Transport and sector coupling

Final Report of a GJETC Working Group
with policy recommendations and fact sheet

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Content

The GJETC Working Group „Transport and Sector coupling" was formed by all Members of the German-Japanese Energy Transition Council. The scientific sectretariats provided the factsheet and summarized the discussion results and policy recommendations.

1. Introduction

In general, both in Germany and in Japan, **priority should be given to implementing transport policies and measures** that result in **reducing the overall energy consumption of the transport sector**. According to the findings of the Federal Environment Agency (UBA) (Schmied 2019, cf. Annex to this report), around half of the necessary GHG emissions reduction in the transport sector in Germany can be achieved with the well-known strategies of **avoiding** motorized transport, **shifting** to lower-emission and zero-emission means of transport and **improving** them. The other half of the GHG emissions reduction necessary for complete decarbonization must be achieved through the energy transition in the transport sector. Therefore, in addition to the familiar transport policy strategies, measures are also needed to significantly expand the direct and indirect use of GHG-neutral energy sources such as electricity generated from renewable sources, 'green' or 'blue' hydrogen and/or synthetic fuels based on GHG-neutral hydrogen in the transport sector. This is the promotion of **sector coupling in the mobility sector**. It should be noted here that the various options for using renewable energy sources in the mobility sector do not represent equal options for all means of transport. For example, the storage of 'green' electricity on board of vehicles in batteries, the storage of 'green' or 'blue' hydrogen in tanks, or the use of 'green' or 'blue' synthetic fuels is not always technically feasible for all means of transport. The same applies, for example, to the equipment of motorways and expressways with high freight traffic volumes with overhead lines currently discussed in

Germany and the EU and already being tested on some road sections, so that heavy trucks can drive electrically on these sections.

The aim of the policy recommendations presented below is to secure both the transport policies of avoiding, shifting, and improving, and the sector coupling policies as well as their overall integration in the long term. The policy recommendations address both the political-administrative and the planning-technical framework. A reliable long-term policy roadmap is relevant insofar as the decision to integrate mobility into sector coupling would involve considerable investments for the public sector, for energy producers and suppliers as well as for users. In this context, reliability means above all ensuring planning security for the relevant actors, which paths of the integration of mobility with sector coupling should be pursued in future with which priority in each case. In concrete terms, this means which forms of energy and energy sources are to be used in the mobility sector in the future, to what extent, and which means of transport are to be integrated into sector coupling, using which technologies and energies, and to what extent. This will certainly depend on the expected development of costs, the energy efficiency, and the potential of the different technical systems for sector coupling.

In **Germany**, all of the EU, federal, state, and municipal levels are relevant for implementation in promoting the integration of mobility into sector coupling, . as each of these levels has certain decision-making competences and responsibilities. This means that at each of these levels the actors can and must design the necessary framework, implement their own measures and thus make a contribution. A central coordination of the various activities is indispensable too, so that they interlock, build on each other and do not work against each other.

For Germany, the European level is important in so far as the country is highly interlinked with its neighbours in both economy and transport terms, through air transport and particularly through road and rail transport. Isolated solutions that stop at national borders would therefore only have very limited spatial effects and would only be able to address a small proportion of traffic. In addition, the EU has the competence for setting fuel efficiency and GHG emission standards for any type of vehicles.

In **Japan**, it is rather the national level with its prefectures and the municipalities that are relevant for implementation. In contrast to Germany and the EU, cross-border road and rail transport do not exist in Japan. Therefore, solutions for road and rail transport within Japan mainland will be important. In addition, coastal shipping is much more important in passenger and freight transport than in Germany and could or should be addressed more intensively.

2. Policy recommendations for Germany – EU and national level

Germany's **sectoral target** set in the national climate action plan is to reduce the annual GHG emissions caused by the transport sector by 50 to 55 million tonnes of CO_{2eq} by 2030. In order to achieve this GHG reduction target for the transport sector, the **German Federal Ministry of Transport** has developed a set of measures. These address various fields of action in passenger transport and freight transport, for example the promotion of alternatives to car use in passenger transport, the expansion of the use of alternative drive systems, and digitalization. The measures are currently included in the parliamentary process on the overall program of measures for achieving Germany's 2030 climate change targets.

Figure 1: GHG mitigation target for transport 2030 in Germany: Measures proposed by the German Ministry of Transport

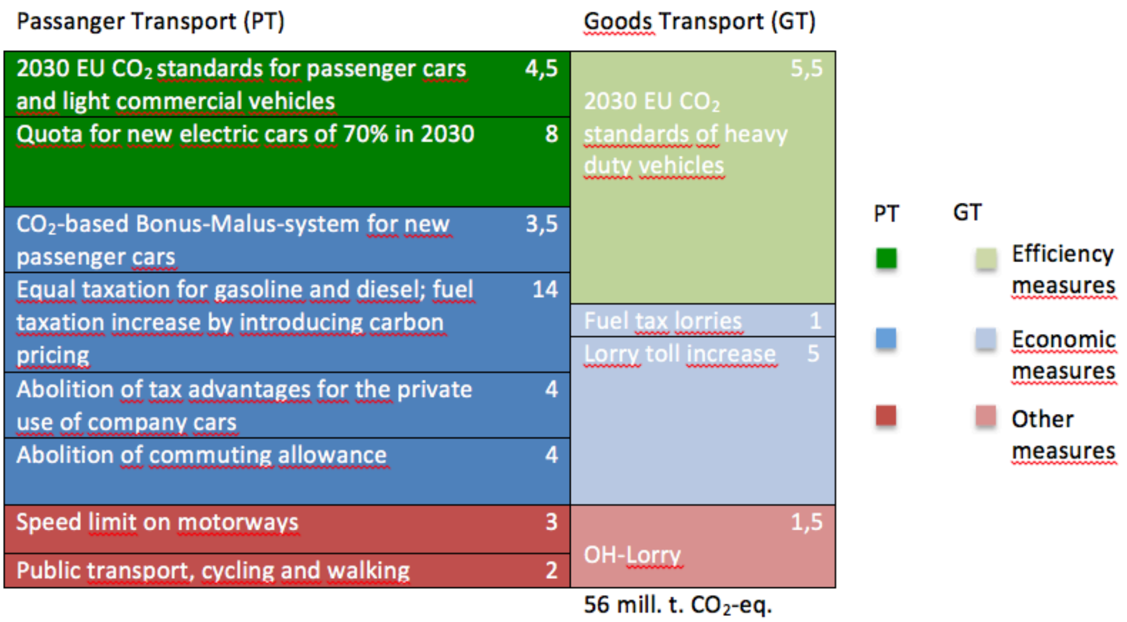
Field of action	Measures	Estimated GHG reduction in million tons CO_2 equivalent / year
1 Public Transport, Bicycles and Pedestrians	• Additional federal funds for infrastructure (e.g. 1 bn Euro for Public Transport) • Reduction of value added tax for train tickets (from 19 to 7%) • Higher state supports for electric buses	**7-8**
2 Alternative Fuels	• Governmental research/support of production sites (PtX / advanced biofuels) • Development of a hydrogen programme (2 bn Euro from 2021)	**9-10**
3 Freight Transport	• Additional federal funds for freight rail infrastructure and inland navigation	**2**
4 Passenger Cars	• Tightening European CO_2 limits for passenger cars 2030 • Increase of buyer's premium for new electric passenger cars • Promotion of climate friendly company cars by revision of tax system • Increasing state supports for charging infrastructure (additional 1 bn Euro)	**9-10**
5 Heavy Duty Vehicles	• Tightening European CO_2 limits for HDV 2030 • Buyer's premium for HDV with alternative fuels • Considering CO_2 emissions for road tolls of trucks • Increasing state supports for charging infrastructure	**17-18**
6 Digitalization	• High-speed mobile networks for automated and connected vehicles • Changing legal framework for digitalized vehicles	**6-7**
		= 50-55 million t. CO_2 equiv.

Source: German Federal Environment Agency (UBA) based on German Ministry of Transport and Digital Infrastructure, May 2019

Looking at this list, many measures are technology-oriented, and the measures supporting alternative fuel systems and digitalization are expected to achieve more than half of the required GHG emission reductions. The combination of measures appears to aim at avoiding any constraints on car and truck mobility. There is no speed limit on highways, nor any measures changing taxation of vehicles or fuels, or road tolls; however, the government's overall package of measures includes a CO_2 pricing scheme, starting at 10 €/tonne in 2021, and increasing to 35 €/tonne in 2025.

The **German Federal Environment Agency**, however, assumes that the measures planned by the Federal Ministry of Transport alone will not be sufficient to achieve the target of 50 to 55 million tonnes of CO_{2eq} in annual GHG emissions reductions for the transport sector by 2030. One reason for this, according to the Federal Environment Agency, is the lack of tax or other economic measures in the Transport Ministry's set that would make car-based mobility and road transport of goods more expensive in certain areas. In addition, the Federal Environment Agency estimates that the reduction potential assumed for other measures is too high. The Federal Environment Agency's recommendations for measures whose implementation could save 50 to 55 million tonnes of transport-related CO_{2eq} by 2030, according to the Federal Environment Agency's estimate, **also include economic measures** such as a significant increase in energy taxes or an increase in the road toll for trucks.

Figure 2: GHG mitigation target for transport 2030 in Germany: Measures proposed by the Federal Environmental Agency (UBA)



Source: German Federal Environment Agency (UBA) 2019; Schmied 2019

Notes by UBA:

- *Basket of measures will reduce the GHG emission by 56 million t CO_2e until 2030.*
- *Most effective measures are efficiency standards, electrification and pricing of transport.*
- *Implementation of all measures at the same time is not feasible.*
  ➔ ***UBA advises implementation in stages***

The fact that the Federal Ministry of Transport has decided against economic measures and that this field of action is very important from the perspective of the Federal Environment Agency clearly points to the need for a discussion in Germany on a balanced mix of strategies and measures for more effective climate protection in transport. It has also become clear that the development and implementation of stronger climate protection strategies and measures in Germany and Europe require clear responsibilities in the political multi-level system. This is because the close economic and political interdependence within the EU as well as between regions within Germany require an equally close interdependency of municipalities, regions and states.

The comparison with Japan (cf. Fact sheet and presentation of Prof. Hayashi in Annex, Hayashi 2019) also shows that in Germany, a much stronger **promotion of rail passenger transport** is necessary, including that passenger and freight transport networks need to be increasingly separated from each other. It would also make sense to further differentiate the network for passenger rail transport by separating the networks for faster long-distance transport and slower regional transport.

3. Policy recommendations for Japan

Japan's **sectoral target** set in the "Long-term energy supply-demand outlook" (Apr 2015), corresponding to the 4th Strategic Energy Plan and the 5th plan as well, is to reduce the annual energy consumption attributed to the transport sector by 26% compared to Fiscal Year (FY) 2013, which can be translated to reduce 62 million tonnes of CO_{2eq} by 2030. In order to achieve this energy efficiency target for the transport sector, the **Japanese Ministry of Trade, Economy, and Industry** (METI) has identified a set of measures and its effect on reducing energy consumption thus GHG emission. These address various fields of action in passenger transport and freight transport, for example the promotion of alternative vehicles, the optimization of freight transport, and automated driving.

Figure 3: Energy efficiency measures and expected effects (unit in million kL of oil equivalent)

	Change from FY2012 to FY2030	Reduction	of which electricity	of which fuel	
Improve fuel economy	HEV 3% >> 29% EV/PHEV 0% >> 16% FCEV 0% >> 1% CDV 0% >> 4%	9.389	-1.001	10.390	•Promote high efficiency vehicle •Strengthen efficiency standard
Other measures	-	6.682	0.624	6.058	•Smoothen the traffic flow •Promote public transport •Shift from truck to rail freight •Green shipping

					•Reduce land transport by optimized shipping point •Low-carbon port •Improve efficiency of train, air craft and ship •Improve efficiency of passenger trasport (e.g. taxi, bus) •Optimize land freight transport •Automated driving •Promote eco-driving •Car sharing
Total reduction		16.071	-0.377	16.448	

Source: METI (2015)

The list indicates that Japan needs to pursue both improvement and transition of vehicles and various other transport meaures when aiming to achive its energy and climate targets.

Based on the presentation by **Prof. Hayashi** (cf. Annex; Hayashi 2019), the following recommendations may be derived:

- Reduction of unnecessary traffic by **improving land use planning**: Land use planning, which avoids the use or development of peripheral areas outside of cities or in other regions with limited access to alternatives to the car, will avoid unnecessary car traffic.
- **Developing public transport** services and improving conditions for **cycling and walking in medium-sized cities**: In middle-sized cities, where cars play a major role in the mobility of citizens, the conditions for using alternatives to cars (public transport, cycling, walking, etc.) will need to be improved.
- **High taxes and bans on large cars in cities:** Put very high taxes on private cars with three or more seats in cities, or even ban these cars. This should be combined with a large tax reduction for newly developed small vehicles with state-of-the-art vehicle technology.

- **Renewable energy sources and sector coupling:** There is the need for an accelerated expansion of electricity generation from renewable energies and of sector coupling. To this end, further discussions are needed in the following fields:
  - ✓ Fundamental study to assess potential and economics of sector coupling technologies, e.g. the Vehicle to Grid or the Power to Liquid, including reuse of battery in Battery Electric Vehicle.
  - ✓ Market / regulatory design, e.g. an inter-linkage with power market reform or power pricing.

4. Further research needs

Studies on a consistent package of measures to achieve ambitious climate protection goals and the potential of integrating (coupling) mobility into energy sector appear to be largely lacking for Japan, other than for Germany. There is still a need for further research in this area in both countries, for example on the priority technology and fuel paths to be followed, the priority modes of transport and the means of transport to be addressed.

In both countries, there is also a considerable need to test and evaluate policies and measures in order to better assess their impact on primary energy savings and GHG emission reduction.

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6. Annex: Factsheet and presentations

It has become clear in our analysis that Japan's insularity and Germany's close economic and transport links within the EU partly create different framework conditions for GHG emissions reduction in the transport sector and, in particular, the integration of transport into sector coupling. The following factsheet describes in more detail, which transport and other framework conditions in Germany and Japan each have an impact on per capita energy consumption in the transport sector, what importance is attached to the integration of transport into sector coupling in both countries, and whether (and if so how) binding CO_2 reduction targets for the transport sector could be integrated into national CO_2 reduction strategies.

The Annex includes the two presentations of Mr. Martin Schmied from the German Federal Environmental Agency (UBA) and Prof. Yoshitsugu Hayashi from Chubu University, which complete this output paper of the GJETC's Working Group on Transport and Sector Coupling.

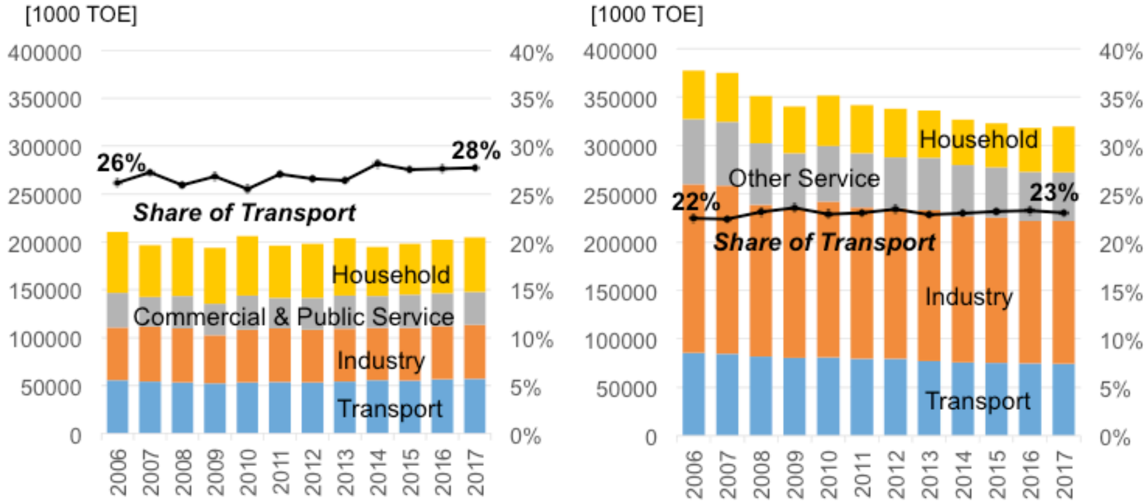
Factsheet: Content

1. Differences in energy consumption

What are the reasons for the fact that energy consumption per capita in transport is much lower in Japan than in Germany (Germany 31,7 PJ/cap, Japan 24,2 PJ/cap)?

1.1 Differences between Germany and Japan

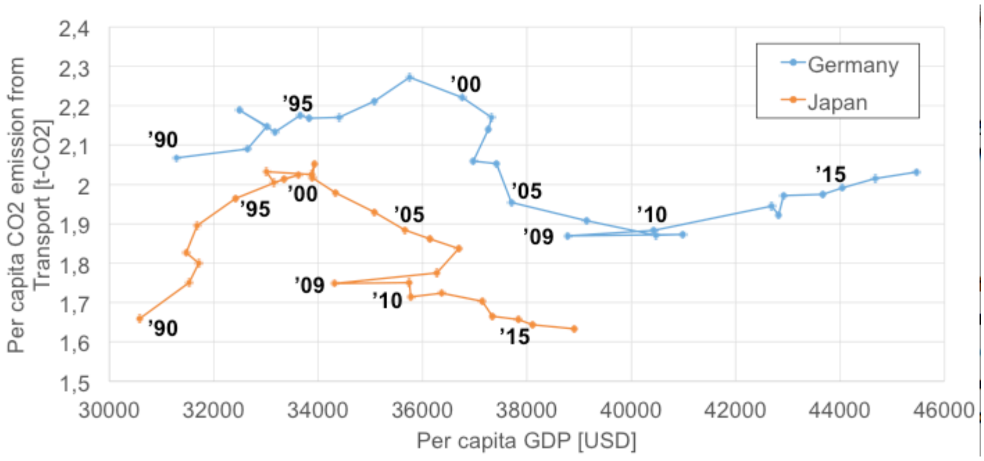
Figure 1: Energy use and Share of Transport



Germany **Japan**

Source: Hayashi (2019)

Figure 2: GDP vs. CO_2 emission from Transport



Source: Hayashi (2019)

1.2 Passenger transport

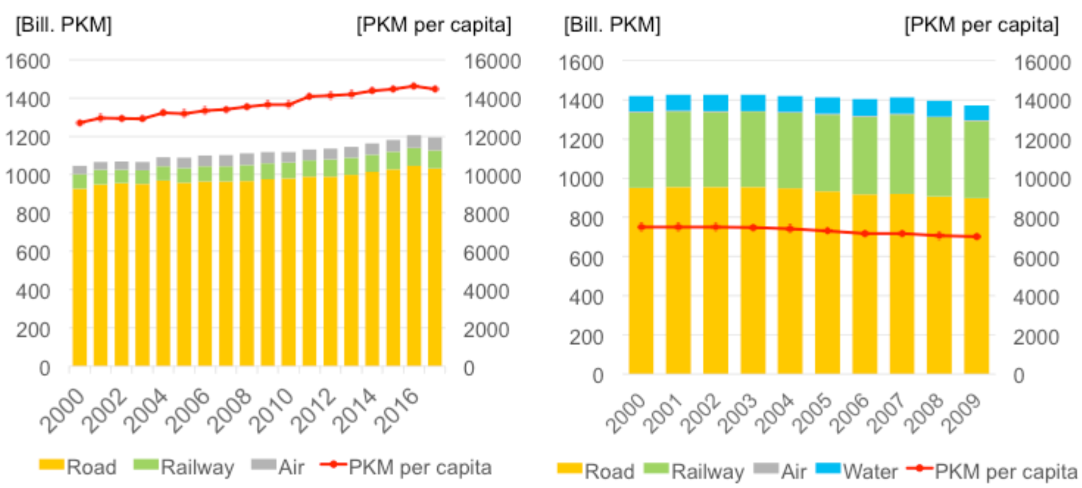
Comparing the modal split of the transport performance of both countries shows that one of the central reasons for the higher per capita energy consumption of the mobility sector in Germany is the significantly higher proportion of private car use in passenger transport. Almost 80 percent of passenger-kilometers covered by motorized transport are car-related in Germany, only 7.8 percent for railways and 6.8 percent for other public transport. In contrast, only about 60 percent of the passenger-kilometers in Japan are accounted for by the car, but over 34 percent by rail and other public transport.

Figure 3: Modal split transport volume passenger transport (passenger kilometers in %)

	passenger car	aviation	railway	public transport
Germany	80,1	5,3	7,8	6,8
Japan	59,7	5,9	29,0	5,2

Sources: Narita et al. (2018); Federal Ministry of Transport and Digital Infrastructure (2018)

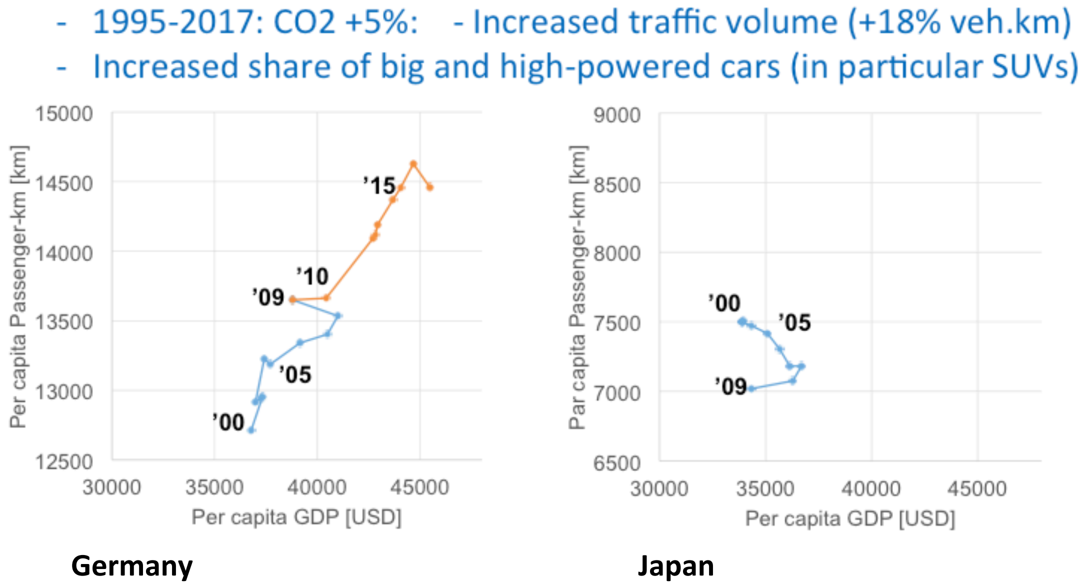
Figure 4: Passenger Transport Volume (PKM) in Germany and Japan



Germany **Japan**

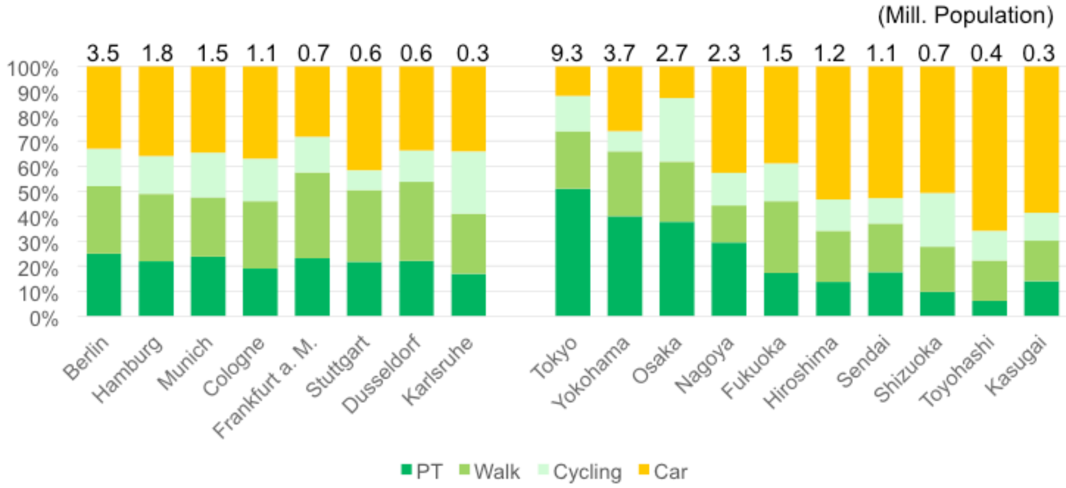
Source: Hayashi (2019)

Figure 5: Passenger Transport Volume vs. GDP in Germany and Japan



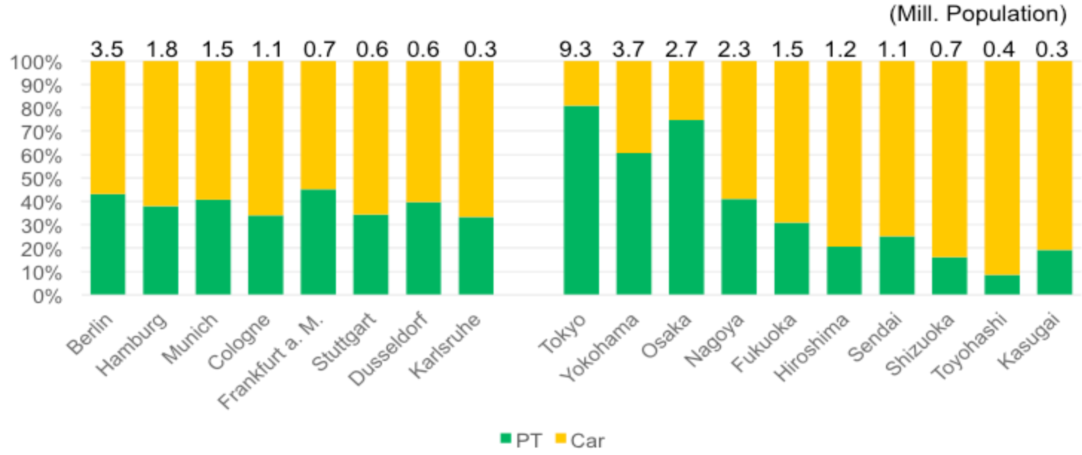
Source: Hayashi (2019)

Figure 6: Modal Share in German and Japanese Cities



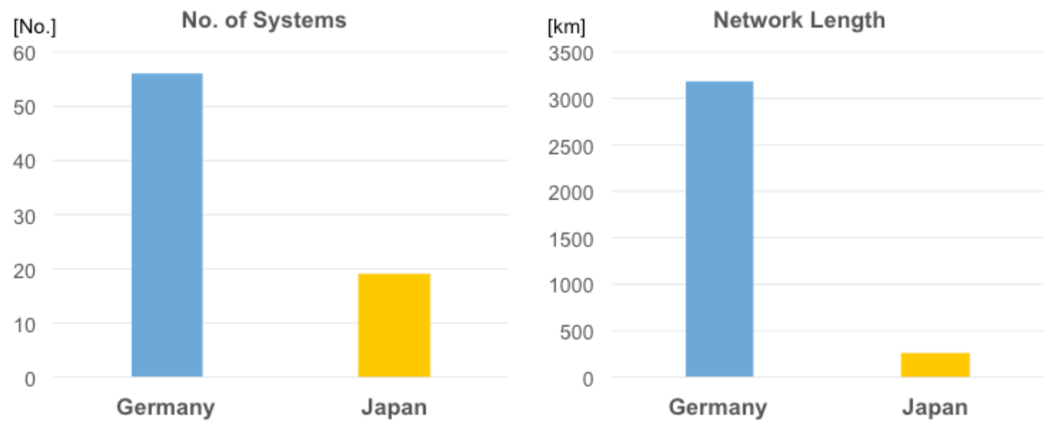
Source: Hayashi (2019)

Figure 7: Modal Share in German and Japanese Cities (Car vs. PT)



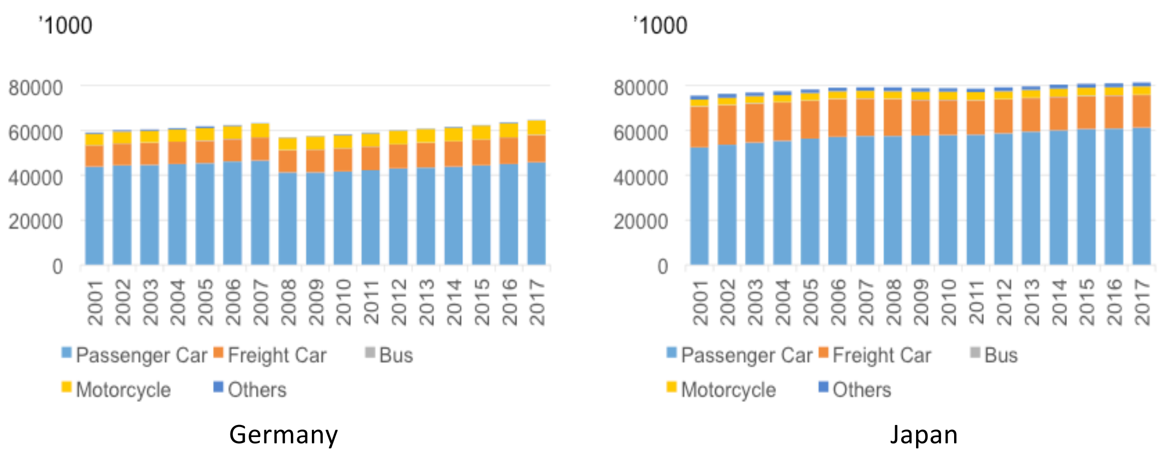
Source: Hayashi (2019)

Figure 8: Light Rail and Tram in Germany and Japan



Source: Hayashi (2019) / ERRAC and UITP (2012)

Figure 9: Vehicle Ownership by Mode in Germany and Japan



Source: Hayashi (2019)

1.3 Freight transport

Another important reason for the different energy consumption in transport are different forms of freight transport. Freight transport (tonne-kilometers total) is higher in Germany than in Japan. The per capita energy consumption in freight transport is correspondingly higher in Germany. The same applies to the total and per capita transported goods. The total quantity of goods transported is larger in Japan than in Germany, but due to the considerably higher population, the volume of goods transported per capita is smaller in Japan than in Germany. In addition, freight transport in Germany has risen by a total of around 76 percent since the mid-1990s. Here, the freight transport on the road has even doubled. In Japan, however, freight transport declined between 1990 and 2010 and has been stagnant since 2010. One reason for the higher freight volume in Germany than in Japan will undoubtedly be Germany's role as a transit area for European freight transport.

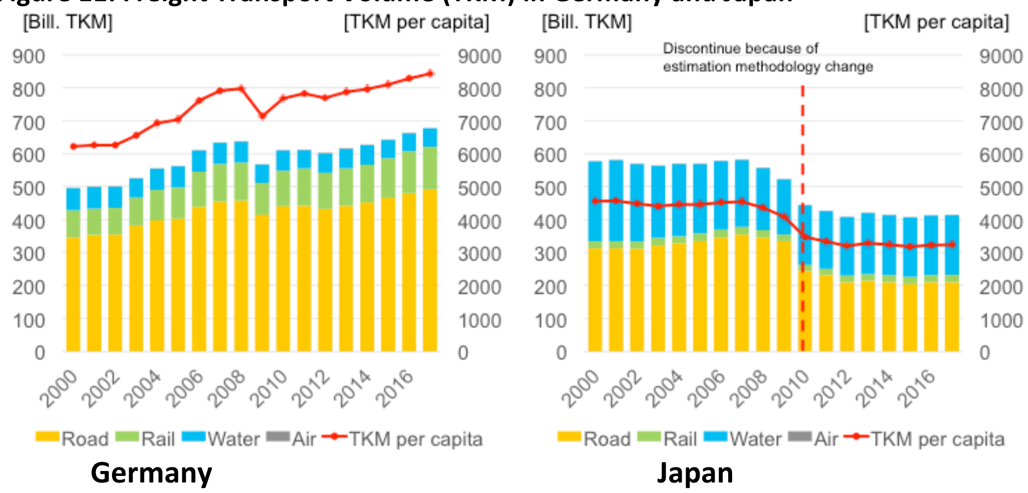
Figure 10: Freight transport and quantity of goods

	Freight transport (billion tonne-kilometers)	Freight transport (tonne-kilometers per capita)	Quantity of goods (billion tons)	Quantity of goods (tons per capita)
Germany	657	8.012	4,4	53,7
Japan	400	3.149	5,0	39,4

Sources: Federal Statistical Office (2019); ECOS Consult (2017); Federal Ministry of Transport and Digital Infrastructure (2018)

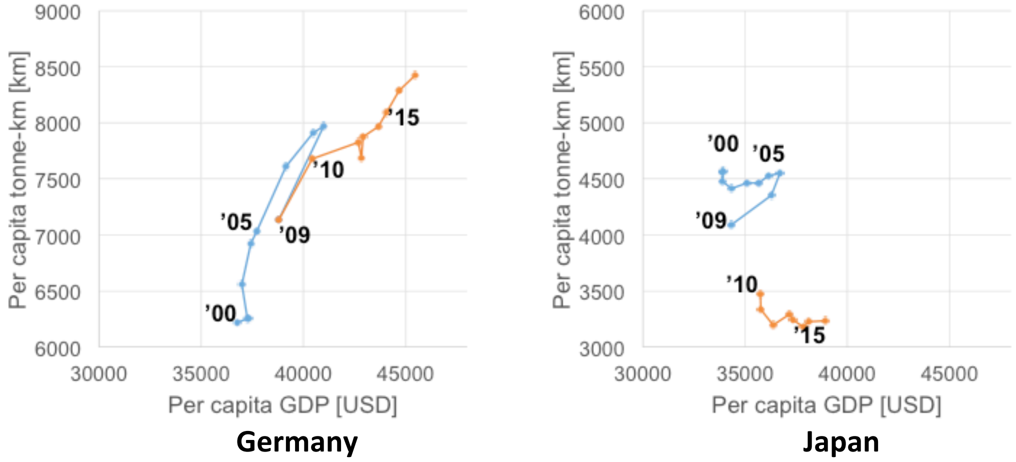
Different modal split shares in freight transport also result in different energy consumption in freight transport. In Japan, for example, the share of goods transport by rail is lower than in Germany, although this also applies to the very energy-intensive freight transport by rail. Significantly higher than in Germany is the proportion of freight transport by ship in Japan. This compensates to some extent for the lower share of rail freight transport.

Figure 11: Freight Transport Volume (TKM) in Germany and Japan



Source: Hayashi (2019)

Figure 12: Freight Transport Volume vs. GDP Germany and Japan



Source: Hayashi (2019)

Figure 13: Modal split freight transport Japan and Germany

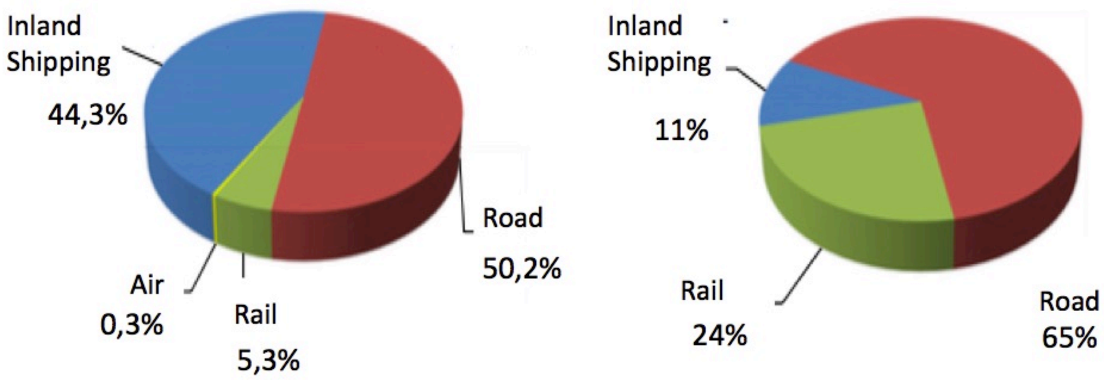


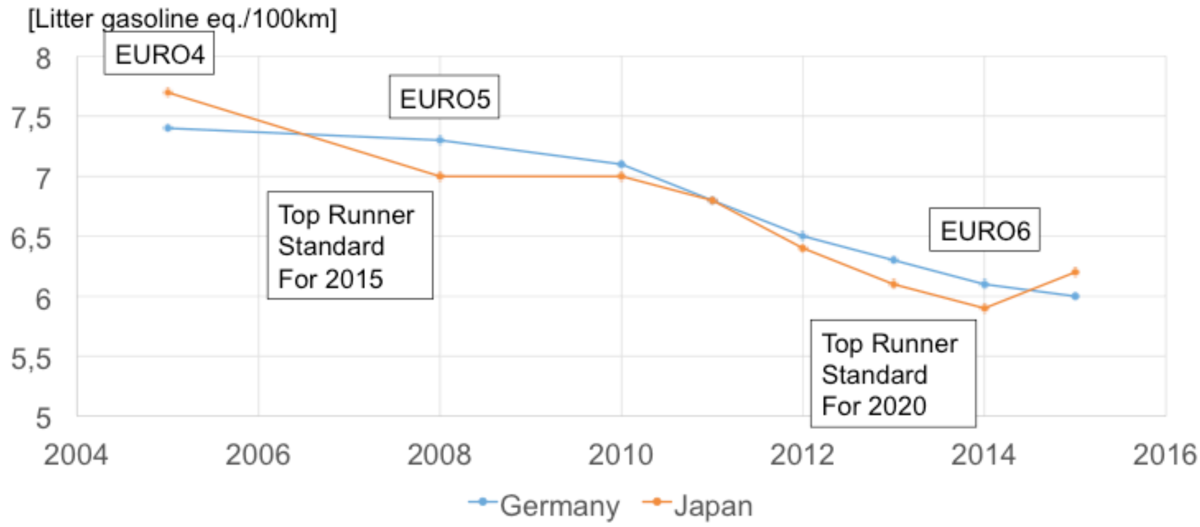
Fig. 1: Freight Traffic Japan 2015 **Fig. 2: Freight Traffic Germany 2016**

Source: Japan Federation of Coastal Shipping Association, German Federal Statistical Office

1.4 Types of drives

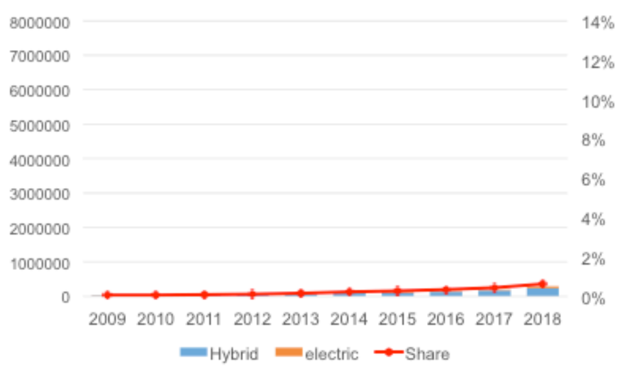
In both countries, conventional combustion engines dominate in passenger cars, with diesel vehicles playing a comparatively minor role in Japan. The share of gas vehicles and BEV in both countries is less than one percent. However, the share of hybrid vehicles in Japan is over twelve percent, whereas in Germany it is only 0.3 percent. It can not be ruled out that the lower energy consumption of hybrid vehicles in Japan will be compensated by the higher proportion of gasoline vehicles and the low importance of diesel vehicles.

Figure 14: Average fuel consumption in Germany and Japan

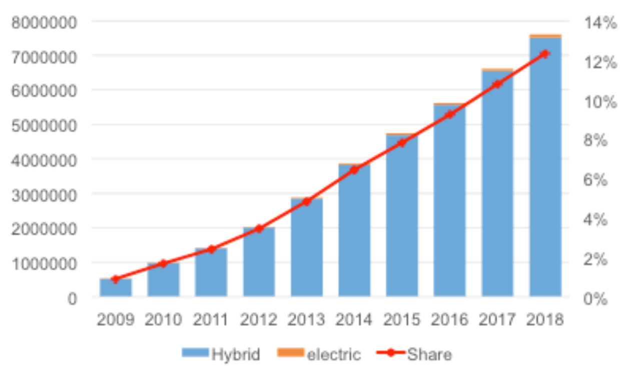


Source: Hayashi (2019); GFEU, IEA (2017)

Figure 15: Share of Hybrid and Electric (in Passenger car) in Germany and Japan



Germany



Japan

Source: Hayashi (2019)

2. Transport and Sector Coupling

Which way of sector coupling is projected by scenarios for the transport sector, in which subsectors, and at which time in the future and under which conditions?

2.1 The role of the mobility sector in sector coupling

Except for line-based systems such as the overhead line in rail transport, the energy carrier must be carried on board the means of transport. Therefore, especially energy sources with the highest possible volumetric energy density and good storage capacity are suitable. These properties are very well met by hydrocarbon based fluids and compressed gases (Ausfelder et. al.).

The market penetration of electric vehicles can be a key component of sector coupling. One of the tasks of electric vehicles can be the temporary storage of renewable electricity in the times in which the vehicles are not used. With powerful batteries and the ability to feed back into power grids or buildings, this concept, known as the Vehicle to Grid (V2G), can help address varying power demands, conserve renewable electricity from renewable energies (RES electricity) in times of low demand, and offset grid fluctuations. Not only battery electric vehicles can be used as a buffer for RES electricity. This is also possible with hydrogen fuel cell vehicles. This is the case when in electrolysis plants renewable electricity is used in the times when more electricity is generated than needed to produce green hydrogen. Renewable produced hydrogen can also be used to produce synthetic fuels such as Synthetic Natural Gas (SNG), which can be used in combustion engines.

2.1.1 Relevant energy sources in the mobility sector and their fields of application

One of the reasons for the intended change in the propulsion technologies of gasoline and diesel-powered internal combustion engines to electric vehicles and fuel cell cars include their kilometer-specific lower energy consumption and the resulting lower CO_2 emissions. Well-to-wheel energy consumption for gasoline and diesel vehicles is 1.4 to 1.7 mega joules per kilometer, for hybrid vehicles, BEVs and fuel cell cars only between 0.4 and 1.2 mega joules per kilometer. The CO_2 emissions for fossil propulsion systems are 75 to 125 grams CO2e, for hybrid vehicles, BEVs and fuel cell cars no more than 60 grams, depending on the type of electricity used. Although the energy consumption of vehicles using biofuels or synthetic fuels of 2 to 3.5 mega joules is higher than for other types of propulsion, the CO_2 emissions per kilometer are comparable to the various types of electric drive.

Hydrogen

In a decarbonized transport sector, hydrogen becomes especially interesting when the ranges and loads of vehicles increase and more energy must be stored on board. Fuel cell vehicles (FCVs) such as buses, trucks, long-distances passenger vehicles and trains as well as certain shipping options are the applications where hydrogen might establish itself in the future (Jensterle et al. 2019, S. 4).

Electricity

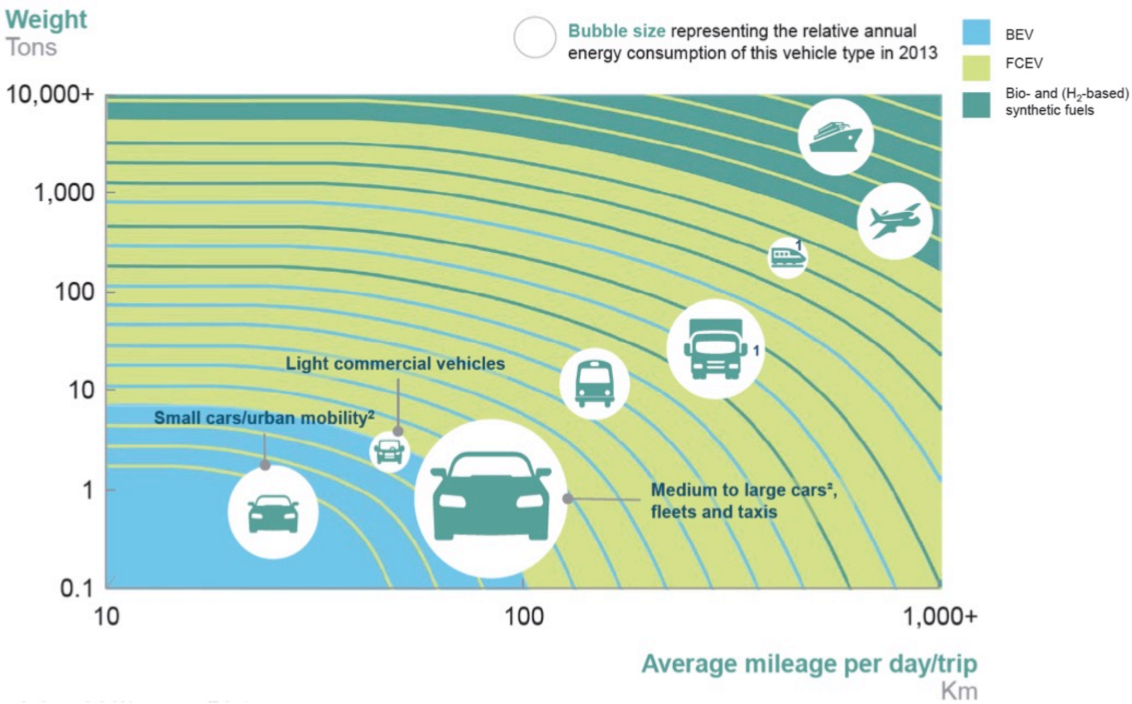
Electric vehicles offer the possibility of using RES electricity in the mobility sector. The direct use of electricity in battery electric vehicles is an option. For line-bound public transport, electricity is already being used extensively as propulsion energy, with the vehicles being supplied with electricity by a catenary. A limitation of the range of the vehicles does not exist in this case. For battery electric cars and light commercial vehicles, the deployment is mainly seen in the short- and medium-range uses, because of their limited battery capacity. However, possible advances in battery technology could make electric vehicles suitable for longer ranges. Longer vehicle ranges can also be achieved by combining combustion engine and electric motor in hybrid vehicles.

Synthetic fuels

The production of synthetic fuels represents another indirect form of using RES electricity in the mobility sector. Synthetic fuels can then be used in vehicles when battery or overhead power supply is not possible. In these cases, the energy carrier must be carried in liquid form in the vehicle. This would be the case, for example, with ships or aircraft. In addition to use in heavy commercial vehicles, there are potential fields of application for synthetic fuels. The production of synthetic fuels based on RES electricity also provides the option of storing renewablely generated electricity (Jensterle et al. 2019, S. 5).

The following figure once again illustrates the suitability of the various alternative drive types depending on the size or weight of the vehicles and the average distance traveled by them.

Figure 16: Potential applications of alternative drives+



Source: Hydrogen Council (2017)

2.1.2 Efficiency of energy sources in the field of mobility

For the transport sector overall efficiencies from the point of feeding the power into the grid to the wheel are 69% for electric vehicles (EVs), 26% for fuel cell vehicles (FCV) and 13% for synthetic fuel combustion engine vehicles (ICEVs) (Agora Verkehrswende et al. (2018). In other words, compared to an EV, hydrogen FCV requires 2.6 times more energy, and a synthetic fuel ICEV 5.3 times more energy. However, the comparative FCV efficiency improves when looking at long distance freight transport (Jensterle et al. 2019, S. 4).

2.2 Germany: Status quo of the mobility - Choice of transport mode

The requirements for the energy supply vary depending on the means of transportation. Road transport, rail transport, shipping and air transport therefore have different requirements for a functioning sector coupling. Motorized private transport makes up by far the largest share of passenger transport in Germany with 76 percent of the passenger kilometers covered by motorized and non-motorized transport. Freight transport is dominated by trucks. Trucks account for around 70 percent of the tonne-kilometers. Overall, an increase in transport is expected by 2050 (Ausfelder et. al.).

2.3 Germany: scenario studies considered

Three scenario studies have been looked at in more detail, which consider the integration of the mobility sector into the sector coupling as a possible future option. The considered studies are three studies which are also the focus of the hydrogen study. The studies are:

Hecking, Harald, Jürgen Kruse, Oliver Henners, Theresa Wildgrube, Dominic Lencz, Martin Hintermayer, Max Gierking, Jakob Peter, Stefan Lorenczik 2018: dena-Leitstudie Integrierte Energiewende. Gutachterbericht, Juni 2018. On behalf of the Deutsche Energie-Agentur. Online available at: https://shop.dena.de/fileadmin/denashop/media/Downloads_Dateien/esd/9261_dena-Leitstudie_Integrierte_Energiewende_lang.pdf.

Ausfelder, Florian, Frank-Detlef Drake, Berit Erlach, Manfred Fischedick, Hans-Martin Henning, Christoph Kost, Wolfram Münch, Karen Pittel, Christian Rehtanz, Jörg Sauer, Katharina Schätzler, Cyrill Stephanos, Michael Themann, Eberhard Umbach, Kurt Wagemann, Hermann-Josef Wagner, Ulrich Wagner (2017): "Sektorkopplung" – Untersuchungen und Überlegungen zur Entwicklung eines integrierten Energiesystems. Online available at: https://www.akademienunion.de/fileadmin/redaktion/user_upload/Publikationen/Stellungnahmen/ESYS_Analyse_Sektorkopplung.pdf.

Repenning, Julia, Lukas Emele, Ruth Blanck, Hannes Böttcher, Günter Dehoust, Hannah Förster, Benjamin Greiner, Ralph Harthan, Klaus Henneberg, Hauke Hermann, Wolfram Jörß, Charlotte Loreck, Sylvie Ludig, Felix Chr. Matthes, Margarether Scheffler, Katja Schumacher, Kirsten Wiegmann, Carina Zell-Ziegler 2015: Klimaschutzszenario 2050 – 2. Endbericht. Last accessed on 27.03.2019 at: https://www.oeko.de/oekodoc/2451/2015-608-de.pdf.

2.3.1 dena pilot study (dena-Leitstudie, Hecking et al. 2018)

Observation period

- 2015 - 2050

Modes of transport

- street
- rail
- ship
- aviation

Transport Types

- Passenger transport (PT)
- Freight transport (FT)

Means of transport

- PT: passenger car, bus, tram, railroad, plane
- FT: light commercial vehicles, heavy commercial vehicle, river transport, plane

Fuels

- street: Petrol, diesel, CH4, H2, electricity
- railroad: Diesel. H2, electricity
- river transport: Diesel, CH4, H2
- aviation: Kerosene, H2

Assumptions and framework conditions (selection)

- transport volume PT up to 2050: aviation and railroad increase, passenger car decrease
- transport volume FT up to 2050: all modes increase
- Investment costs passenger car: vary according to drive type, FCV highest costs

Investigated module Sector coupling with mobility reference

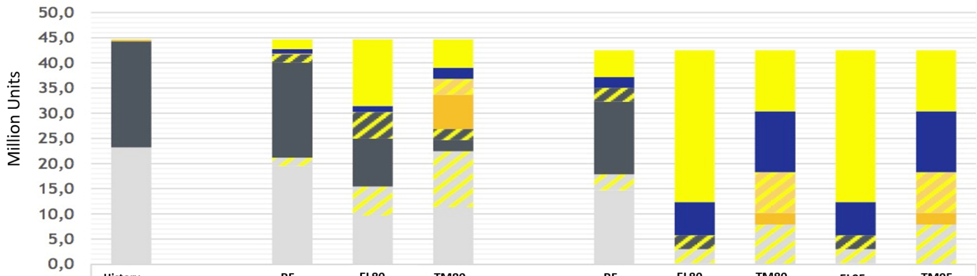
- Synthetic fuels:
  - Synthetic generation of gaseous and liquid hydrogen
  - Production of synthetic methane from synthetic hydrogen and CO_2
  - Synthetic production of oil derivatives (diesel, gasoline, kerosene, light fuel oil, heavy fuel oil)
- Renewable generation of electricity
  - PV
  - Wind onshore und offshore
  - Power generation with biomass
  - Power generation with biogas

Scenarios related to research questions

- Passenger transport
  - Reference scenario

- Electrification scenario: BEV dominate the market in the long term, battery costs are falling, ranges are rising
- Technology-mix-scenario: BEV and FCV dominate the market in 2050

Figure 17: Development of fleet composition (passenger cars)



	History 2015	RF	EL80 2030	TM80	RF	EL80	TM80 2050	EL95	TM95
total	44,7	44,7	44,7	44,7	42,5	42,5	42,5	42,5	42,5
PC BEW	0,1	1,9	13,3	5,6	5,3	30,2	12,1	30,2	12,1
PC H2 FCV	0,0	0,9	1,2	2,2	2,1	6,6	12,1	6,6	12,1
PC CH4 PHEV	0,0	0,0	0,0	3,1	0,0	0,0	8,1	0,0	8,1
PC CH4 (Methane)	0,3	0,1	0,0	6,8	0,0	0,0	2,3	0,0	2,3
PC Diesel PHEV	0,0	1,6	5,3	2,2	2,8	2,8	0,0	2,8	0,0
PC Diesel	21,1	18,9	9,5	2,2	14,5	0,0	0,0	0,0	0,0
PC Petrol PHEV	0,0	1,6	5,7	11,1	3,2	2,8	7,9	2,8	7,9
PC Petrol	23,2	19,5	9,7	11,3	14,7	0,2	0,0	0,2	0,0

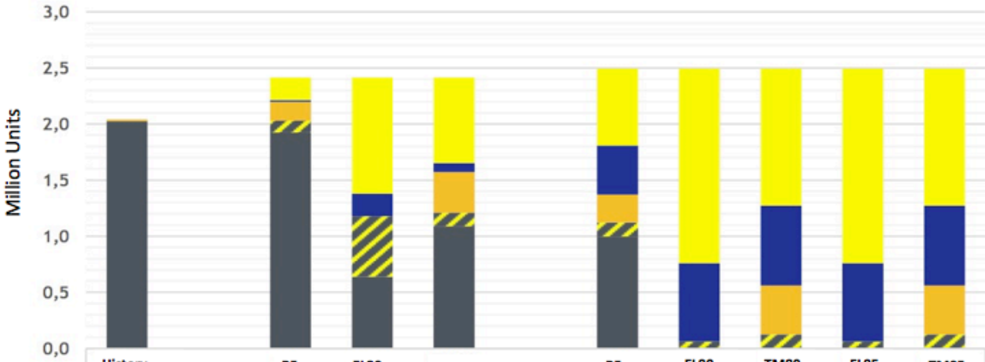
ᶜ Inclusive mild and full hybrid Vehicle

Source: Hecking et al. (2018)

- Freight transport (light commercial vehicles)
  - Reference scenario
  - Electrification scenario: Replacement of diesel drive by directly or indirectly electrically powered drives by 2050
  - Technology-mix-scenario: In 2050, BEV dominated urban use, FCV long distances and gas vehicles the flexible use in the city and surrounding area

- Freight transport (heavy commercial vehicles)
  - Reference scenario
  - Electrification scenario: In 2050, only 6% of all trucks have a diesel drive, BEV in the range up to 12 tons, FCV over 12 tons gross weight dominant
  - Technology-mix scenario: In 2050, FCV (36%) and gas vehicles (35%) have the highest market shares. Also diesel vehicles are still used in long-distance transport. BEVs have lower share

Figure 18: Development of fleet composition (light commercial vehicles)

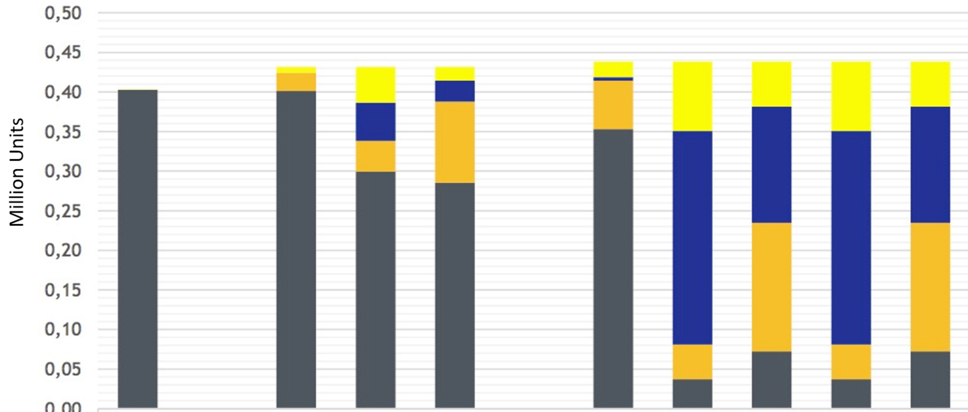


	History 2015	RF	EL80 2030	TM80	RF	EL80	TM80 2050	EL95	TM95
total	2,0	2,4	2,4	2,4	2,5	2,5	2,5	2,5	2,5
LNF BEV	0,0	0,2	1,0	0,8	0,7	1,7	1,2	1,7	1,2
LNF H2 FCV	0,0	0,0	0,2	0,1	0,4	0,7	0,7	0,7	0,7
LNF Methan PHEV	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
LNF Methan	0,0	0,2	0,0	0,4	0,2	0,0	0,4	0,0	0,4
LNF Diesel PHEV	0,0	0,1	0,5	0,1	0,1	0,1	0,1	0,1	0,1
LNF Diesel	2,0	1,9	0,6	1,1	1,0	0,0	0,0	0,0	0,0

* Inclusive mild and full hybrid Vehicle

Source: Hecking et al. (2018)

Figure 19: Development of fleet composition (heavy commercial vehicles)



	History 2015	RF	EL80 2030	TM80	RF	EL80	TM80 2050	EL95	TM95
total	0,40	0,43	0,43	0,43	0,44	0,44	0,44	0,44	0,44
Truck (>12t) BEV	0,00	0,01	0,05	0,02	0,02	0,09	0,06	0,09	0,06
Truck (>12t) H2 FCV	0,00	0,00	0,05	0,03	0,00	0,27	0,15	0,27	0,15
Truck (>12t) CH4	0,00	0,02	0,04	0,10	0,06	0,04	0,16	0,04	0,16
Truck (>12t) Diesel *	0,40	0,40	0,30	0,29	0,35	0,04	0,07	0,04	0,07

* Inclusive mild and full hybrid Vehicle

Source: Hecking et al. (2018)

- Passenger transport (railroad and aviation)
  Reference scenario
  - Electrification scenario: Rail in 2050 almost completely electrified, small proportions fuel cell, air in addition to kerosene small proportions of liquid hydrogen
  - Technology-mix scenario: Rail in 2050 almost completely electrified, low proportions of diesel and fuel cell, air almost exclusively kerosene

Figure 20: Types of propulsion rail and air (passenger transport)

		2015	2030			2050		
			RF	EL80/95	TM80/95	RF	EL80/95	TM80/95
Rail Transport	Electric	90%	91%	91%	91%	92%	93%	92%
	Diesel	10%	8%	6%	7%	6%	0%	4%
	H2-FCV	0%	1%	3%	2%	2%	7%	4%
Air Transport	Kerosene	100%	100%	92%	99%	100%	65%	92%
	LH2-FC	0%	0%	8%	1%	0%	35%	8%

Source: Hecking et al. (2018)

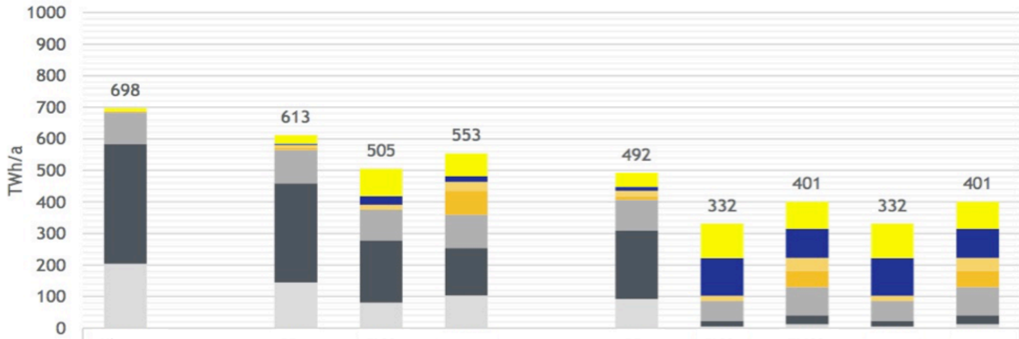
- Freight transport (rail, ship, air)
    - Reference scenario
    - Electrification scenario: Rail in 2050 almost completely electrified, low share of diesel, ship high shares of diesel and LNG, low shares of fuel cell, aircraft two-thirds of kerosene and one-third of liquid hydrogen
    - Technology-mix scenario: Rail in 2050 almost completely electrified, low shares of diesel and fuel cell, ship high shares of diesel and LNG, small shre fuel cell, air higher proportion of kerosene and low proportion of liquid hydrogen

Figure 21: Types of propulsion (rail, ship, air)

		2015	2030			2050		
			RF	EL	TM80/95	RF	EL	TM80/95
Rail Transport	Electric	93%	93%	93%	93%	93%	93%	93%
	Diesel	7%	7%	5%	7%	6%	3%	5%
	H2-FCV	0%	0%	2%	0%	1%	4%	2%
Inland shipping	Diesel	100%	98%	94%	93%	95%	70%	60%
	LNG	0%	2%	4%	7%	5%	8%	35%
	H2-FCV	0%	0%	2%	1%	0%	7%	1%
	LH2-FCV	0%	0%	0%	0%	0%	15%	4%
Air Transport	Kerosene	100%	100%	92%	99%	100%	65%	92%
	LH2-FC	0%	0%	8%	1%	0%	35%	8%

Source: Hecking et al. (2018)

Figure 22: Final energy consumption of the transport sector



	History 2015*	RF	EL80 2030	TM80	RF	EL80	TM80 2050	EL95	TM95
total	698	613	505	553	492	332	401	332	401
Energy	11	29	87	72	44	110	86	110	86
Hydrogen **	0	4	27	18	13	120	92	120	92
LNG **	0	8	13	28	18	13	42	13	42
Gas **	4	8	3	76	11	3	52	3	52
Kerosene **	101	106	98	105	98	64	89	64	89
Diesel **	379	314	197	151	216	18	28	18	28
Petrol **	204	145	81	103	92	5	12	5	12

* Historical value according to AGEB (2017) ** conventional, biogenic and synthetic

Source: Hecking et al. (2018)

- The primary energy consumption in Germany in the climate change scenarios will decrease by 44 to 50 percent compared to 2015 by 2050 to around 2000 TWh
- In the mobility sector, the 95% reduction in CO_2 emissions is also due to the substitution of synthetic fuels for the fossil fuels kerosene, diesel and gasoline. Without synthetic energy sources, this ambitious reduction for the mobility sector will not be achievable. However, much of the synthetic fuel required for this will have to be imported from abroad

2.3.2 »Sector coupling« - Investigations and considerations for the development of an integrated energy system, ("Sektorkopplung" – Untersuchungen und Überlegungen zur Entwicklung eines integrierten Energiesystems, Ausfelder et al. 2017)

Observation period

- 2017 (?) - 2050

Modes of transport

- street
- railroad, ship, aviation (not deepened)

Transport types

- Passenger transport (PT)
- Freight transport (FT)

Means of transport

- PV: passenger car, plane
- FT: light and heavy commercial cars (not differentiated in scenario documentation)

Fuels

- street: Benzine, Diesel, CH4, H2, electricity, synthetic fuels
- railroad, ship, aviation (not deepened)

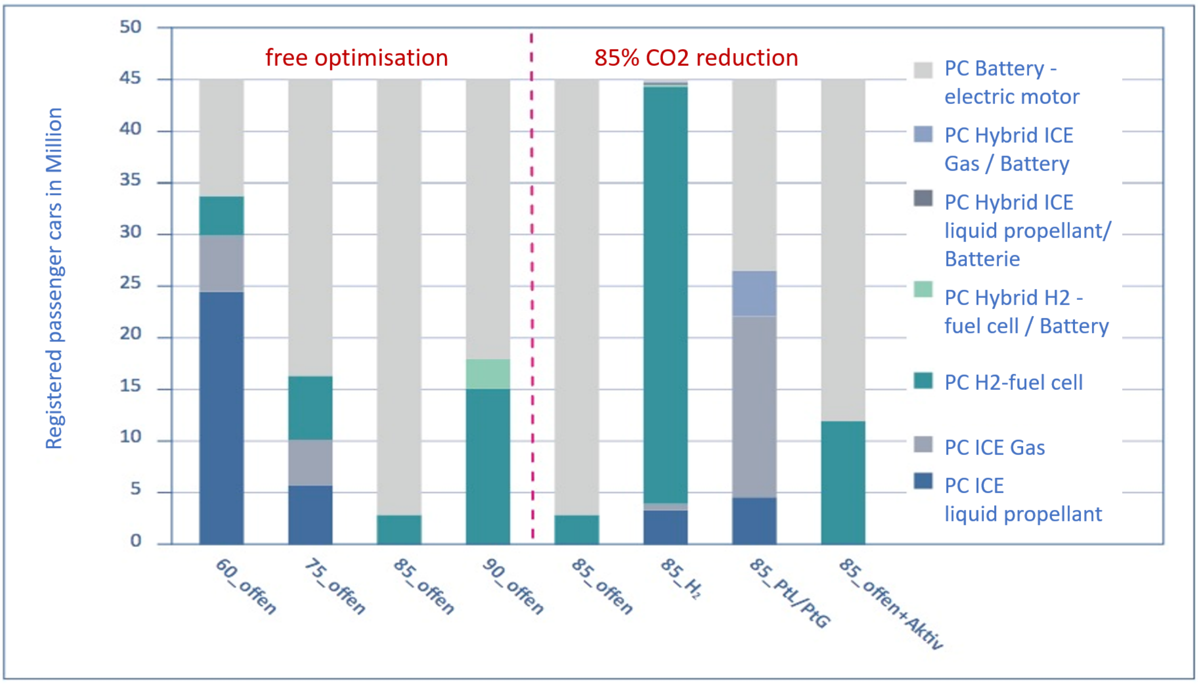
Assumptions and framework conditions (selection)

- No renewable energies are imported to Germany
- By 2050, the number of vehicles in passenger cars will drop by five percent compared to the base year (?) and by five percent by 2050 for trucks

Investigated module Sector coupling with mobility reference

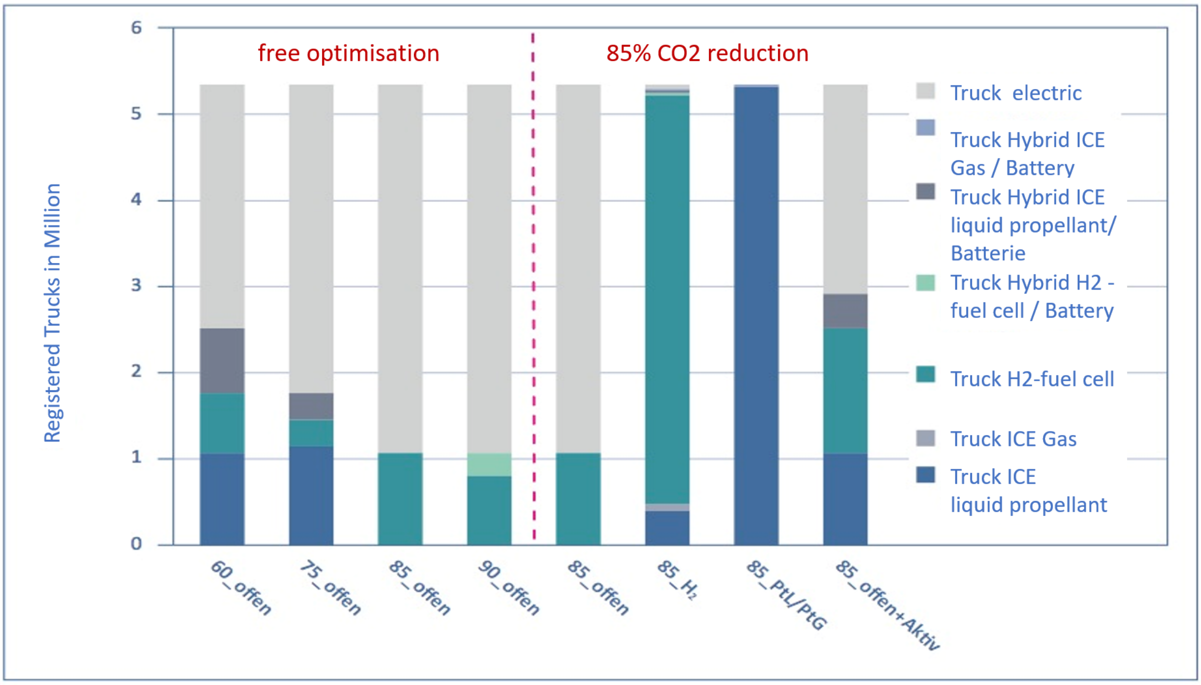
- Synthetic fuels
  - Synthetic generation of gaseous and liquid hydrogen by RES electricity
  - Generation of other synthetic fuels by RES electricity
- Conventional power generation plus wind power (onshore and offshore), PV, hydropower, biomass, direct use of electricity and production of synthetic fuels
- Power-to-Gas und Power-to-Liquid produces hydrogen and synthetic fuels

Figure 23: Development of fleet composition in 2050 (passenger cars)



Source: Ausfelder et al. (2017)

Figure 24: Development of fleet composition in 2050 (commercial vehicles)



Source: Ausfelder et al. (2017)

Central results

- Conventional fossil fuels will become less important in passenger cars, light commercial vehicles and heavy commercial vehicles by 2050, with the direct use of electricity, hydrogen and synthetic fuels dominating
- With increased use of electricity in the mobility sector, the demand for electricity is rising sharply overall. Particularly in the 90 percent reduction scenario with its high shares of power to gas, power to liquid and the increased use of hydrogen, the use of electricity in all sectors is 1150 TWh, while the reduction by 60 percent scenario is only about 660 TWh
- the higher the CO_2 reduction to be achieved, the higher the share of indirect electricity use in transport (production of synthetic fuels)
- Depending on the scenario path and the targeted CO2 reduction, between five and 30 TWh of electricity would have to be imported (to produce synthetic fuels).
- The indirect use of electricity in transport becomes relevant as synthetic fuels can be transported more easily due to the higher energy density
    - Relevance of indirect power use therefore also or especially in shipping and aviation
- A mix of electricity and hydrogen-based mobility is expected to be required to achieve high CO_2 reductions, and reduction targets are unlikely to be achieved if fossil fuels continue to be used heavily
    - Synthetic renewably produced fuels enable a temporal decoupling of production and consumption
- The need to integrate transport into sector coupling increases with the reduction targets that are to be achieved
- Switching to electric and hydrogen mobility is central to achieving ambitious reduction targets

2.3.3 Klimaschutzszenario 2050 (Climate protection scenario 2050, Repenning et al. 2015)

Observation period

- 2010 - 2050

Modes of transport

- Passenger transport: street, railroad, aviation
- Freight transport: street, railroad, ship, aviation

Transport types

- Passenger transport (PT)
- Freight transport (FT)

Means of transport

- PT: passenger car, bus, tram, railroad, plane
- GV: light and heavy commercial vehicles, railroad, ship, plane

Fuels in transport sector

- Fossil fuels and biofuels
- Conventional and RES electricity (inkl. power to liquid)
    - hydropower
    - windpower (on- und offshore)
    - PV
    - biomass

Assumptions and framework conditions (selection)

- efficiency development of the different drive types
- development of transport, energy and fuel costs
- development of transport demand
- population decline by 2050 compared to 2010, with a shift in the age pyramid
- gross domestic product rising from 2.5 trillion euros to 3.4 trillion
- decline in the number of persons subject to social security contributions from 2010 to 2050

Investigated module Sector coupling with mobility reference

- Power Generated Fuels:
    - not used in BAU and KS 80, in KS 95 they cover 60 percent of the energy requirement
- Passenger transport cars: efficiency
    - current measures scenario (BAU): Significant increase in efficiency (MJ / Fzkm) for new registrations by 2050 for all drive types
    - climate protection scenario 80: Significant increase in efficiency (MJ / Fzkm) in new registrations by 2050 for all types of drive, higher than in BAU
    - climate protection scenario 95: Significant increase in efficiency (MJ / Fzkm) in new registrations by 2050 for all types of drive, higher than in BAU

Figure 25: Efficiency development of passenger cars

	2010	2020	2030	2040	2050
	MJ/km				
AMS					
Diesel	2,36	1,95	1,79	1,74	1,66
Gasoline engine	2,59	2,00	1,87	1,79	1,65
Gas vehicle	2,59	2,00	1,87	1,79	1,65
BEV – range 150 km	0,81	0,74	0,70	0,69	0,66
BEV – range 300 km	0,90	0,81	0,71	0,70	0,67
Plug-In-Hybrid - electrical mode	0,81	0,84	0,79	0,75	0,70
Plug-In-Hybrid - conventional mode	2,38	1,89	1,76	1,71	1,63
Range Extender - electrical mode	0,81	0,74	0,71	0,70	0,67
Range Extender - conventional mode	2,79	2,21	2,11	2,05	1,97
KS 80 und KS 95					
Diesel	2,36	2,01	1,68	1,32	1,21
Gasoline engine	2,59	2,06	1,74	1,18	1,11
Gas vehicle	2,59	2,06	1,74	1,18	1,11
BEV – range 150 km	0,81	0,76	0,70	0,60	0,56
BEV – range 300 km	0,90	0,82	0,71	0,62	0,57
Plug-In-Hybrid - electrical mode	0,81	0,76	0,73	0,63	0,58
Plug-In-Hybrid - conventional mode	2,38	1,90	1,76	1,18	1,11
Range Extender - electrical mode	0,81	0,76	0,71	0,61	0,57
Range Extender - conventional mode	2,79	2,23	2,11	1,50	1,39
	2010	**2020**	**2030**	**2040**	**2050**
	Change compared to 2010				
AMS					
Diesel		-17%	-24%	-26%	-30%
Gasoline engine		-23%	-28%	-31%	-36%
Gas vehicle		-23%	-28%	-31%	-36%
BEV – range 150 km		-8%	-14%	-15%	-18%
BEV – range 300 km		-10%	-20%	-22%	-25%
Plug-In-Hybrid - electrical mode		4%	-2%	-8%	-13%
Plug-In-Hybrid - conventional mode		-21%	-26%	-28%	-32%
Range Extender - electrical mode		-8%	-12%	-14%	-17%
Range Extender - conventional mode		-21%	-25%	-27%	-30%
KS 80 und KS 95					
Diesel		-15%	-29%	-44%	-49%
Gasoline engine		-20%	-33%	-55%	-57%
Gas vehicle		-20%	-33%	-55%	-57%
BEV – range 150 km		-6%	-14%	-25%	-31%
BEV – range 300 km		-8%	-20%	-31%	-36%
Plug-In-Hybrid - electrical mode		-6%	-10%	-22%	-28%
Plug-In-Hybrid - conventional mode		-20%	-26%	-50%	-53%
Range Extender - electrical mode		-6%	-12%	-24%	-30%
Range Extender - conventional mode		-20%	-25%	-46%	-50%

Source: Repenning et al. (2015)

- Passenger cars: registrations
  - current measures scenario (BAU): By 2050, diesel and gasoline will decline to around 60 percent, 25 percent BEV to me Range Extender, total stock compared to 2010 in 2050 almost unchanged
  - climate protection scenario 80: gasoline and diesel disappear almost completely from the market until 2050, high share BEV. Total inventory slightly lower in 2050 compared to 2010
  - climate protection scenario 95: gasoline and diesel disappear almost completely from the market by 2050, very high share of BEV, car vehicle stock in 2050 significantly lower than in 2010

Figure 26: Development of fleet composition Passenger cars

	2010	2020	2030	2040	2050
	Percentage of new registrations				
AMS					
Petrol	58%	54%	44%	36%	33%
Diesel	42%	40%	35%	30%	28%
BEV 150	0%	1%	4%	7%	8%
Gas	0%	1%	1%	1%	1%
PHEV	0%	2%	7%	11%	5%
REEV	0%	2%	9%	15%	25%
KS 80					
Petrol	58%	55%	43%	10%	3%
Diesel	42%	34%	27%	8%	3%
BEV 150	0%	2%	4%	28%	41%
BEV 300	0%	0%	4%	14%	23%
Gas	0%	3%	5%	7%	10%
PHEV	0%	3%	7%	11%	5%
REEV	0%	3%	10%	22%	16%
KS 95					
Petrol	58%	59%	43%	1%	1%
Diesel	42%	32%	20%	1%	0%
BEV 150	0%	2%	9%	35%	42%
BEV 300	0%	0%	4%	29%	34%
Gas	0%	1%	1%	0%	0%
PHEV	0%	3%	10%	12%	5%
REEV	0%	3%	13%	22%	17%

Source: Repenning et al. (2015)

- Light and heavy commercial vehicles: efficiency
  - current measures scenario (BAU): moderate increase in efficiency (MJ / Fkm) for new registrations by 2050 for all drive types
  - climate protection scenario 80: Significant increase in efficiency (MJ / Fzkm) for new registrations by 2050 for all drive types, higher than in BAU
  - climate protection scenario 95: Significant increase in efficiency (MJ / Fzkm) for new registrations by 2050 for all drive types, higher than in BAU

Figure 27: Efficiency development light and heavy commercial cars

	2010	2020	2030	2040	2050
	MJ/km				
AMS					
light commercial vehicles					
Diesel	3,04	2,94	2,81	2,63	2,35
Electric drive		0,89	0,85	0,84	0,79
Gas		2,94	2,81	2,63	2,35
REEV			0,82	0,76	0,67
Truck 3.5-7.5 t					
Diesel	4,41	3,83	3,63	3,20	3,09
Electric drive		1,88	1,72	1,73	1,68
PHEV			2,00	2,02	1,97
Truck 7.5-12 t					
Diesel	6,24	5,42	5,14	4,41	4,37
Electric drive		2,75	2,46	2,44	2,40
PHEV			3,09	3,08	3,05
Truck > 12 t					
Diesel	9,19	7,68	7,09	6,48	5,99
PHFV			4,60	4,42	4,40
articulated truck					
Diesel	10,82	9,00	8,57	7,87	7,52
KS 80 and KS 95					
light commercial vehicles					
Diesel	3,04	2,70	2,34		
Electric drive		0,82	0,78	0,72	0,70
Gas		2,70	2,34	2,06	1,93
REEV			0,70	0,61	0,54
Truck 3.5-7.5 t					
Diesel	4,41	3,83	3,30		
Electric drive		1,88	1,72	1,70	1,68
PHEV			2,00	1,94	1,93
Truck 7.5-12 t					
Diesel	6,24	5,42	4,67		
Electric drive		2,75	2,46	2,43	2,40
PHEV			3,09	2,98	2,96
Truck > 12 t					
Diesel	9,19	7,68	6,04		
PHEV			4,44	4,38	4,05
articulated truck					
Diesel	10,82	9,00	7,58	7,09	
Gas		10,09	8,99	8,40	8,37
Catenary vehicle			4,81	4,47	4,44

Source: Repenning et al. (2015)

- Light and heavy commercial vehicles: new registrations
  - current measures scenario (BAU): Diesel until 2050 with light and heavy commercial vehicles clearly dominating drive type
  - climate protection scenario 80: Diesel will not play a role in 2050 anymore
  - climate protection scenario 95: Use of overhead line trucks (semitrailer)

- Freight transport 2010-2050
    - current measures scenario BAU: Road moderate rise, rail doubling, ship stable
    - climate protection scenario 80: road stable, railroad more than tripled, ship stable
    - climate protection scenario 95: Road low rise, rail about tripling, ship stable

- Final energy demand of the transport sector 2010 - 2050, differentiated according to types of transport and energy sources
    - current measures scenario BAU: total minus 34 percent, consumption of diesel fuel decline by 30, gasoline over 60 percent, tripling electricity use
    - climate protection scenario 80: Reduction by almost 60 percent in national transport by 2050
    - climate protection scenario 95: Reduction Final energy demand by the year 2050 by 68 percent

- Greenhouse gas emissions from transport 1990 – 2050
    - are shown differentiated according to climate gases for all scenarios

- Central results
    - As far as possible, motorized transport is based on the direct use of renewable electricity (battery electric vehicles, rail transport, and overhead line trucks, if applicable)
    - Where direct electrification is not an option, electricity-based fuels will be used in KS 95 from 2030 onwards (Hydrogen and synthetic fuels).

Figure 28: Development of fleet composition light and heavy commercial cars

	2010	2020	2030	2040	2050
	Percentage of new registrations				
AMS					
light commercial vehicles					
Petrol	5%	0%	0%	0%	0%
BEV	0%	1%	3%	4%	6%
Diesel	95%	97%	90%	84%	82%
Gas	0%	2%	2%	2%	2%
REEV	0%	0%	5%	10%	10%
Truck > 12 t					
Diesel	100%	100%	96%	90%	88%
FHEV	0%	0%	4%	10%	12%
articulated truck					
Diesel	100%	100%	100%	100%	100%
KS 80					
light commercial vehicles					
Petrol	5%	0%	0%	0%	0%
BEV	0%	5%	25%	90%	90%
Diesel	95%	93%	70%	0%	0%
Gas	0%	2%	0%	0%	0%
REEV	0%	0%	5%	10%	10%
Truck > 12 t					
Diesel	100%	100%	75%	0%	0%
FHEV	0%	0%	25%	100%	100%
articulated truck					
Diesel	100%	98%	80%	10%	0%
Gas	0%	2%	20%	90%	100%
KS 95					
light commercial vehicles					
Petrol	5%	0%	0%	0%	0%
BEV	0%	5%	25%	90%	90%
Diesel	95%	93%	70%	0%	0%
Gas	0%	2%	0%	0%	0%
REEV	0%	0%	5%	10%	10%
Truck > 12 t					
Diesel	100%	100%	75%	0%	0%
FHEV	0%	0%	25%	100%	100%
articulated truck					
Diesel	100%	100%	90%	20%	10%
Catenary vehicle	0%	0%	10%	80%	90%

Source: Repenning et al. (2015)

Figure 29: Share of electricity generated liquid fuels in the transport sector

	2010	2020	2030	2040	2050
	Proportion of electricity generated fuels				
KS 95					
Petrol	0%	0%	0%	25%	50%
Diesel	0%	0%	0%	25%	50%
Kerosene	0%	0%	0%	25%	50%

Source: own representation

2.3.4 Conclusion of the scenario analysis

- The climate protection scenario 2050 also sees an option for electric vehicles with combustion engines as Ranger Extenders for 2050. According to the current state of the discussion, this assessment is no longer realistic.
- For complete decarbonisation or reduction of at least 90 percent, the entire transport sector must be switched to BEV, hydrogen or synthetic fuels. This will only be possible by fully integrating the transport sector into sectoral coupling.
- The share of hydrogen or synthetic fuels is rising beyond 80 % of GHG reductions, because then electrolysis will be needed to provide flexibility in the electricity system.

2.4 Japan

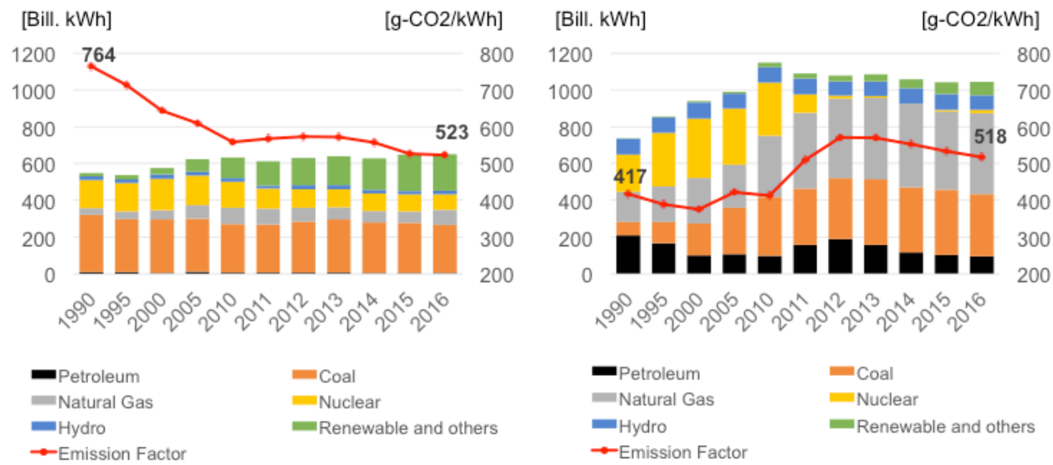
At the moment there is no Japan specific data available.

3. Reduction targets and policy strategies

How can sector specific GHG emission reduction targets and policies for the transport sector be integrated into national GHG mitigation strategies?

3.1 Comparison of the status quo

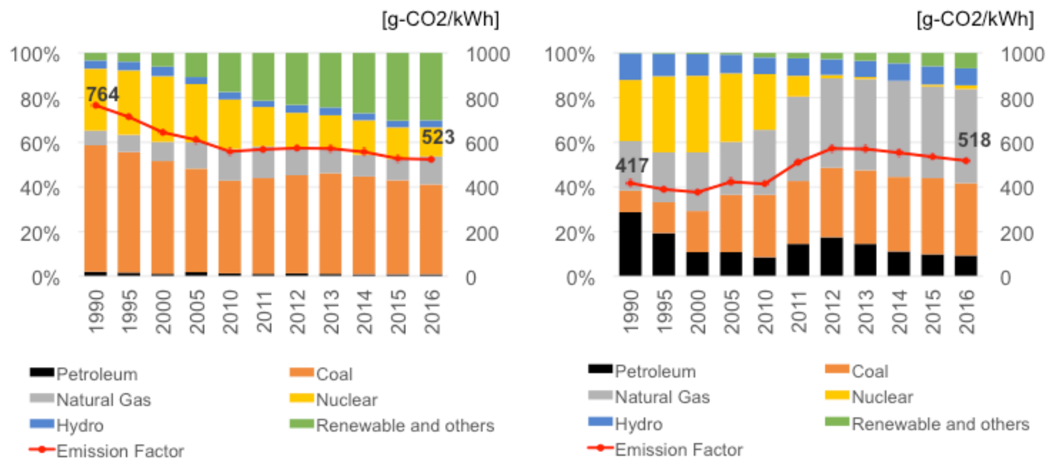
Figure 30: Power mix and emission factor in Germany and Japan



Germany **Japan**

Source: Hayashi (2019)

Figure 31: Power mix and emission factors (in %) in Germany and Japan



Germany **Japan**

Source: Hayashi (2019)

3.2 Germany

In November 2016, the German government adopted the Climate Action Plan 2050. The long-term goal is a largely greenhouse gas-neutral Germany by 2050. In the medium term, greenhouse gas emissions in Germany are to be reduced by at least 55 percent compared to

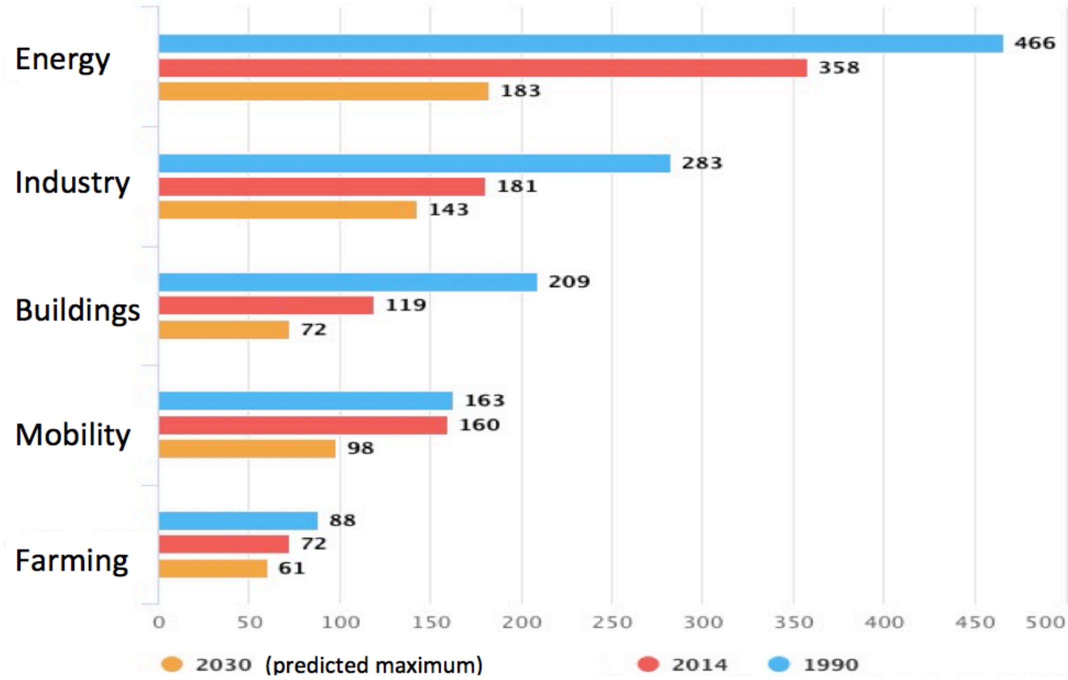
1990 by 2030. The Climate Change Plan sets specific emission reduction targets for the year 2030 for all consumption sectors. The target reduction of 55 per cent does not therefore apply to each of the sectors but represents the overall objective across all consumption sectors. For example, while the energy sector is expected to reduce its emissions by around 60 per cent by 2030 compared to 1990, the mobility sector is about 40 per cent emission reduction. which are to be achieved. The integration of a reduction target for transport as well as the strategies and measures with which this reduction target is to be achieved into a national mitigation strategy is therefore given in Germany.
In order for the transport sector to reach its mitigation targets, the Climate Action Plan 2050 includes measures to prevent transport, measures to promote alternative drives (including sectoral coupling), measures to promote public transport, rail, cycling and walking.

Figure 32: Sectoral reduction targets anchored in the Federal Government's climate protection plan

fields of activity	1990 (in millions of tons C02 equivalent)	2014 (in millions of tons C02 equivalent)	2030 (in millions of tons C02 equivalent)	2030 (Percentage reduction compared to 1990)
Energy	466	358	175 Up to 183	62 Up to 61
Buildings	209	119	70 Up to 72	67 Up to 66
Mobility	163	160	95 Up to 98	42 Up to 40
Industry	283	181	140 Up to 143	51 Up to 49
Farming	88	72	58 Up to 61	34 Up to 31
Subtotal	**1209**	**890**	**538 Up to 557**	**56 Up to 54**
other	39	12	5	87
Total	**1248**	**902**	**543 bis 562**	**56 bis 55**

Source: Federal Environment Ministry (2016)

Figure 33: reduction targets of the different sectors anchored in the Federal Government's climate protection plan



Source: Federal Environment Ministery (2016)

At the EU level too, binding reduction targets apply to the member states. If these goals are not achieved by member states, then these countries must pay penalties. This also applies to Germany, which is unlikely to meet its targets for the years 2020 to 2022. Expenditure of 100 million euros is planned for this purpose in the federal budget. The ministries must participate according to a fixed distribution rate.

However, the binding anchoring of sectoral objectives in an overall mitigation strategy requires clear sanctioning mechanisms with clear responsibilities, should certain sectors miss their mitigation targets. In order to make the individual ministries more responsible, the bill for a climate protection law drawn up by the Federal Ministry for the Environment stipulates that the sectoral reduction targets of the Climate Action Plan should be transposed into law. The draft of the Climate Change Act provides that the ministries will finance the fines from their budgets if the sector responsible for failing to meet the reduction targets falls within their jurisdiction. Whether this procedure is actually specified in the planned Climate Protection Act is not yet clear.

3.3 Japan

The long-term enrgy supply-demand outlook published in July 2015, which is a supporting document for the Strategic Energy Plan, indicate planned sectoral energy related CO_2 emission reduction target. For he transport sector, CO_2 emission in fiscal year (FY) 2030 is anticipated 28% reduction from the base year FY 2013.

To this end, the long-term energy supply-demand outlook also present energy efficiency target for transport sector during the period. This objective is equivalent to energy saving of 16.701 million kL of oil equivalent compared to the Reference Scenario.

The actual implementation instrument is the Energy Efficiency Act. The law requires vehicle manufacturers to reduce the fuel consumption of their vehicles as part of the Top Runner Program. The law also requires that passenger (eg rail, bus) and freight companies (eg shipping companies) need to improve their energy efficiency.

The Ministry of Economy, Trade and Industry (METI) is responsible for the law with its regional offices. If companies break the law they will be punished. Sanctions include the order of ministers to present an action plan to improve the situation, government publication of the company name, or up to a million yen fine, depending on the extent of the infringement.

Figure 34: Sectoral CO_2 reduction targets

	FY 2013 (base year)	FY2030	Change from FY2013 to FY2030 **
Industry	429	401	-7%
Commercial	279	168	-40%
Household	201	122	-39%
Transport	225	163	-28%
Transformation*	101	73	-28%
Total	12.35	9.27	-25%

Unit = million ton CO_2

* Power generation, oil refinery, etc.

** Calculated by author

Source: METI (2015)

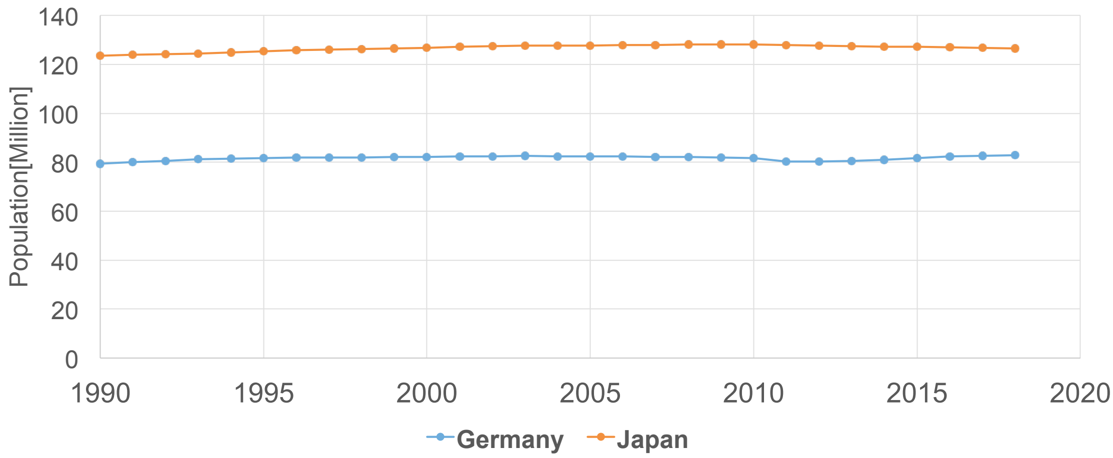
Key Issues

1. Similarities and differences in Japan and Germany
   - current status and the future development of the transport sector
2. Mechanism for decarbonisation
   - whether and how a fully decarbonized transport sector is possible in future
3. Technology for decarbonisation of the transport sector
   - „electrification“ of the transport sector
     - direct use of green electricity for electric vehicles
     - via transforming surplus of variable green electricity into hydrogen
   - using it by FC-vehicles.
4. Coupling the transport and the power sector
   - battery capacity of car fleets as storage of variable electricity (by wind or PV) on the supply side.

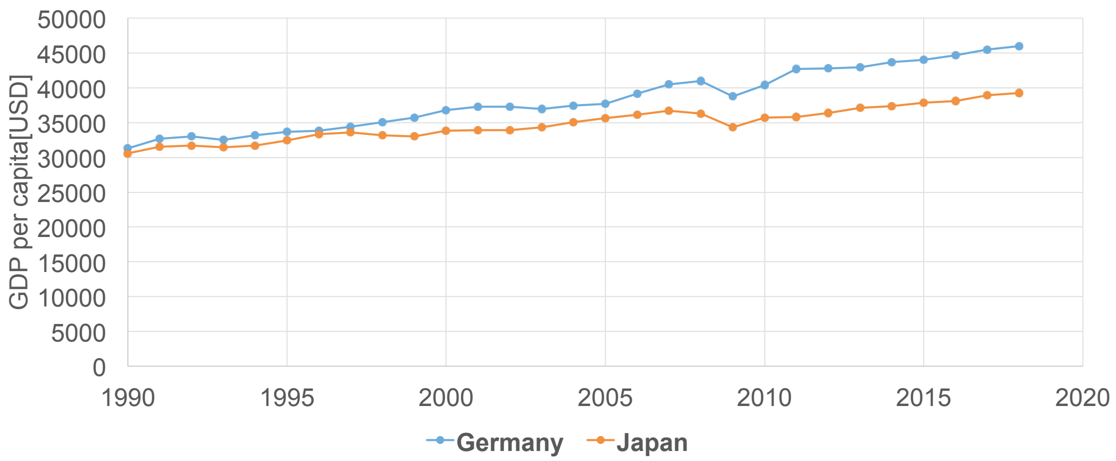
Content 1

Similarities and Differences between Germany and Japan

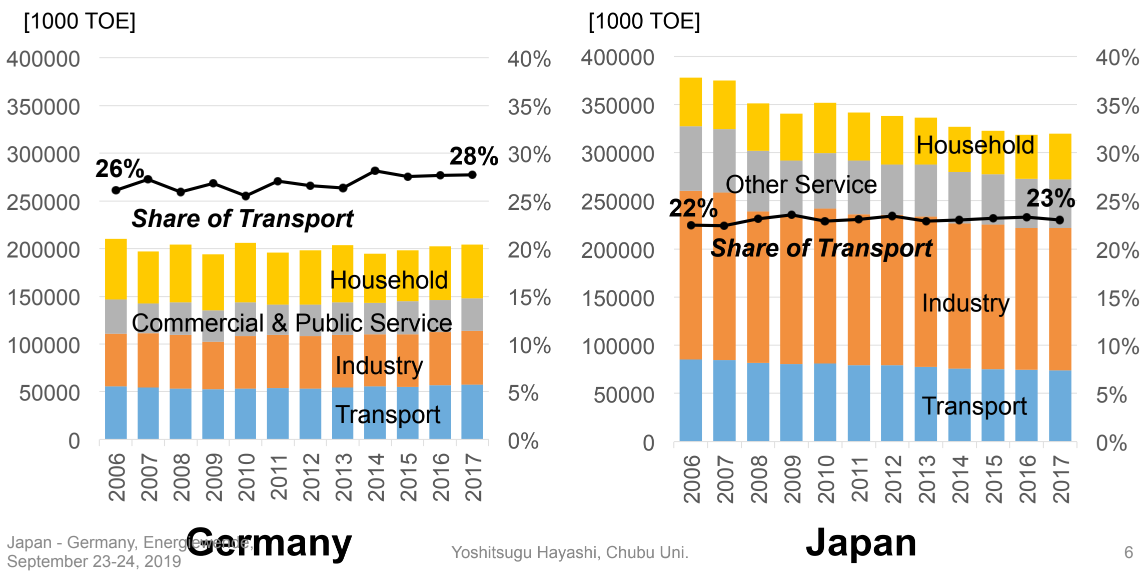
Population



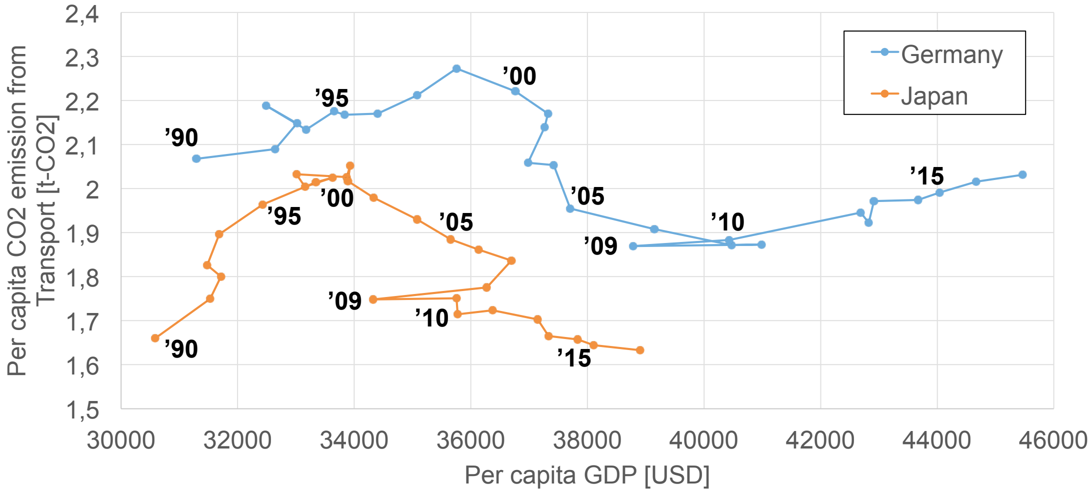
GDP per capita (PPP)



Energy Use and Share of Transport



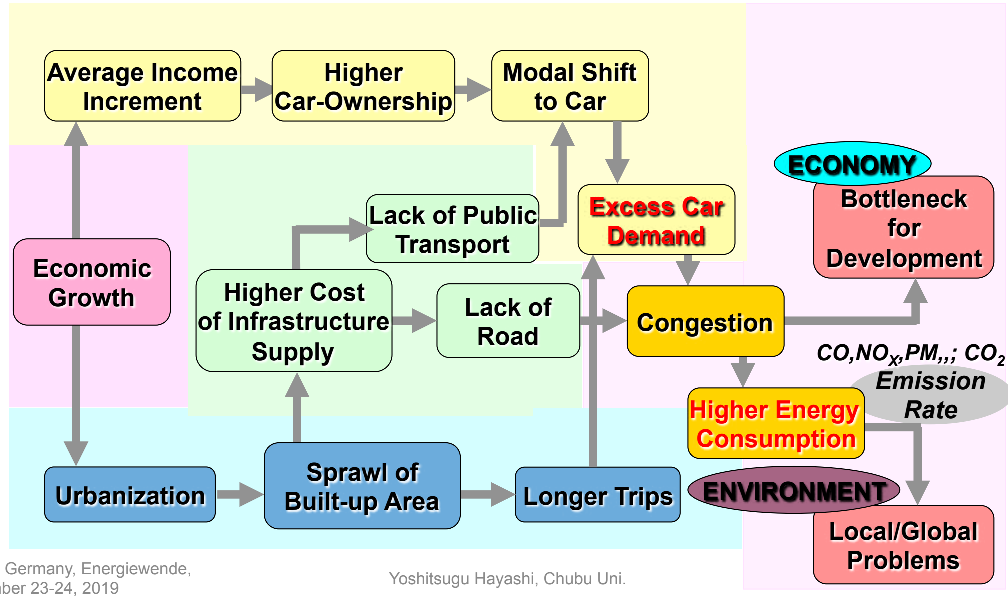
GDP vs CO2 emission from Transport



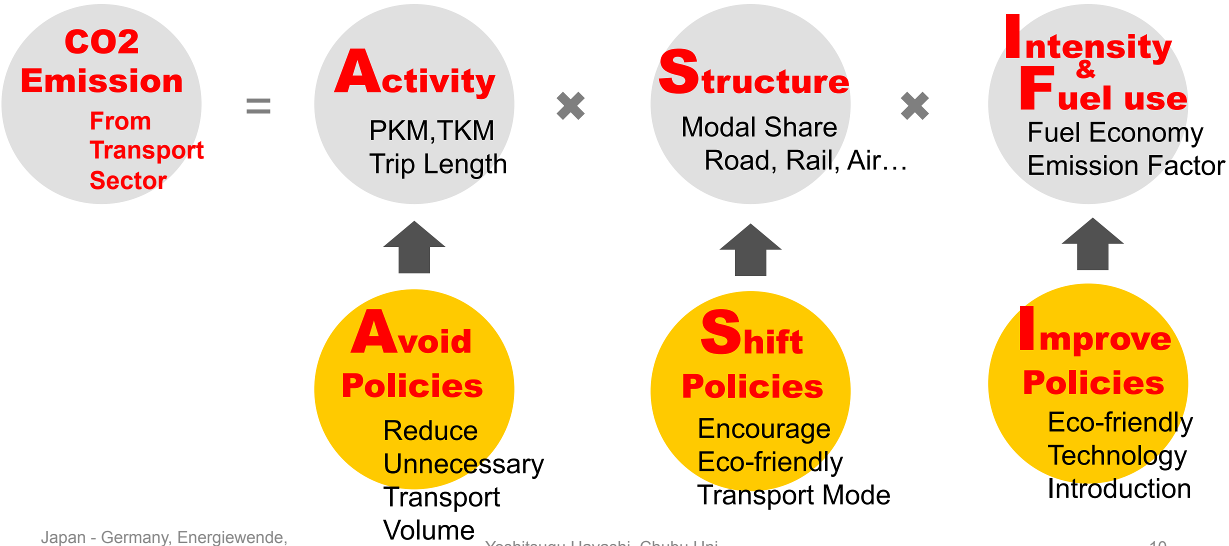
Content 2

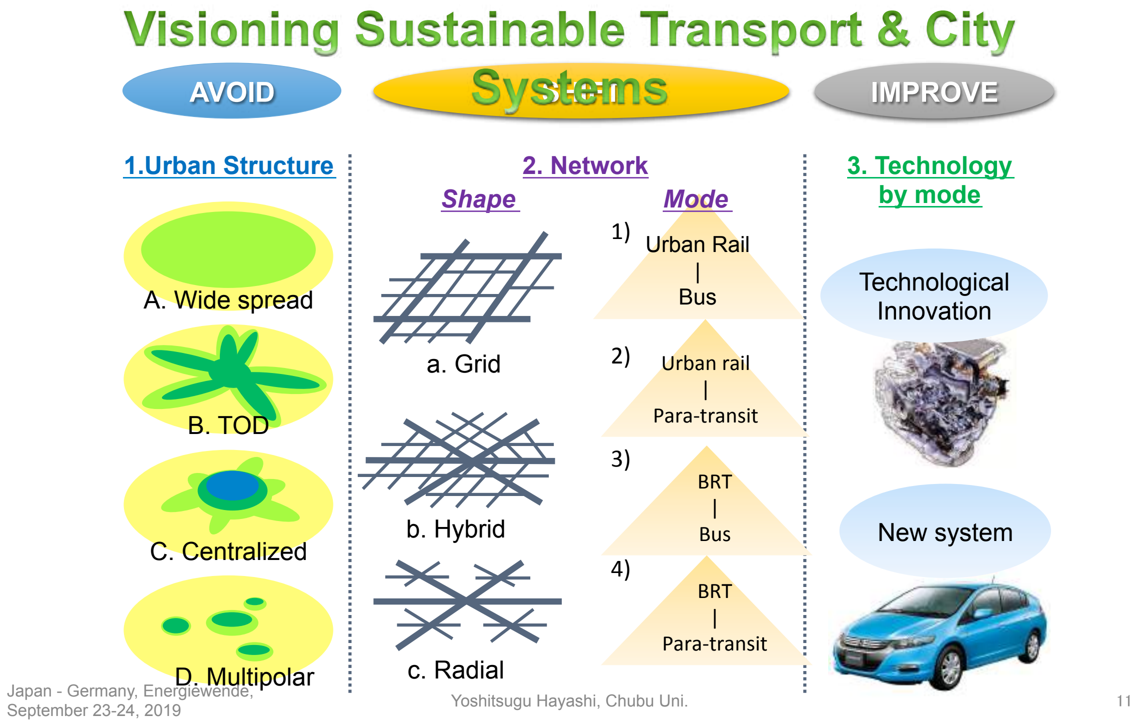
Mechanism for Decarbonisation

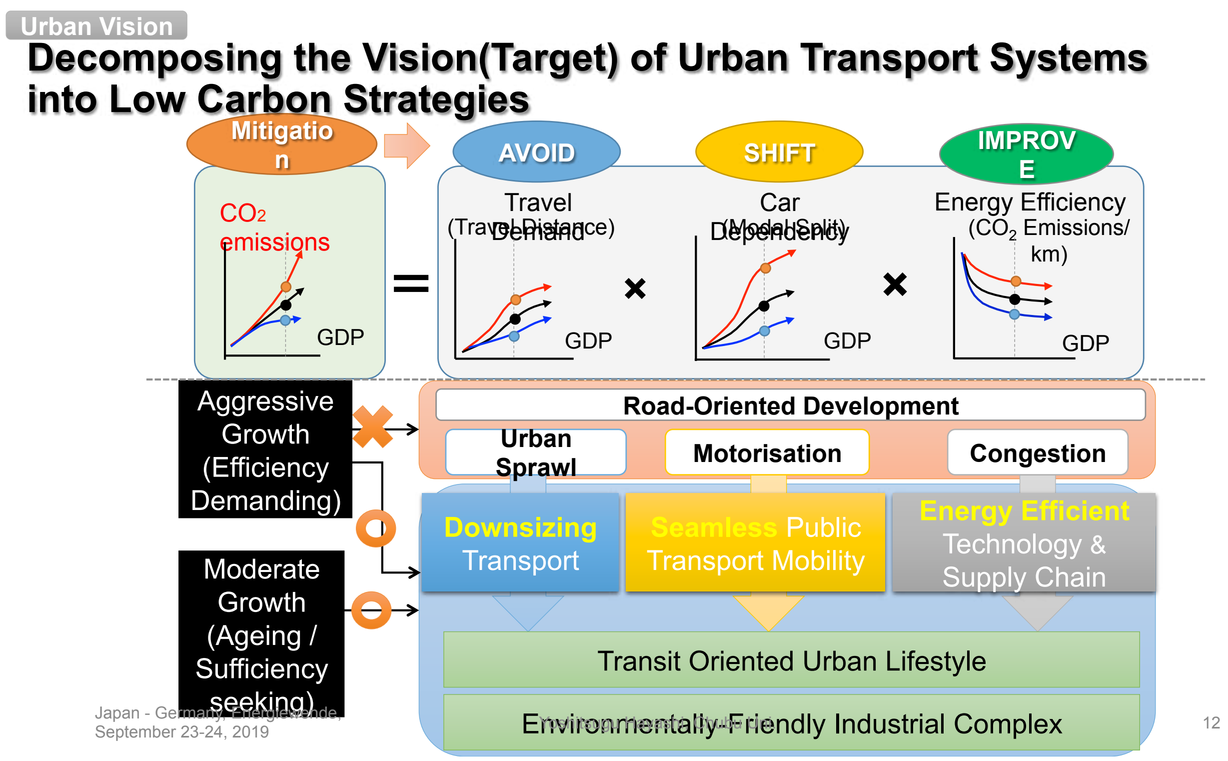
Mechanism of Motorization and Urbanization Affecting Economy and Environment



ASIF Framework for CO2 emission estimation




Visioning Sustainable Transport & City
AVOID
Systems
IMPROVE
1.Urban Structure
A. Wide spread
B. TOD
C. Centralized
D. Multipolar
2. Network
Shape
a. Grid
b. Hybrid
c. Radial
Mode
1) Urban Rail | Bus
2) Urban rail | Para-transit
3) BRT | Bus
4) BRT | Para-transit
3. Technology by mode
Technological Innovation
New system
Japan - Germany, Energiewende, September 23-24, 2019
Yoshitsugu Hayashi, Chubu Uni.
11


Urban Vision
Decomposing the Vision(Target) of Urban Transport Systems into Low Carbon Strategies
Mitigation
AVOID
SHIFT
IMPROVE
CO2 emissions
GDP
=
Travel Demand
(Travel Distance)
GDP
×
Car Dependency
(Modal Split)
GDP
×
Energy Efficiency
(CO2 Emissions/ km)
GDP
Aggressive Growth (Efficiency Demanding)
Moderate Growth (Ageing / Sufficiency seeking)
Road-Oriented Development
Urban Sprawl
Motorisation
Congestion
Downsizing Transport
Seamless Public Transport Mobility
Energy Efficient Technology & Supply Chain
Transit Oriented Urban Lifestyle
Environmentally-Friendly Industrial Complex
Japan - Germany, Energiewende, September 23-24, 2019
12

Policy/Technology options（CUTE Matrix）

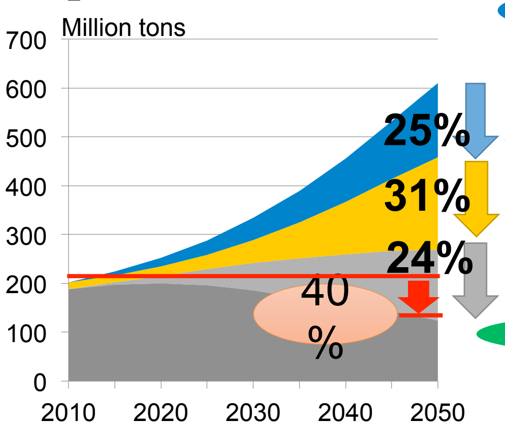
Strategies / Means	AVOID	SHIFT	IMPROVE
Technologies	• Transport oriented development (TOD) • Poly-centric development • Efficient freight distribution	• Railways and BRT development • Interchange improvement among railway, BRT, bus and para-transit modes • Facilities for personal mobility and pedestrians	•Electric vehicles • Biomass fuel • Autonomous driving • "Smart grid“ development
Regulations	• Land-use control	• Separation of bus/para-transit trunk and feeder routes • Local circulating service • Control on driving and parking	• Emissions standards • “Top-runner" approach
Information	• Telecommuting • Online shopping • Lifestyle change	• ITS public transport operation	• "Eco-driving" • ITS traffic-flow management • Vehicle performance labeling
Economy	• Subsidies and taxation to location	• Park & ride • Cooperative fare systems among modes	• Fuel tax/carbon tax • Subsidies and taxation to low-emissions vehicles

Spurce: Nakamura, Hayashi, May(2004)
Urban Transport and Environment, Elsevier

Example of Back-cast Analysis

The Roadmap for Low-Carbon Urban Transport Development in ASEAN Megacities

CO_2-emission reduction



AVOID

Land-use control (3% less annual expansion of built-up area)

SHIFT

4,568 km MRT development, (6cities, Ave.: 760 km/city)

23,337km BRT development (23cities, Ave.:1015km/city)

IMPROVE

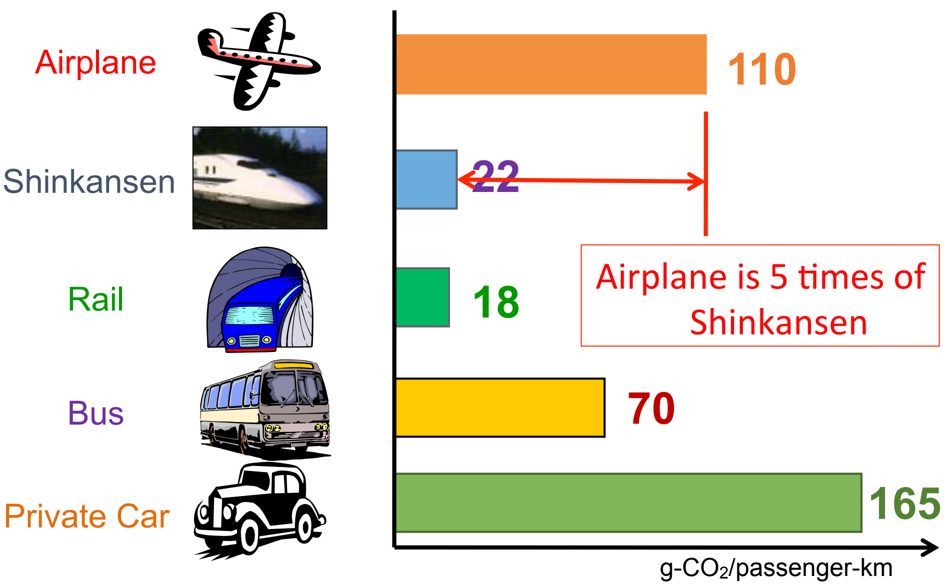
Increasing LEV share (EV76%, HV23%), Improving Fuel Efficiencies (by 28%)
Emission intensity of power generation ($2005:1269g\text{-}CO_2/kwh$; $2050: 546g\text{-}CO_2/kwh$)

CUTE matrix for inter-city transport system

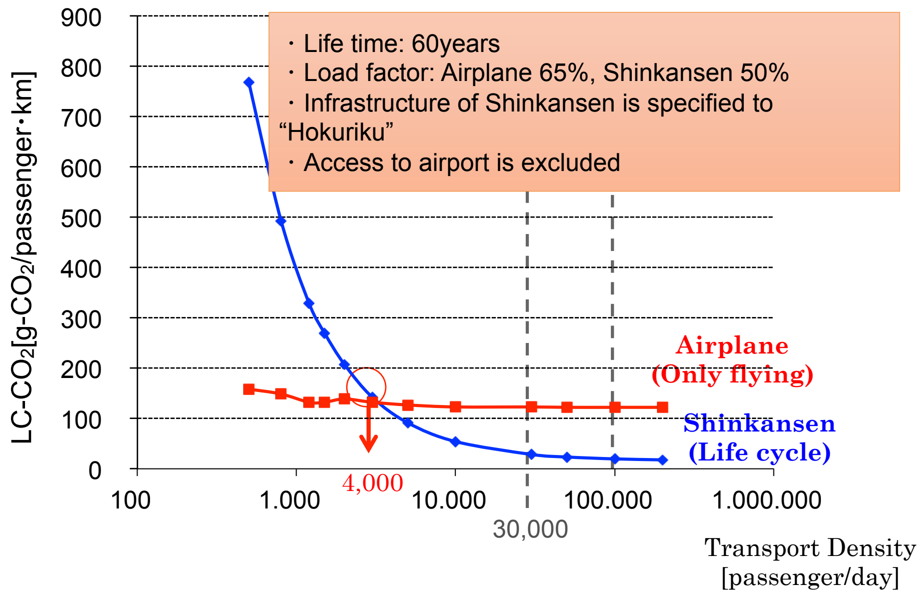
Strategy / Instrument	Land Transport					Aviation Transport	Water Transport
	Reduce need to travel	***Reduce fuel-vehicle use***	***Improve alternative modes***	***Improve road networks***	***Improve vehicles and fuels***		
Technology	●Multifunctional city		●High-speed rail		●Alternative fuel	●Low emission aircraft	●Gas turbines
Regulation	●Incentive consumption of local products			●Traffic flow control	●Emission standard	●Closure of short distance flights	
Information	●Teleworking	●Awareness campaigns			●IT/ITS	●Optimization of flights	●IT for route optimization
Economics	●City-entrance pricing	●Road pricing	●Rail fare	●Road pricing	●Fuel tax	●Emission trade	●Emission trade

Comparison of travel/flight LC-CO2 emissions

～Japanese National Average～



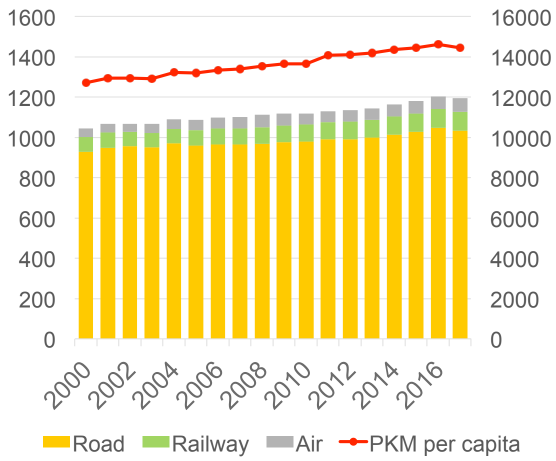
Transport Density and LC-CO2 per passenger-km

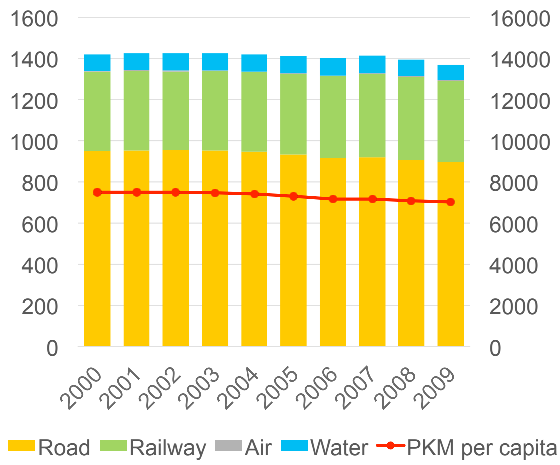


Activity

Decoupling Economic Growth vs. Traffic Volume (Energy Consumption)

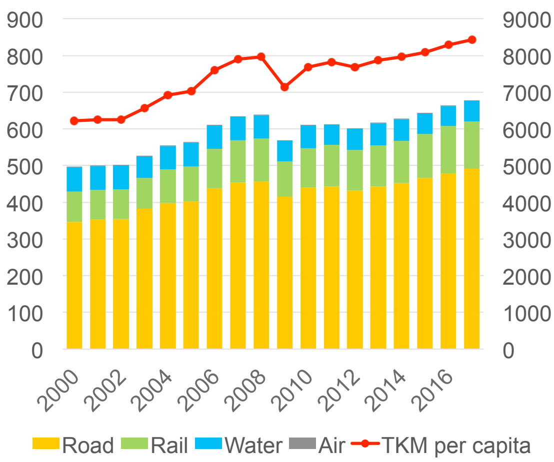
Passenger Transport Volume (PKM)

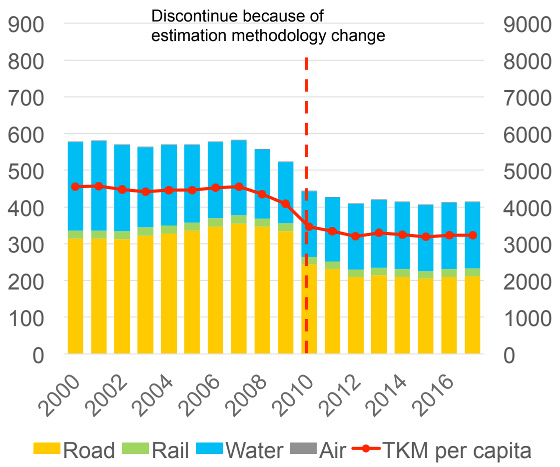




Germany **Japan**

Freight Transport Volume (TKM)

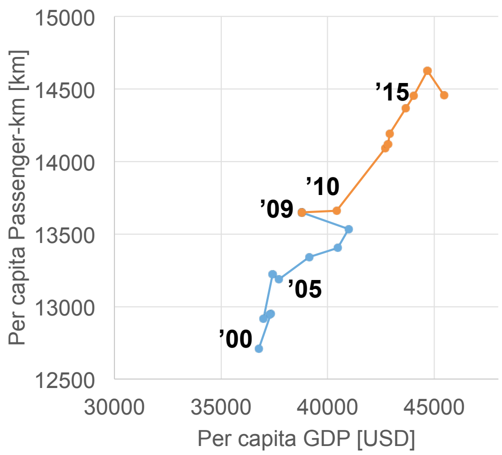




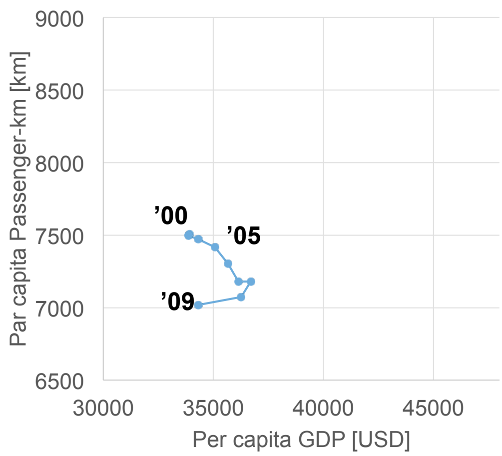
Germany **Japan**

Passenger Transport Volume vs GDP

- 1995-2017: CO_2 +5%: - Increased traffic volume (+18% veh.km)
- Increased share of big and high-powered cars (in particular SUVs)



Germany

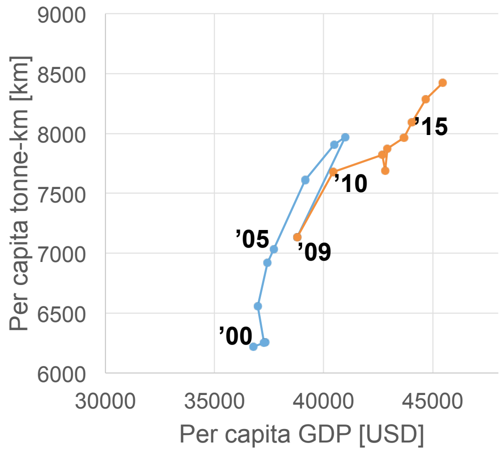


Japan

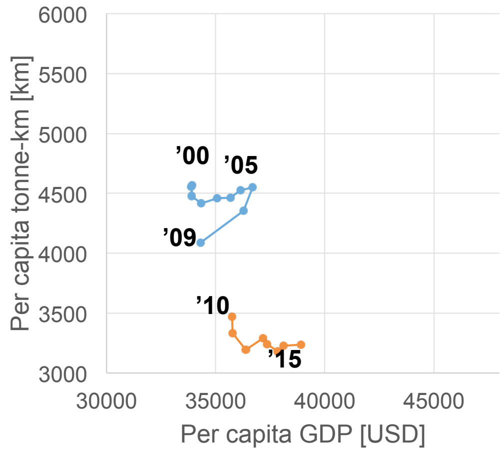
Freight Transport Volume vs GDP

1995 - 2017 CO_2 +20% - Increased traffic volume (+70% ton.km)

- Increased share of heavy trucks (growth of long-distance transport absorbed by road freight transport, rail share on freight transport market slightly decreasing)



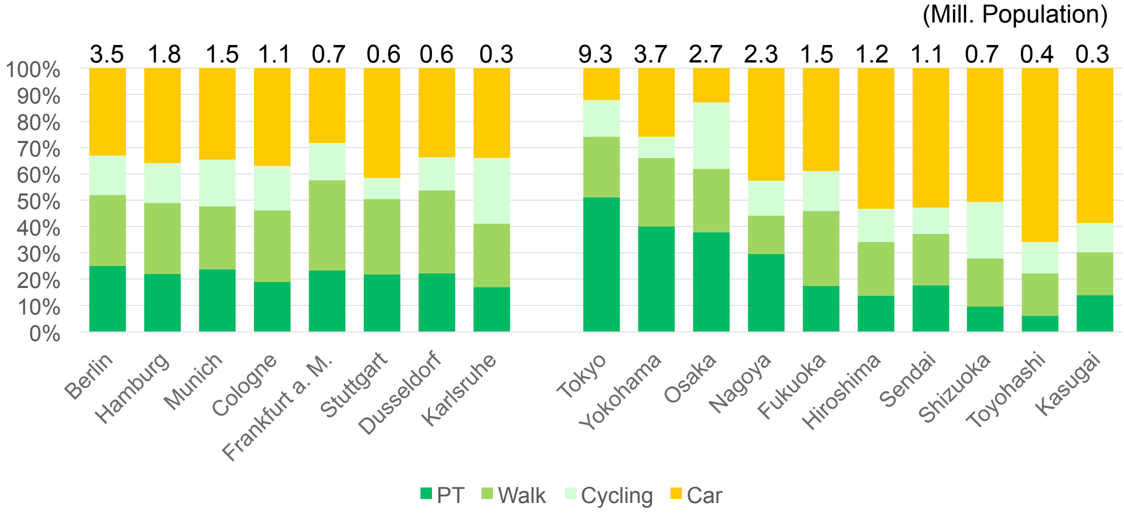
Germany



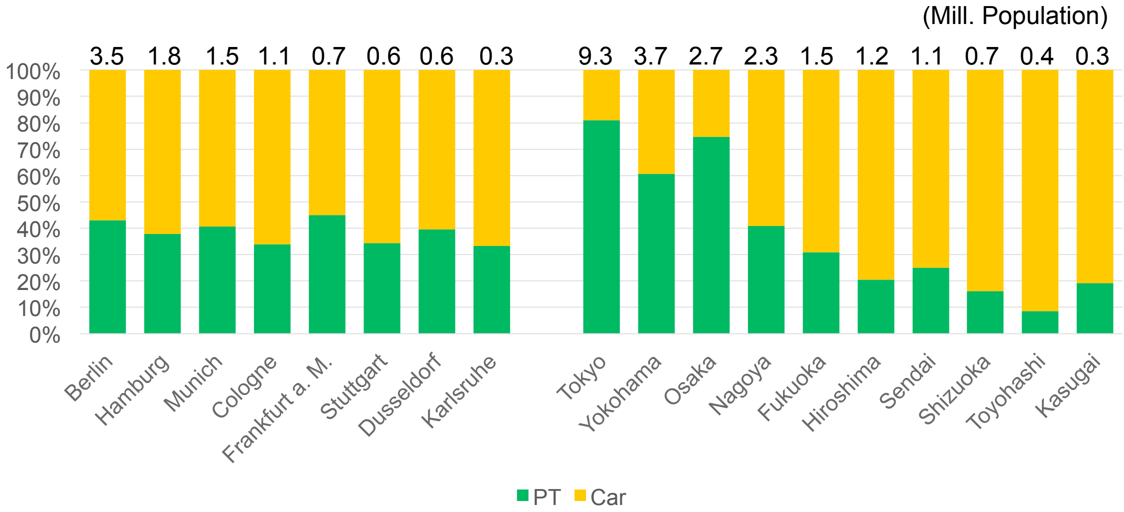
Japan

Structure

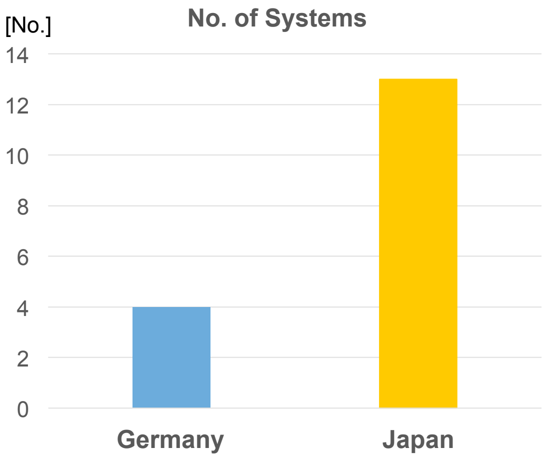
Modal Share in Cities

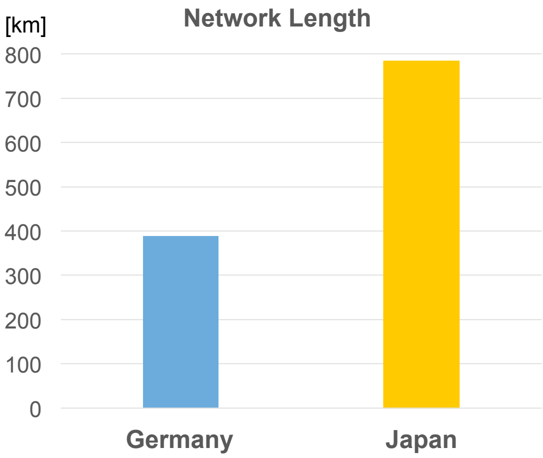


Modal Share in Cities (Car vs PT)



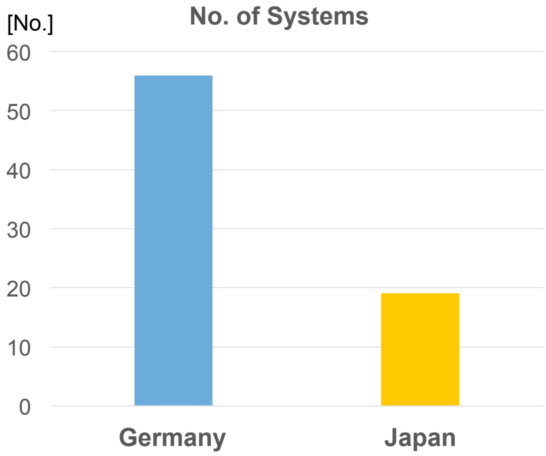
Metro/U-Bahn System

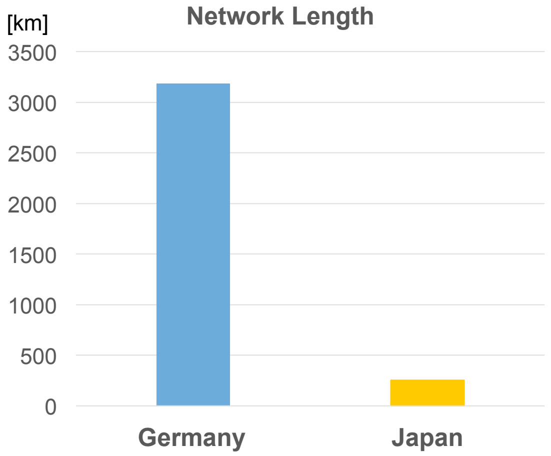




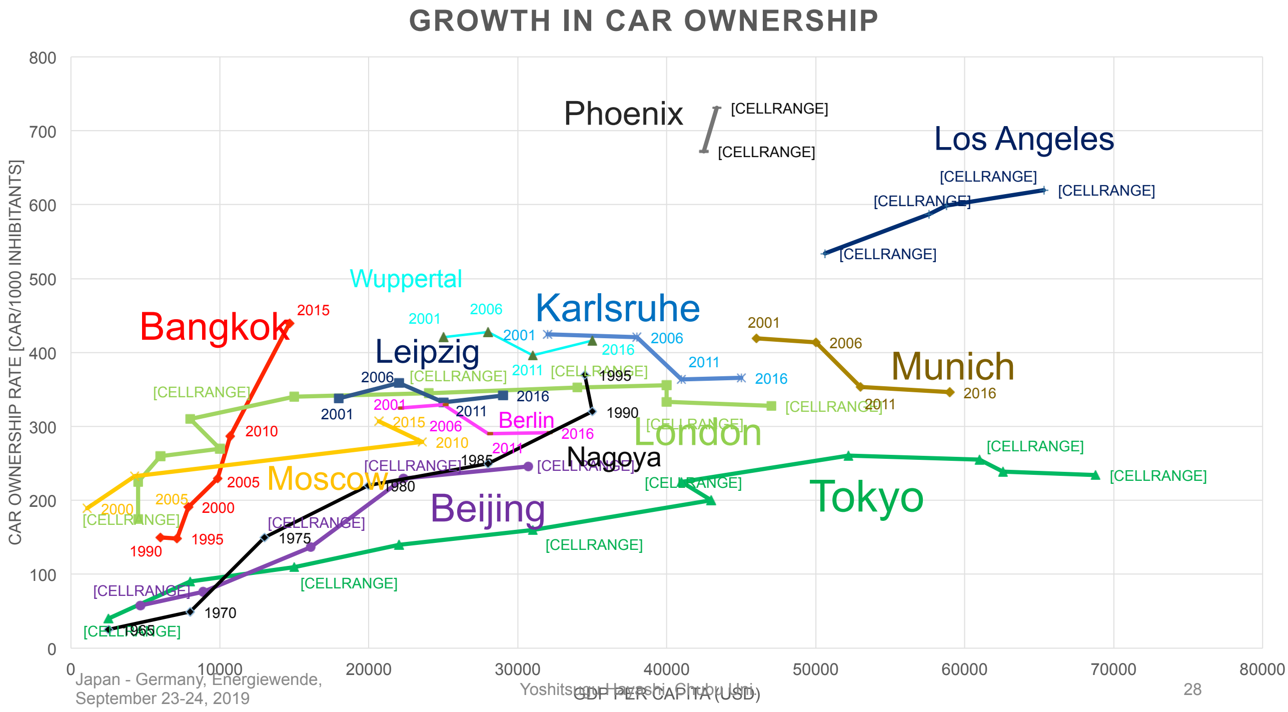
Source: https://en.wikipedia.org/wiki/List_of_metro_systems

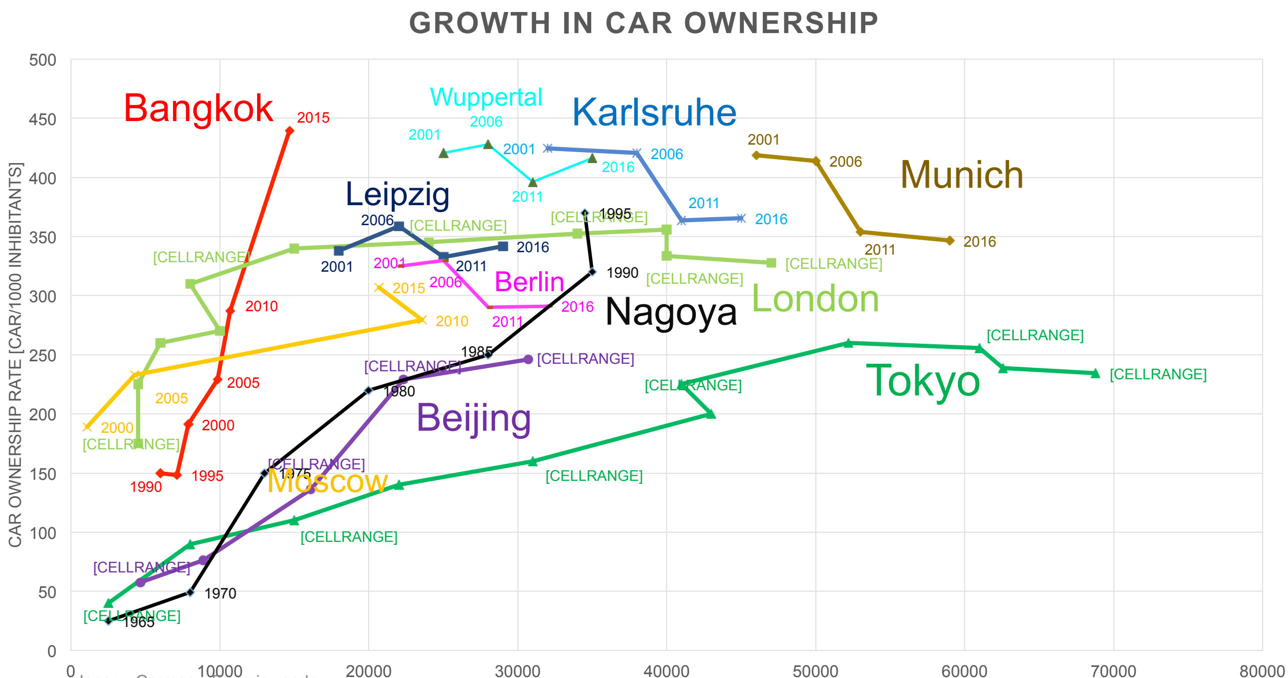
Light Rail and Tram



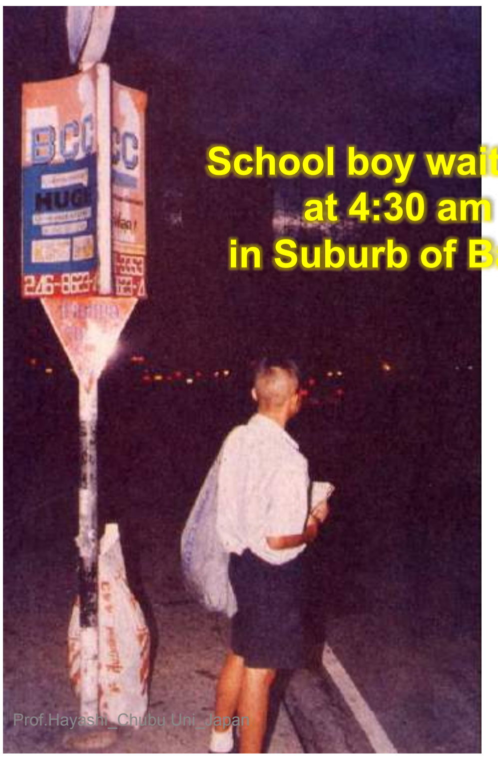


Source: Metro, light rail and tram systems in Europe (ERRAC, UITP), Japan Transportation Planning Association





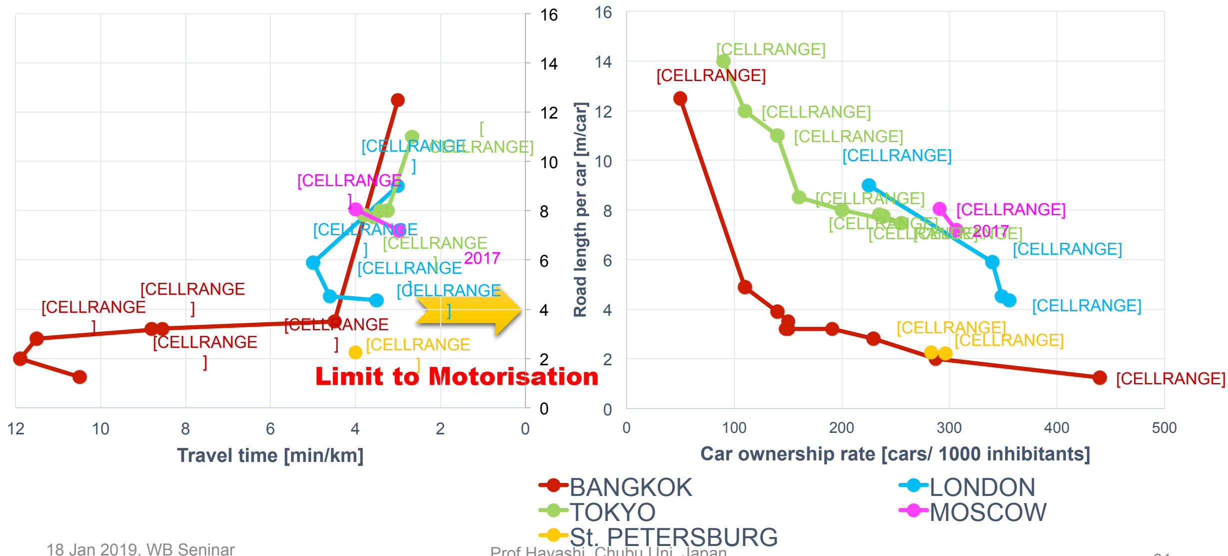
Failure of Urban Transport System



School boy waiting for bus at 4:30 am in Suburb of Bangkok

Bangkok Post
4 Sept 1993

Road Infrastructure Supply vs. Motorisation Level vs. Peak-hour Speed

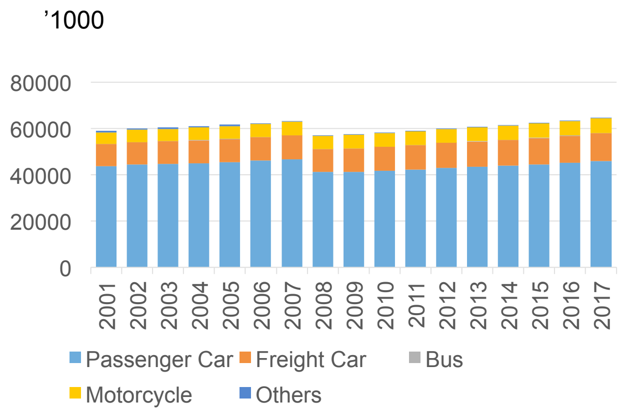


Intensity & Fuel use

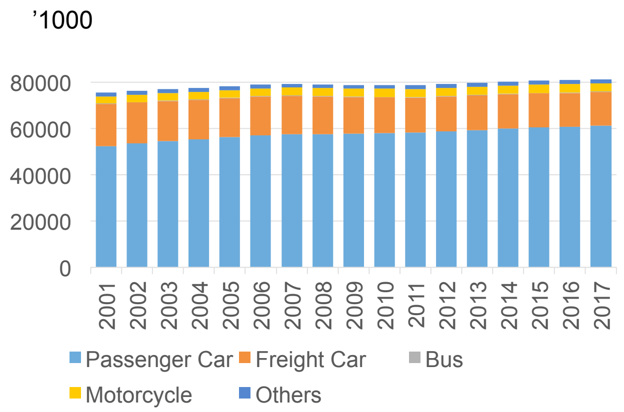
Content 3

Promotion of Technology for Decarbonisation

Vehicle Ownership by Mode

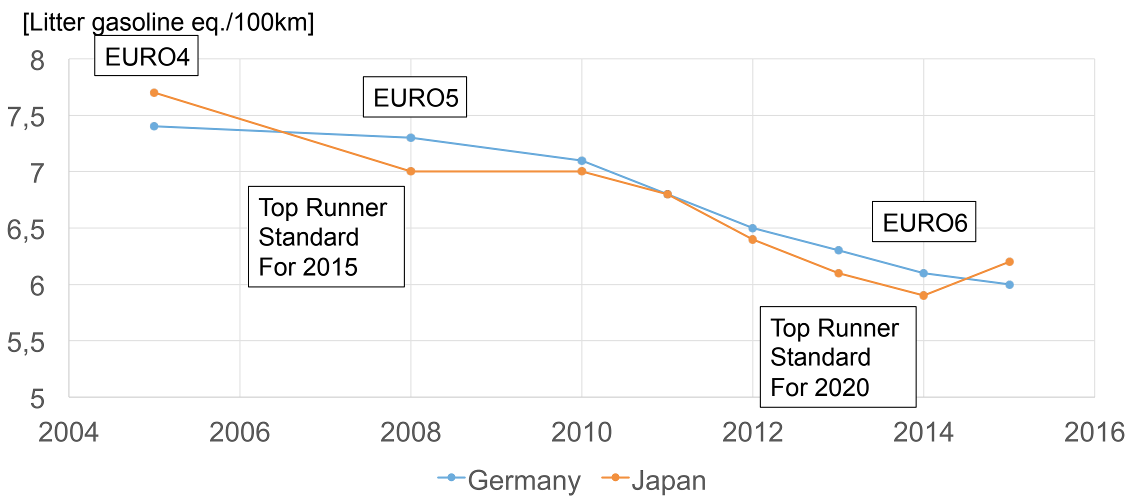


Germany



Japan

Average fuel consumption

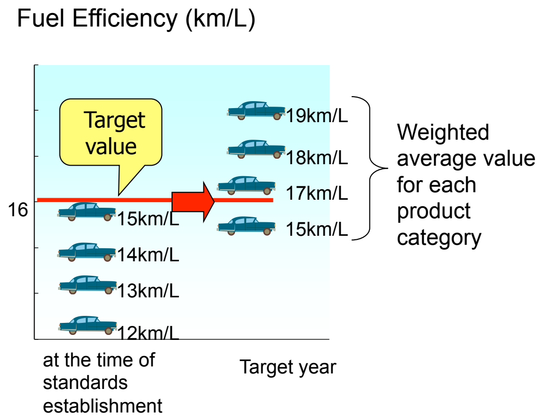


Source: INTERNATIONAL COMPARISON OF LIGHT-DUTY VEHICLE FUEL ECONOMY 2005-2015 Ten years of fuel economy benchmarking (GFEI, IEA)

Prescription : Innovation of Transport System

The "Top Runner" program: Efficiency improvement (Ministry of Economy, Trade and Industry)

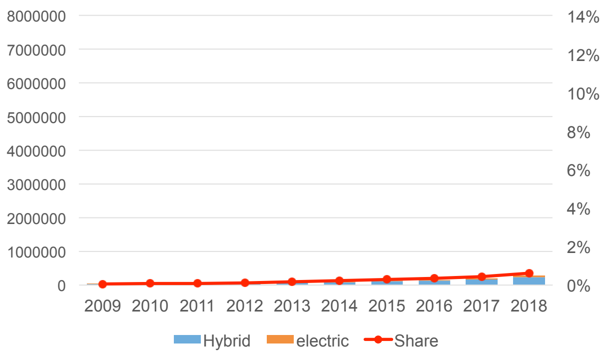
Top Runner Program with vehicles



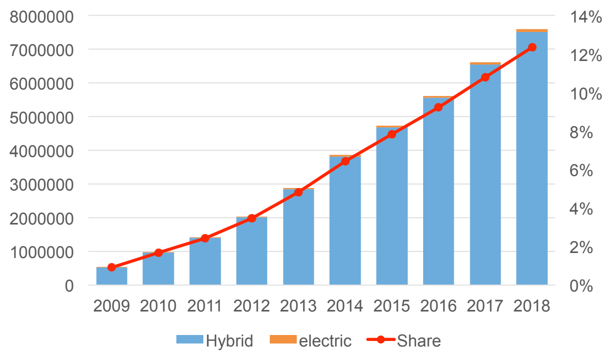
List of the Specified 21 Appliances

Passenger Vehicles
Freight Vehicles
Air Conditioners
Electric Refrigerators
Electric Freezers
Electric Rice Cookers
Microwave Ovens
Fluorescent Lights
Electric Toilet Seats
TV Sets (CRT, LCD, Plasma)
Video Cassette Recorders
DVD Recorders
Computers
Magnetic Disk Units
Copying Machines
Space Heaters
Gas Cooking Appliances
Gas Water Heaters
Oil Water Heaters
Vending Machines
Transformers

Share of Hybrid and Electric (in Passenger car)



Germany



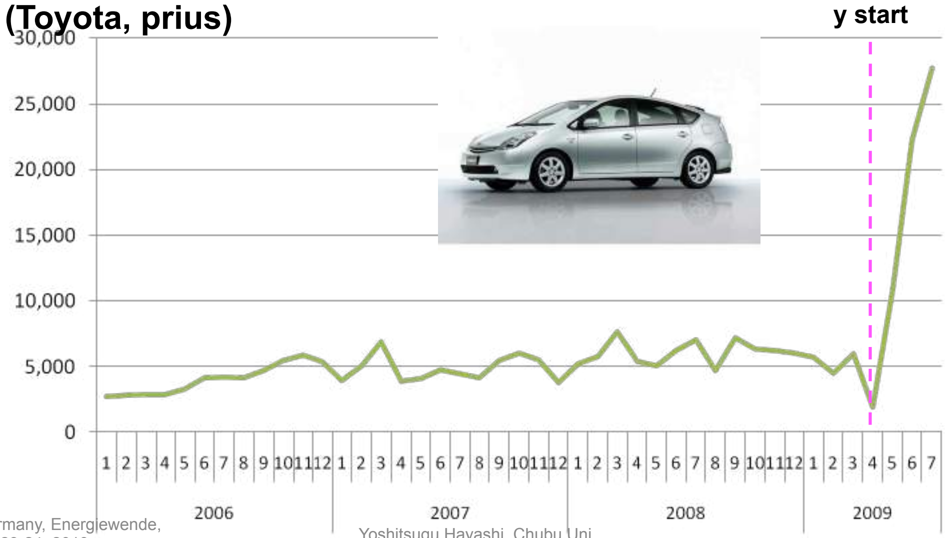
Japan

Prescription : Innovation of Transport System

Effect of Subsidy for Low Emission Cars

Domestic sales of new cars (Toyota, prius)

Subsidy start

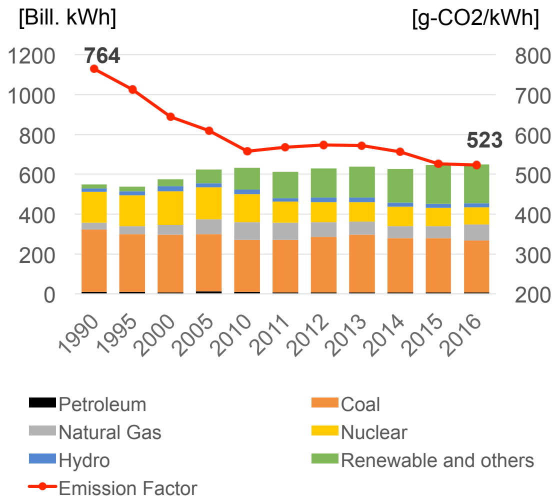


Year & Month

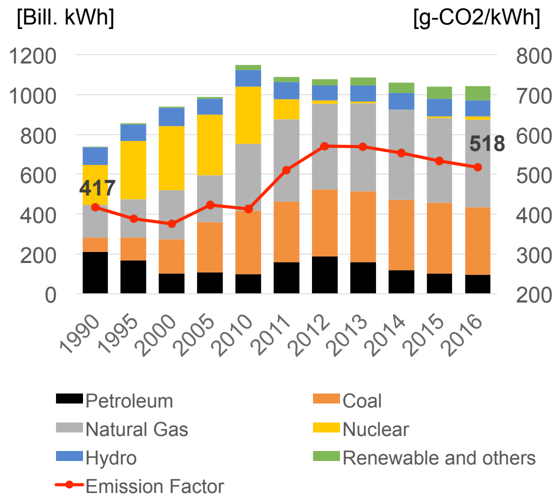
Content 4

Coupling Transport with the Power Sector

Power mix and Emission factor

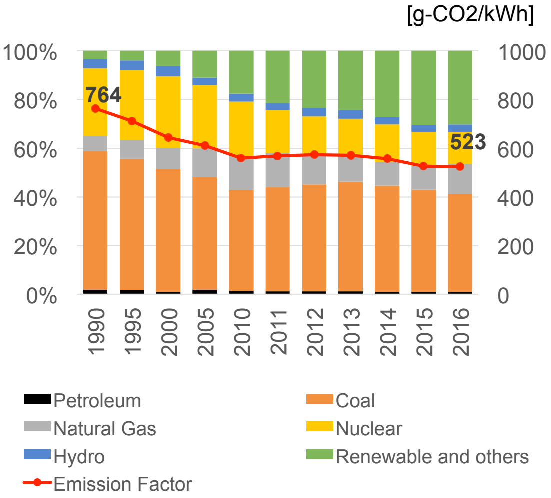


Germany

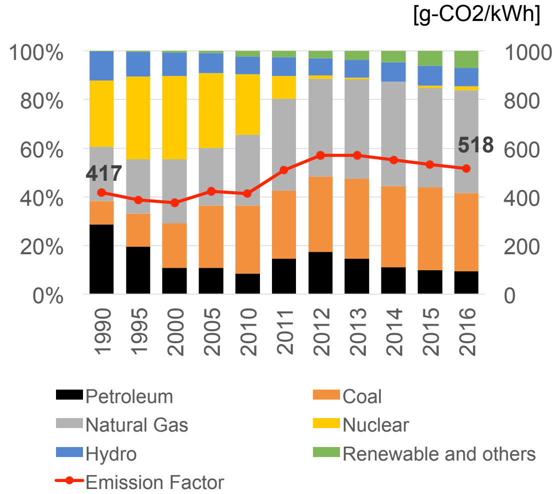


Japan

Power mix and Emission factor (in %)

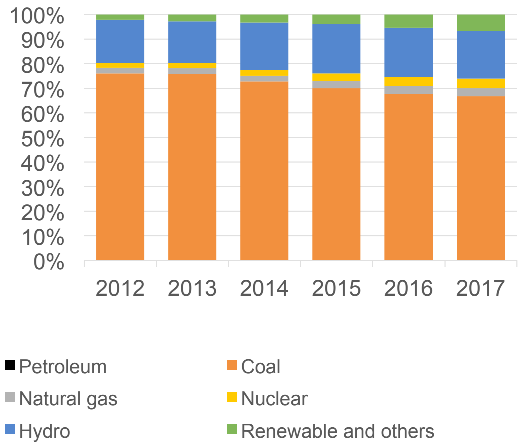


Germany

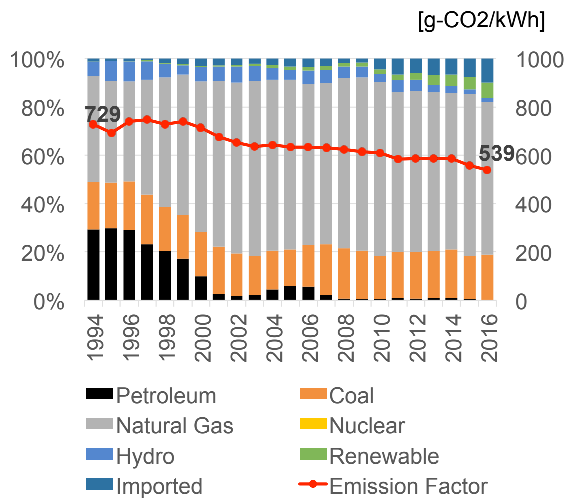


Japan

Power mix and Emission factor



China



Thailand

How much CO2 emission from HV and EV?

- If CO2 emission factor of power generation will be same as current situation

  - HV(TOYOTA PRIUS): **92.9 g-CO2/km**
    *Fuel consumption: 25km/L
  - EV(NISSAN LEAF): **86.3 g-CO2/km(Japan)**
    87.2 g-CO2/km(Germany)
    *Fuel consumption: 6km/kWh

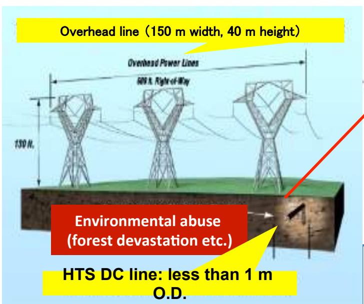
  →Not so different !
  *HV is more environmentally friendly than EV
  if emission factor of power generation exceeds **558 g-CO2/kWh**

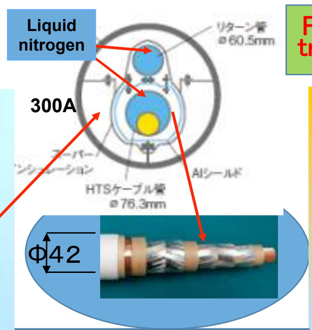
Technology for Using Green Energy

High Temperature Superconductivity (HTS) DC Transmission (Chubu University)

Contribution to the Sustainable Society

Conventional overhead power transmission line





Cross-sectional view (top),
HTS cable (bottom)
(rated at 20kV, 5 kA)

Features of HTS DC power transmission and distribution

Reduction of the transmission loss

Renewable energy integration in Power Grids

Saving resources: the weight of materials is about 1/10 of the weight of the HV (>500kV) overhead line

Environmentally friendly
- No electromagnetic pollution
- Sharing with existing transportation infrastructure

Development of the basic technology: HTS tapes, converters, energy storage systems

Courtesy: Iiyoshi Ishikari Forum on HTS DC, 24 June, 2017

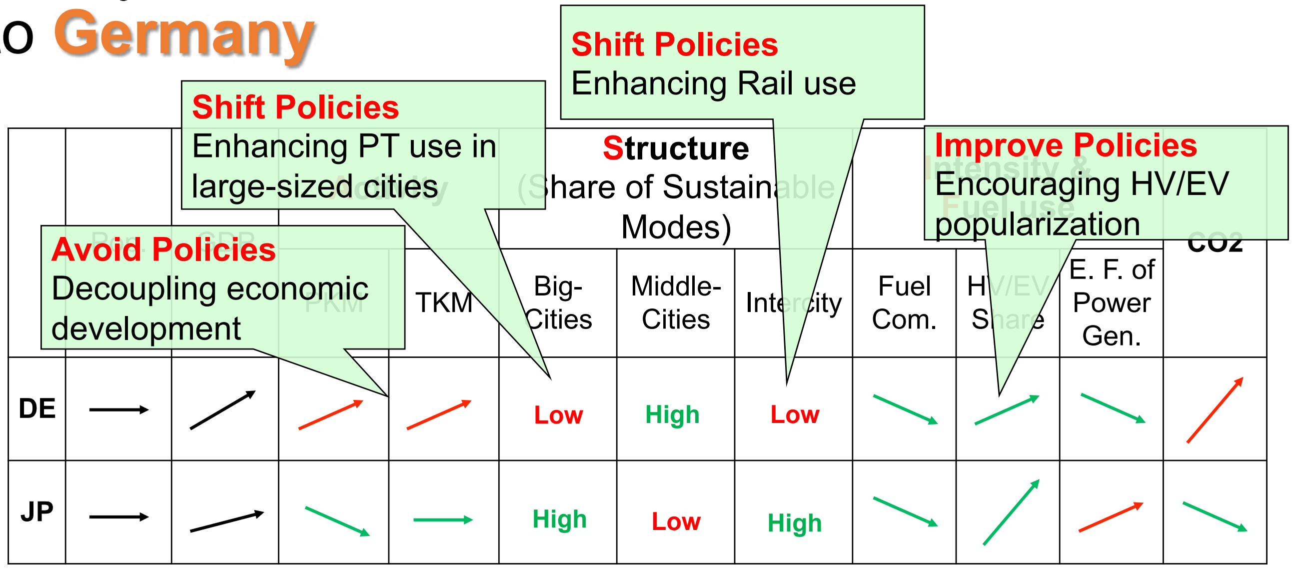
Content 5

Recommendations

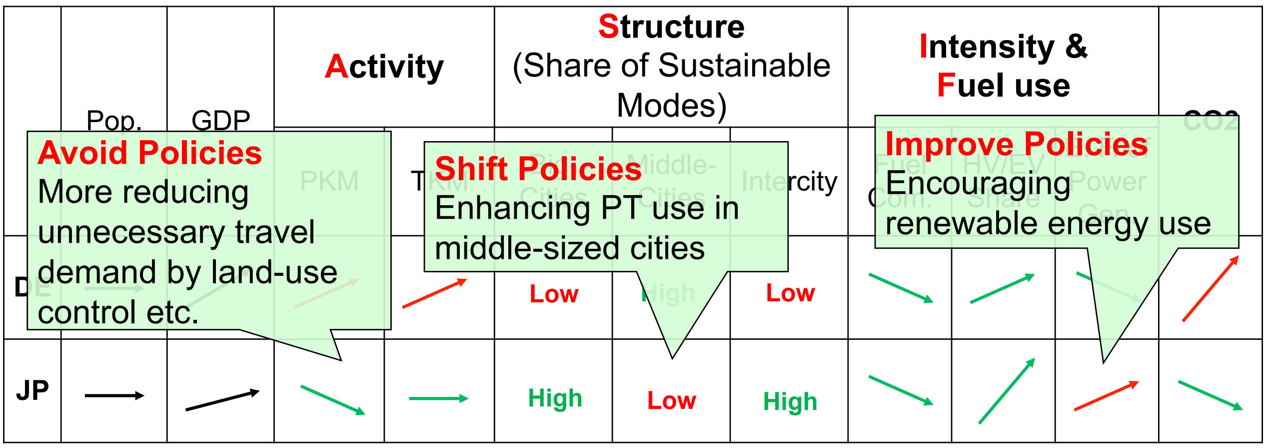
Summary

	Pop.	GDP	Activity		Structure (Share of Sustainable Modes)			Intensity & Fuel use			CO2
			Passenger-km	Freight-km	Big-Cities	Middle-Cities	Intercity	Fuel Com.	HV/EV Share	E. F. of Power Gen.	
DE	→	↗	↗	↗	**Low**	**High**	**Low**	↘	↗	↘	↗
JP	→	↗	↘	→	**High**	**Low**	**High**	↘	↗	↗	↘

Policy Recommendations to **Germany**



Policy Recommendations to **Japan**



Policy Recommendations to Germany

- Intercity Transport
  - Delay in Railway operation → construct overtaking tracks in stations
  - Strong Preferential Policy to High Speed Rail by back-casting from the goal cap of energy consumption and CO_2 emission in 2050 under the big risk of Climate Emergency.
  - Improve Overtaking tracks in stations for ICE/priority trains, which can drastically reduce delays and shift much more share of passengers from air
- Urban Transport
  - Introduction of Top Runner system for industrial products
  - High tax to Big cars for their possession of road surface and subsidies to develop Variety of Small Movers
  - Prohibit or very high tax for 3 or more seater - ownership cars within cities, and instead to conduct big tax reduction for newly developed Small Smart Vehicles

Policy Recommendations to Japan

- Intercity Transport
  - Improvement of connecter rail networks to airport
- Urban Transport
  - Avoid policies: Stricter land use control
  - Shift policies: In middle sized cities, tax/subsidy supporting system of LRT should be introduced. Also, encouraging measures for walk and cycling should be introduced
  - Improve policies: Renewable energy use should be subsidised
  - Prohibit or very high tax for 3 or more seater - ownership cars within cities, and instead to conduct big tax reduction for newly developed Small Smart Vehicles

For our Environment

Umwelt Bundesamt

German-Japanese Energy Transition Council – GJETC

Transportation and sector coupling: The German perspective - 4 Facts

Martin Schmied
German Environment Agency
Head of Department I 2 "Transport, Noise and Spatial Development“

Tokyo, 24th of September 2019

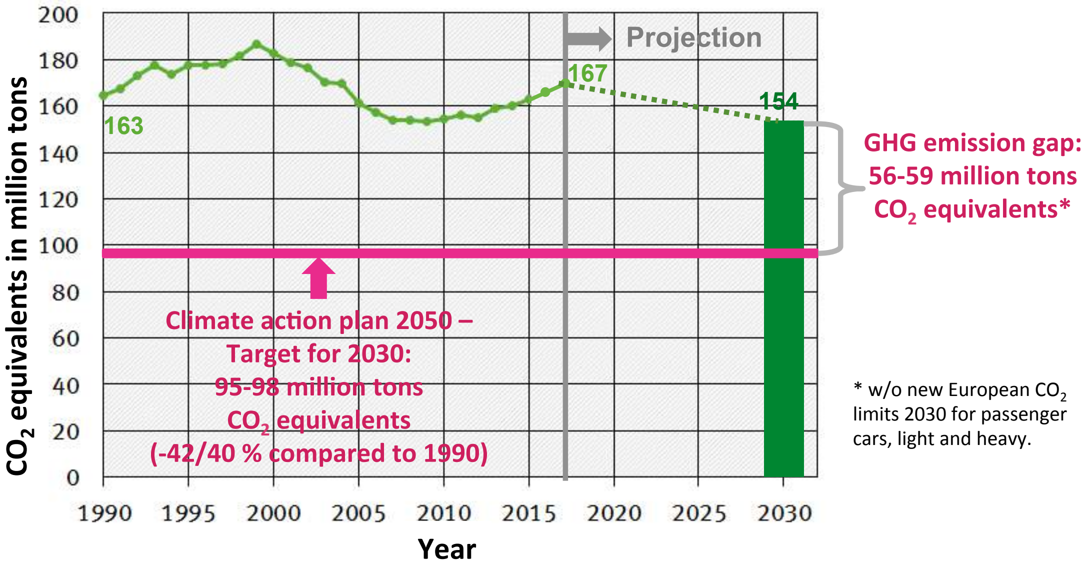
Fact 1

The German climate action plan 2050 requires a greenhouse gas-neutral transport system in long-term

Picture: stockWERK / Fotolia.com

Measures decided up to now are not enough to reach the climate targets in transport in 2030

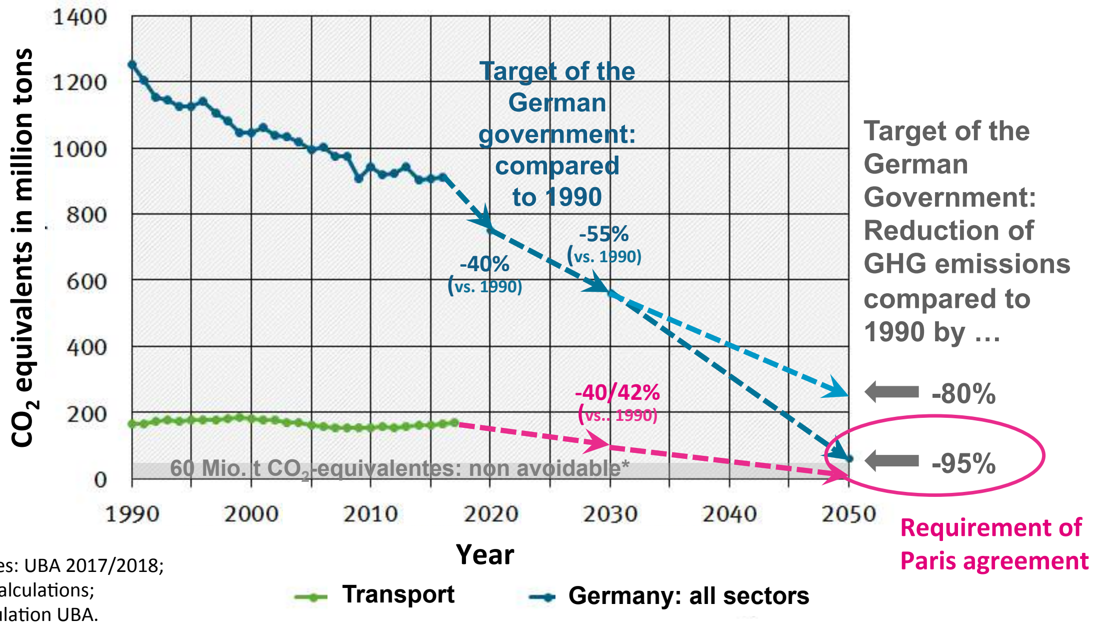
Development of GHG emissions of transport in Germany 1990-2017 and projection until 2030 (only decided measures*)



Source: UBA 2019; Projection report 2017 for Germany in accordance with EU regulation No. 525/2013.

Transport sector has to be GHG-neutral 2050 to contribute to the ambitious GHG reduction targets in Germany

Development of GHG emission in Germany from 1990 until 2050, Projection from 2017, climate target 2050



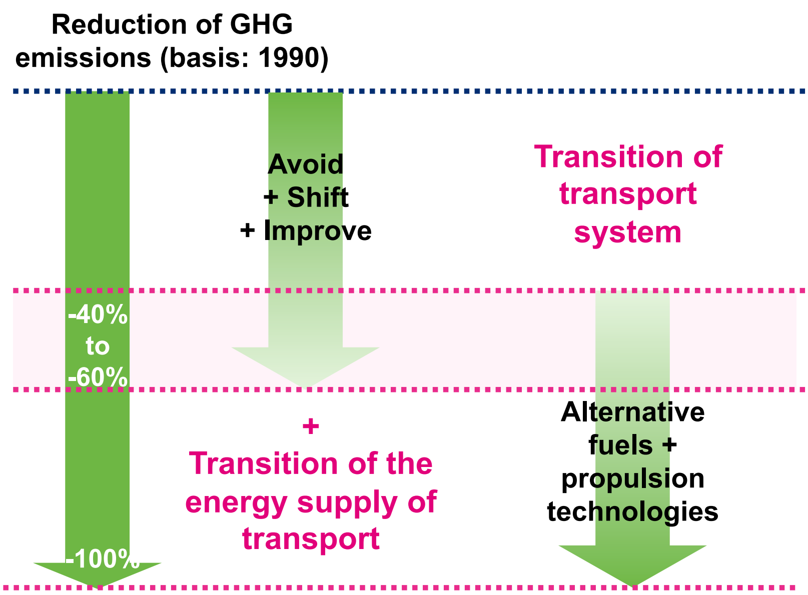
Sources: UBA 2017/2018; own calculations; *Calculation UBA.

Fact 2

Decarbonisation of transport needs both: transport transition as well as energy transition

Picture: Schmied.

Ambitious GHG emission target requires transition of the transport sector as well as of the energy supply of transport



- **GHG mitigation goals above 60 %** can be only reached with an **energy transition in the transport sector**
- For **reducing costs of energy transition** a **trans-port transition** with avoiding, shifting and improving of traffic is needed

Fact 3

Key element of the energy transition of the transport sectors is electric mobility

Picture: Fotolia.com

Three ~~Four~~ potential pathways in a carbon-neutral future of the transport sector in Germany

Conventional drives (Internal Combustion Engine)

Cultivated biomass: Ecological risks

Gaseous and liquid **biofuels**

Residual biomass: Problem of quantity

Gaseous and liquid **electricity-based hydro-carbons** (Power-to-Liquids, Power-to-Gas)

Energy transition in transport

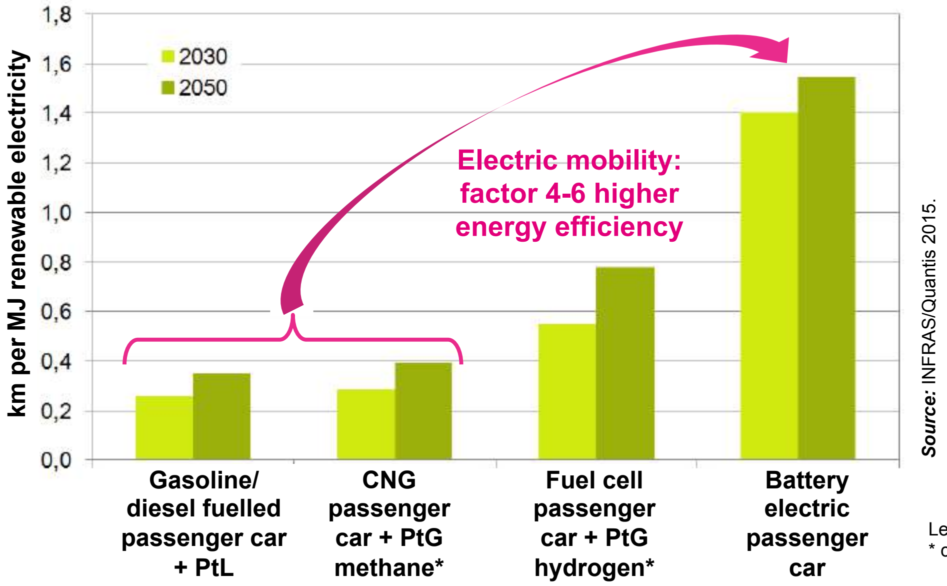
Electric vehicles (incl. off-vehicle charging hybrids and overhead catenary vehicles) and **renewable electricity**

Fuel cell vehicles that use **electricity-based hydrogen**

Alternative drives

Direct use of renewable electricity is the most efficient post fossil energy supply option for road transport

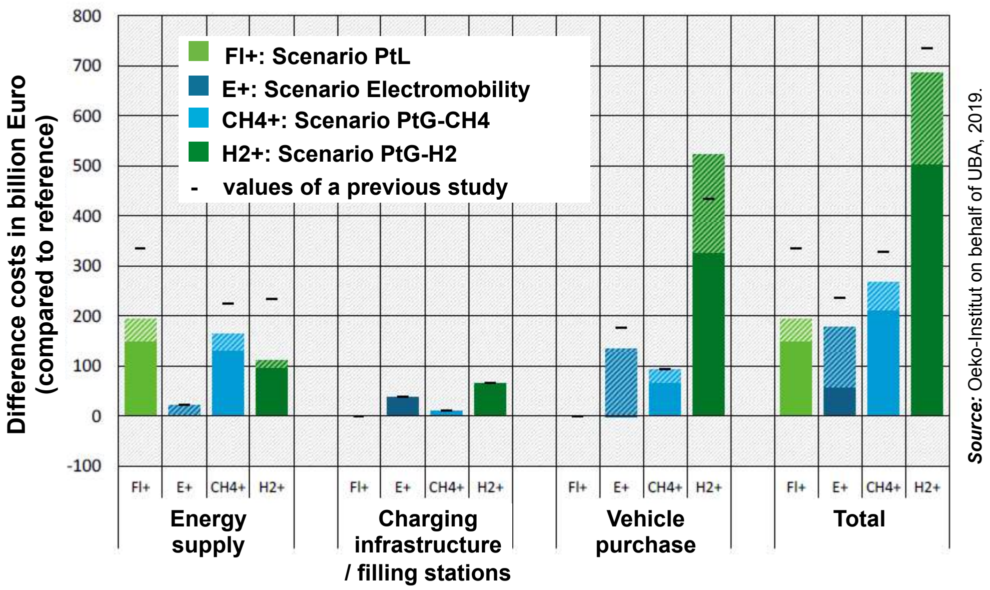
Distance driven by a medium-sized passenger car 2030/2050 using 1 MJ renewable electricity:



Legend:
* compressed.

Electromobility has economic advantages compared to other post-fossil options – PC/LDV/short-haul trucks

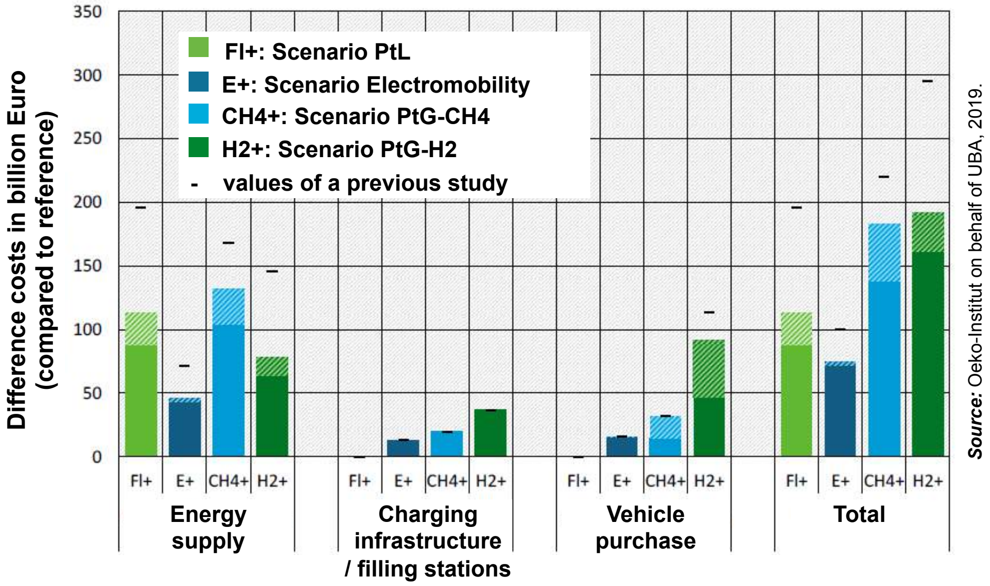
Passenger cars/LDV/short-haul truck: economic difference costs in comparison to reference scenario for time period 2020-2050



Notes: Reference scenario = use of conventional fuels / positive = additional costs.

Electromobility has economic advantages compared to other post-fossil options – long-haul trucks/buses

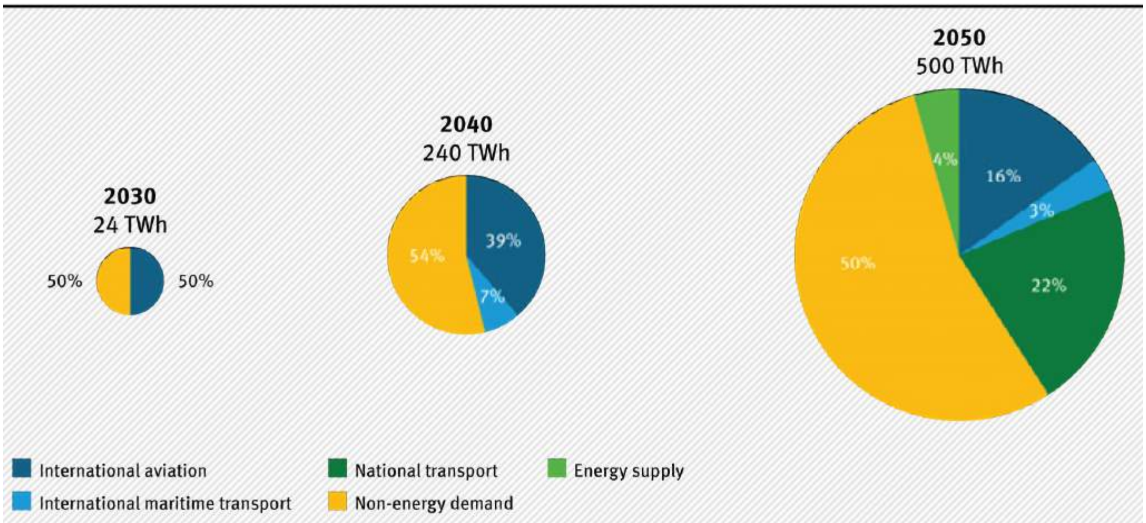
Long-haul trucks/buses: economic difference costs in comparison to reference scenario for time period 2020-2050



Notes: Reference scenario = use of conventional fuels / positive = additional costs.

BUT: Power-to-Liquid generated by using electric power from renewable resources is not available for road transport 2030

UBA project: A resource efficient pathway towards a greenhouse gas neutral Germany 2050.
Amounts of imported Power-to-Liquids and their distributions to sectors (Scenario GreenEe)



Source: UBA: A resource efficient pathway towards a greenhouse gas neutral Germany. Dessau-Rosslau: 2019.

Post-fossil energy supply options for different modes of transport 2050: German Perspective

Energy transition leads to an interlinking of transport and electricity sector:

Car/LDV	HDV ?	Urban bus
Electric mobility is the core option	Route into future for long haul trucks under discussion	Fast charging of batteries the most promising option

Airplanes	Ships	Train
Power-to-Liquids as alternative to bio fuels	Electricity based fuels are indispensable	Preferably complete electrification + renewable electricity

Source: INFRAS/Quantis 2015

Fact 4

GHG mitigation goals are only reachable with a basket of measures

Picture: Schmied.

GHG mitigation target for transport 2030 in Germany: Proposed measures of German Ministry of Transport

Field of action	Measures	GHG reduction in million tons CO_2 equivlanet
1 Public Transport, Bicycles and Pedestrians	- Additional federal funds for infrastructure (e.g. 1 bn Euro for PT)	7-8
	- Reduction of value added tax for train tickets (from 19 to 7 %)	
	- Higher state supports for electric buses	
2 Alternative Fuels	- Govermental research/support of production sites (PtX /advanced biofuels)	9-10
	- Development of a hydrogen programme (2 bn Euro from 2021)	
3 Freight Transport	- Additional federal funds for freight rail infrastructure and inland navigation	2
4 Passenger Cars	- Tightening European CO_2 limits for passenger cars 2030	9-10
	- Increase of buyer's premium for new electric passenger cars	
	- Promotion of climate friendly company cars by revision of tax system	
	- Increasing state supports for charging infrastructure (additional 1 bn Euro)	
5 Heavy Duty Vehicles	- Tightening European CO_2 limits for HDV 2030	17-18
	- Buyer's premium for HDV with alternative fuels	
	- Considering CO_2 emissions for road tolls of trucks	
	- Increasing state supports for charging infrastructure	
6 Digitisation	- High-speed mobile networks for automated and connected vehicles	6-7
	- Changing legal framework for digitilisied vehicles	

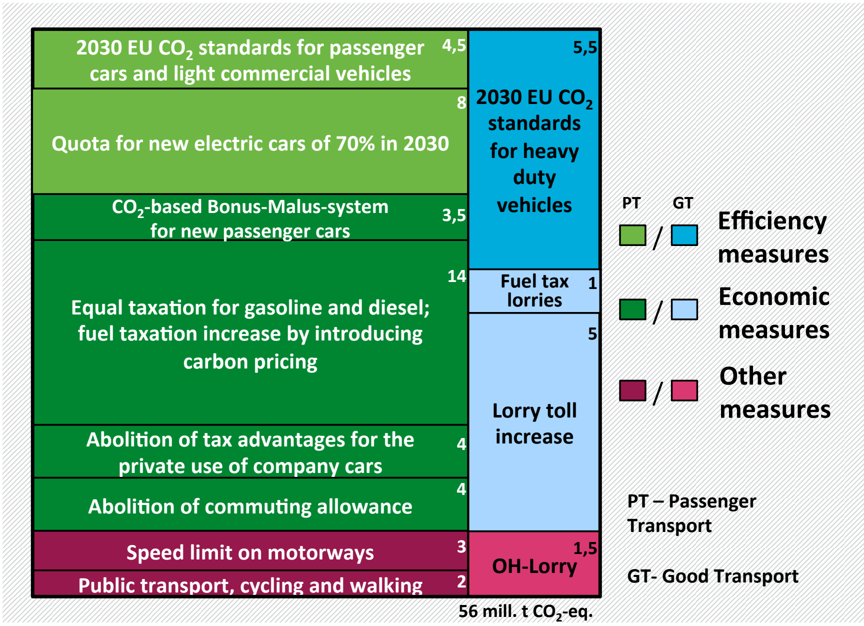
50-55 million t CO_2 equivalents

Source: UBA based on German Ministry of Transport and Digital Infrastructure, May 2019.

Update on the Climate Cabinet decision of 20th September 2019 focused on transport

- **Introduction of national CO_2 price for Non-ETS-sector (2021: 10 Euro/tCO_2, 2025: 35 Euro/t CO_2)**
  - increase of fuel prices from 3 Cent/liter in 2021 to 10-11 Cent/Liter in 2025
  - Increase of commuting allowance (+ 5 Cent/km from 2021)
- **Promotion of electric vehicles (7-10 m electric vehicles in 2030)**
  - Increase of buyer's premium for new electric passenger cars (doubling) and reduction of company car tax (car price below 40.000 Euro)
  - Expansion of charging infrastructure (1 million charging points in 2030)
  - Increasing state supports for alternative fuels/propulsion system for trucks
- **Reform of vehicle taxes and road tolls**
  - Introduction of a CO_2 based vehicle tax
  - Implementation of CO_2 component into HDV road toll (from 2021)
- **Development/strengthening of use of advanced biofuels/PtX fuels**
  - Development of H_2 strategy for the transport sector
- **Support/improvements of public, rail and non-motorized transport**
  - Increasing of investments in infrastructures (and vehicles)
  - Reduction of VAT for train tickets from 19 to 7 %/ increase ticket tax for air traffic

GHG mitigation target for transport 2030 in Germany: Proposed measures from UBA



Source: UBA 2019 (unpublished)

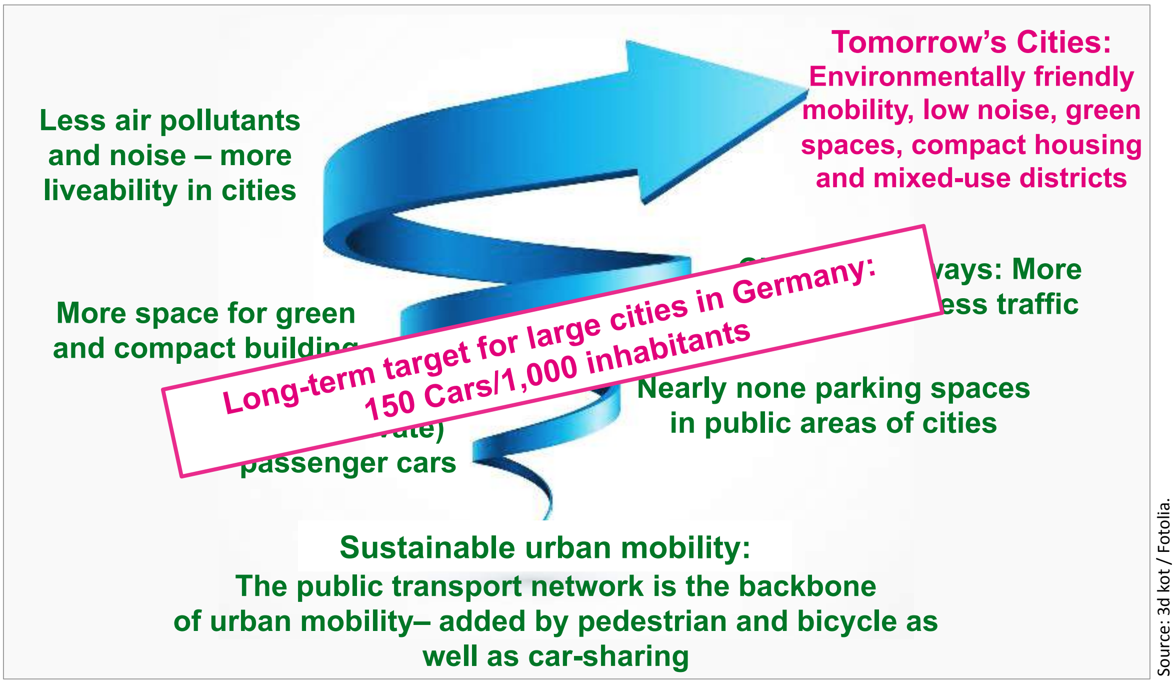
- **Basket of measures** will reduce the GHG emission by **56 million t CO_2e until 2030**.
- **Most effective measures** are **efficiency standards**, **electrification** and **pricing of transport**.
- Implementation of all measures at the same time is not feasible.

⇨ **UBA advises implementation in stages**

Transportation and sector coupling in Germany: Conclusions

1. **To meet the ambitious climate mitigation goals in Germany the transport sector must become greenhouse gas-neutral by 2050 (decarbonisation of transport) – and this is possible!**
2. **Besides a transport transition with avoiding, shifting and improving of traffic a energy transition of the transport sector is needed and required.**
3. **Key element of an energy transition of transport is electric mobility supplemented by renewable energy-based Power-to-Liquids (PtL) or Power-to-Gas (PtG) (sectors coupling!).**
4. **Transport and energy transition needs actions today. Therefore a broad basket of measures is needed including pricing.**
5. **Sustainable mobility is much more than climate-friendly or GHG-neutral transport – for liveable cities a transport transition is needed as urgent as in the past.**

Tomorrow's Cities: Less passenger cars create space in cities and enables a sustainable urban development



Umwelt Bundesamt

Thank you for your attention!

Martin Schmied
Head of Department I 2 "Transport, Noise and Spatial Development"

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