The method serves to assess long-term developments through identifying opportunities and risks, and aims to provide guidance for complex thematic fields, which are subject to great uncertainty.
As a first step, studies on international transport scenarios were evaluated systematically (see table 1). Thereby, the project team gained a solid understanding of the current state of research and developed a common understanding of possible pathways to a global transformation of the transport sector.

Then, **context mapping** was implemented in order to identify relevant issues and generate hypotheses. This took the form of pre-structured qualitative expert interviews. The questions were clustered into eight themes, revolving around the main topic of mobility transformation: (1) policy action (2) technologies, (3) digital transformation, (4) energy and raw materials, (5) international relations, (6) infrastructure and spatial planning, (7) acceptance and equity, (8) finance and economics.

26 Further information can be retrieved from: www.t4under2.org. All details on methods and collected data can be requested from the project team.

Table 01 | Analysed studies on international transport scenarios

Year	Author	Title	Retrieved from
2004	World Business Council for Sustainable Development	Mobility 2030: Meeting the challenges to sustainability	https://bit.ly/3hcPmlW
2005	World Business Council for Sustainable Development	Pathways to 2050. Energy & Climate Change	https://bit.ly/3kXaH52
2007	World Energy Council	Transport Technologies and Policy Scenarios to 2050	https://bit.ly/2YfbTaq
2007	Energy Information Administration (EIA)	International Energy Outlook	https://bit.ly/3aEveXl
2009	OECD/International Energy Agency	Transport, Energy and CO_2 – Moving Toward Sustainability	https://bit.ly/3aBPZ6g

Year	Author	Title	Retrieved from
2010	International Energy Agency	The prospect for modal shifts in passenger transport worldwide and impactson energy use and CO_2	https://bit.ly/34gJt3H
2011	World Energy Council	Global Transport Scenarios 2050	https://bit.ly/3g1EaqY
2012	International Council on Clean Transportation	Global transportation energy and climate roadmap	https://bit.ly/315f9GX
2014	Institute for Transportation and Development (ITDP), University of California Davis	A Global High Shift Scenario: Impacts And Potential For More Public Transport, Walking, And Cycling With Lower Car Use	https://bit.ly/3494AEL
2014	National Cooperative Highway Research Program (NCHRP)	Strategic Issues Facing Transportation, Volume 5: Preparing State Transportation Agencies for an Uncertain Energy Future	https://bit.ly/2EfjBKe
2016	SLoCaT Partnership on Sustainable, Low Carbon Transport	Implications of 2DS and 1.5DS for Land Transport Carbon Emissions in 2050	https://bit.ly/3iQj7cD
2016	Innovationszentrum für Mobilität und gesellschaftlichen Wandel (InnoZ)	Future mobility and decarbonisation. Visioning transport futures. Pathways to decarbonisation in transport scenarios.	https://bit.ly/2Yb0okd
2016	International Energy Agency	Energy Technology Perspectives 2016 – Towards Sustainable Urban Energy Systems	https://bit.ly/3kW9IlK
2017	OECD/International Transport Forum	ITF Transport Outlook 2017	https://bit.ly/3h8QUxm
2017	International Energy Agency	World Energy Outlook 2017	https://bit.ly/2FuTgIN
2018	Shell	Shell Scenarios Sky - Meeting the Goals of the Paris Agreement	https://go.shell.com/3h6rBMs

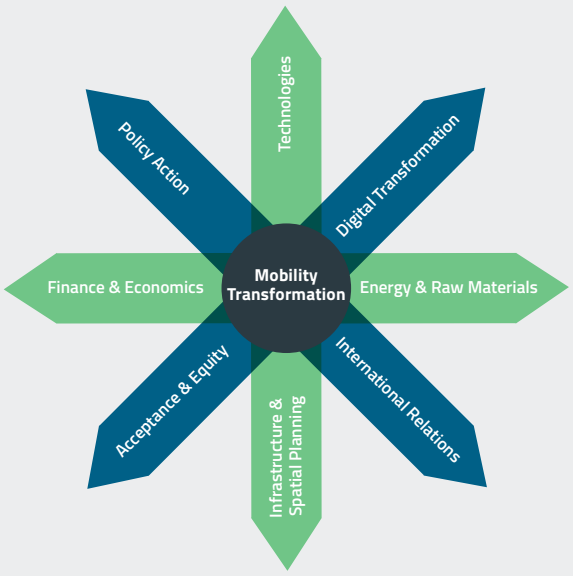
The collected data was analysed on the basis of pre-defined categories and structured into a so-called context map, which summarises response patterns and open answers from the interview participants. On this basis, hypotheses on mobility trends and their possible interactions in different sectors and policy areas were developed.

In the second step, a two-stage **Delphi survey,** those hypotheses were discussed and evaluated by a group of experts. The experts replied anonymously to a questionnaire and subsequently received feedback in the form of a statistical representation of the "group response". The process was then repeated. By seeing the previous results and comments, experts can consider them in their final assessment.

This process has specific advantages. First, it creates structured communication in a group of experts. Since it is conducted anonymously, the influence of hierarchies and power dynamics on the answers is reduced. Moreover, the method combines different perspectives since experts with different focal points are brought together, and thus can identify potential trend breaks at an early stage. As differing individual opinions are presented, scenarios that are not supported by the majority are also considered.

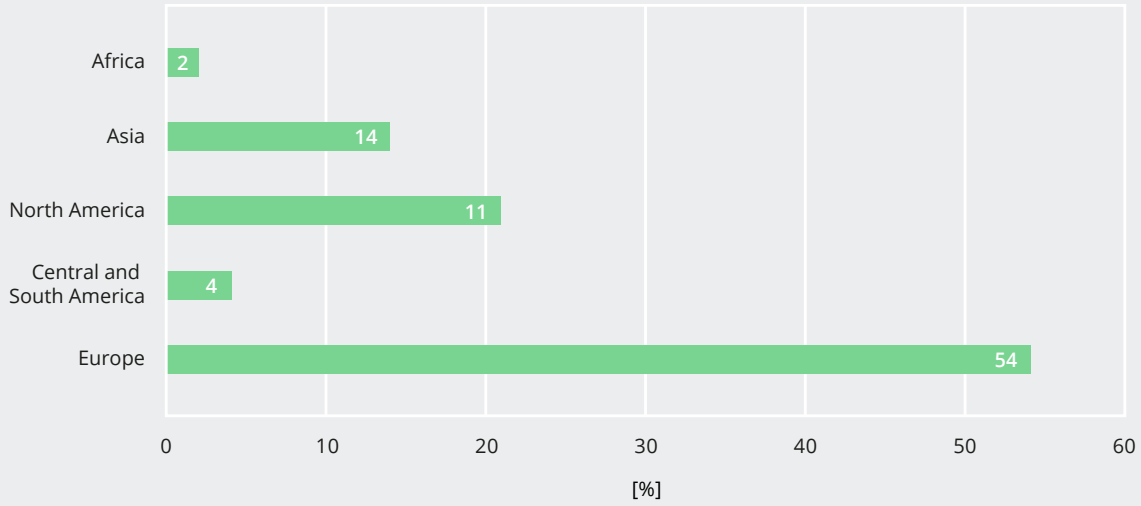
In the third and final step, the Delphi findings were condensed into narratives from which globally relevant options and recommendations for action could emerge. This took place during workshops with the project team and other experts. They took a deep dive into the context of selected countries and regions in order to assess the implications for policymakers and other stakeholders in the fields of foreign policy, diplomacy and international cooperation to create the best approach towards a low-carbon transition in the transport sector.

Figure 26 | Main focus areas of the context mapping



Own representation

Figure 27 | Participants of the context mapping by region



Representation based on the T4<2 context mapping

The sample of the context mapping

Fifty-six experts participated in the first phase of the study, representing the business and science community working in the field of transport or mobility. Most of them were from Western Europe or North America, while a smaller number were from Asia, Africa and Latin America. Around 15% of the surveyed experts were female, while the majority (85%) were male.

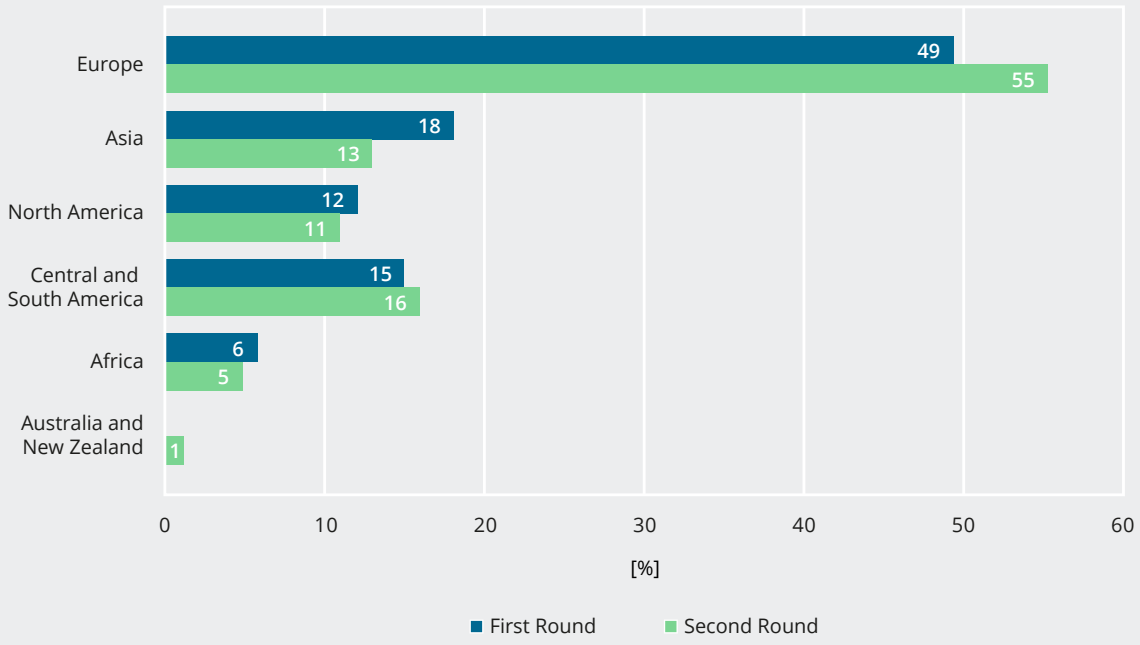
The Delphi survey sample

Both rounds of the Delphi survey were implemented through an online survey tool. During the first round (October and November 2019), 290 international experts participated. In the second round (January and February 2020), 103 international experts participated.

Most participants had a professional background in transport (63% in the first and 67% in the second round) or energy (24% in both rounds). Most had more than 10 years of professional experience in relevant thematic areas, working as senior or executive pr. 58% and 65% (round one and two respectively) of experts had experience of more than 10 years. The different sectors (politics/public administration, academia/research, private sector, civil society/non-governmental organisation (NGO)) were equally represented.

Generally, the sample shows an imbalance towards male experts (67% in the first and 73% in the second round). This can be explained through a male bias in the expert networks, which the project team approached. When considering the regional distribution, there is a clear bias towards Western Europe and Germany in particular, although all world regions were significantly represented, allowing for broad regional differentiation over rounds 1 and 2.

Figure 28 | Participants of the Delphi study by region



Representation based on the results of the T4<2°-Delphi survey

The questionnaire

The questionnaire consisted of 25 questions, each representing a hypothesis on the future of transport. The main topics were the decarbonisation and transition of the transport sector and the steps needed to make it happen. The questions revolved around necessary policies, possible sources of funding, social and geopolitical implications, innovation potential and the respondents' predictions of the dominant forms of transport and energy sources in the future.

Different types of questions were used. Some of them were designed as Likert scale questions asking respondents to select their opinion on a scale from 0 to 6. Other questions allowed for a selection, for example which means of transport will dominate in rural areas around the middle of the century. Another type of question asked the experts to select a predefined number of options from a list of possible answers. Another set of questions included the ranking of a predefined list of options in a specific order. Further questions were asked as open questions.

The context mapping and the Delphi survey in this study had very good response rates. All world regions are represented, and participants were fully engaged during the qualitative interviews and through the option to leave additional remarks as part of the Delphi survey. The main challenge was the integration of a variety of different perspectives and interests on transport transformation. As the statistical descriptions of the participating samples show, the data is biased towards male experts from Germany/Western Europe and the US/North America as well as senior experts. This imbalance should be kept in mind when discussing findings and implications.

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T4<2° | Transport For Under Two Degrees | The Global Foresight Project on Transforming Mobility by Mid-Century

T4<2° (Transport For Under Two Degrees) is the global foresight project on transforming mobility by mid-century. It aims to develop policy recommendations that promote pathways towards a zero-carbon transport sector, based on a global foresight study and with particular focus on foreign policy, diplomacy and international co-operation. T4<2° was commissioned by the German Federal Foreign Office and has been carried out by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), the World Economic Forum (WEF) and Agora Verkehrswende.

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