2050 scenario analysis using the EU CTI 2050 Roadmap Tool

TRANSPORT sector documentation

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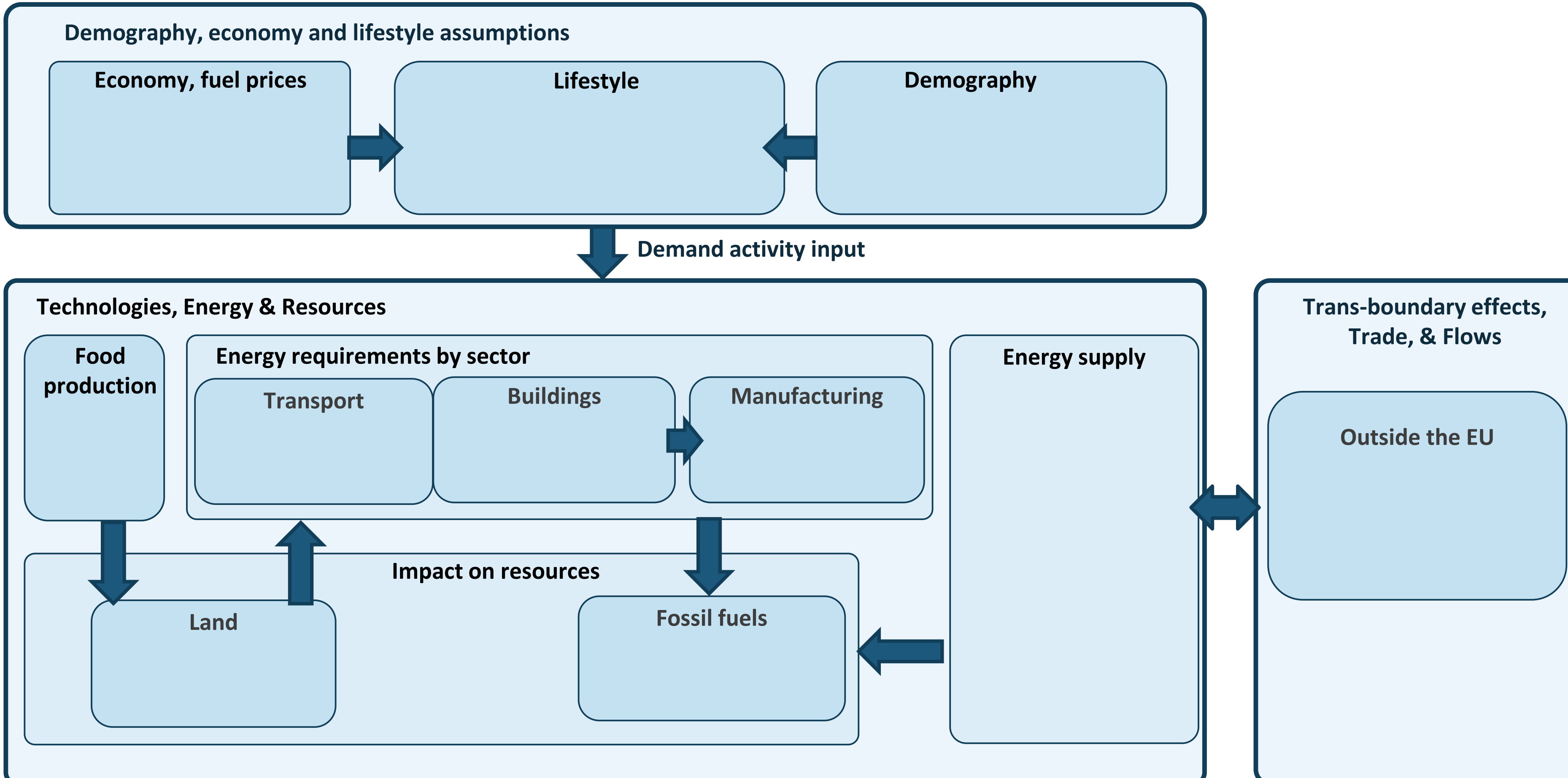
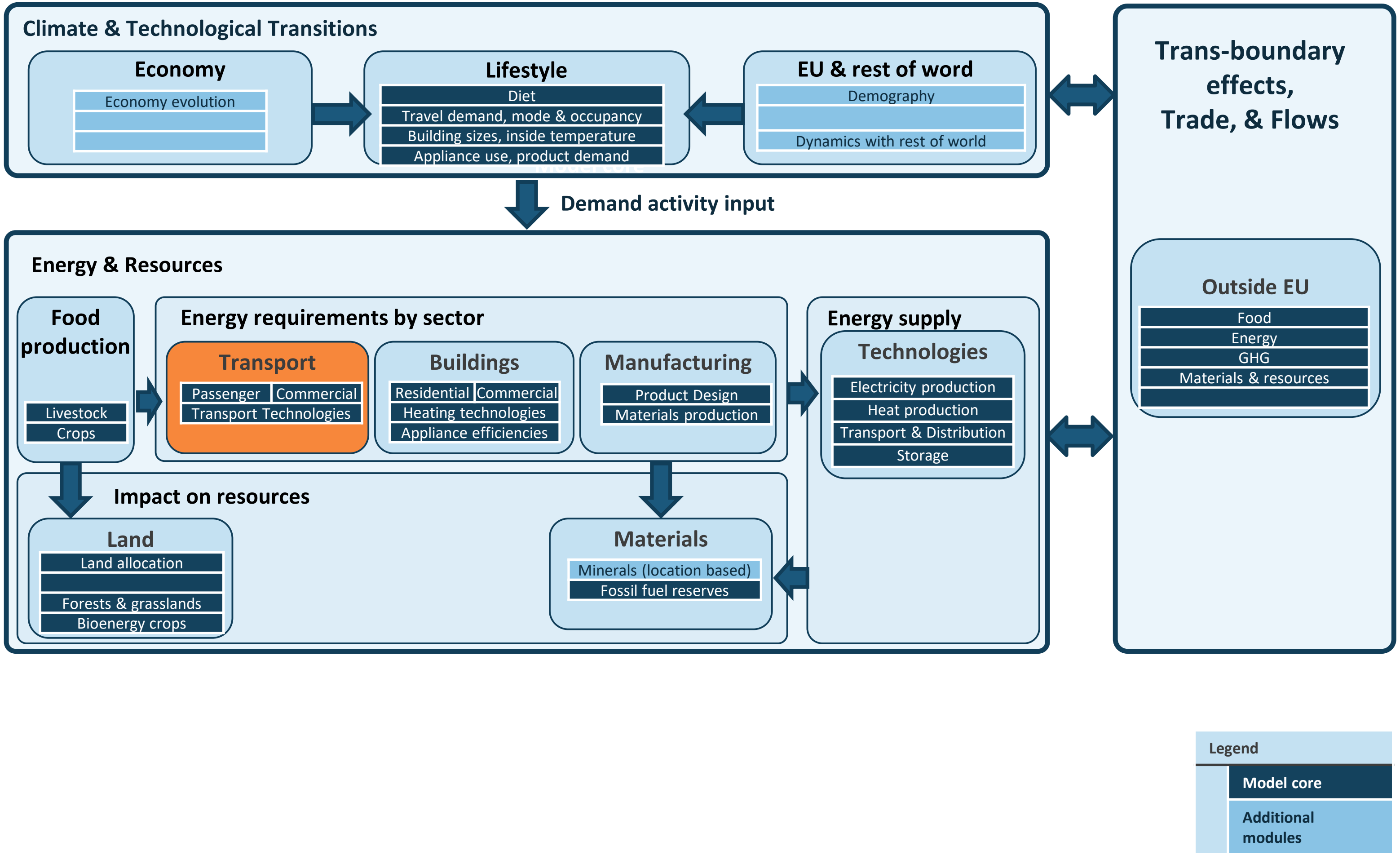
Content

Structure of the ECF EU CTI 2050 Roadmap model



Structure of the ECF EU CTI 2050 Roadmap model



4 ambition levels are used as boundaries to create scenarios
Any value can be chosen in between

Level 0

- **Current development** scenario (existing legal obligations)
- No additional effort
- « BAU scenario »

Level 1

- **Increased ambition** compared to BAU
- No breakthrough, but more extensive use of existing technologies

Level 2

- **Ambitious:** Significant effort requiring extensive changes in the system, leveraging best practices available today
- Typically reaching –85%

Level 3

- **Transformational:** Max potential based on transformational changes but reflecting technical or physical constraints

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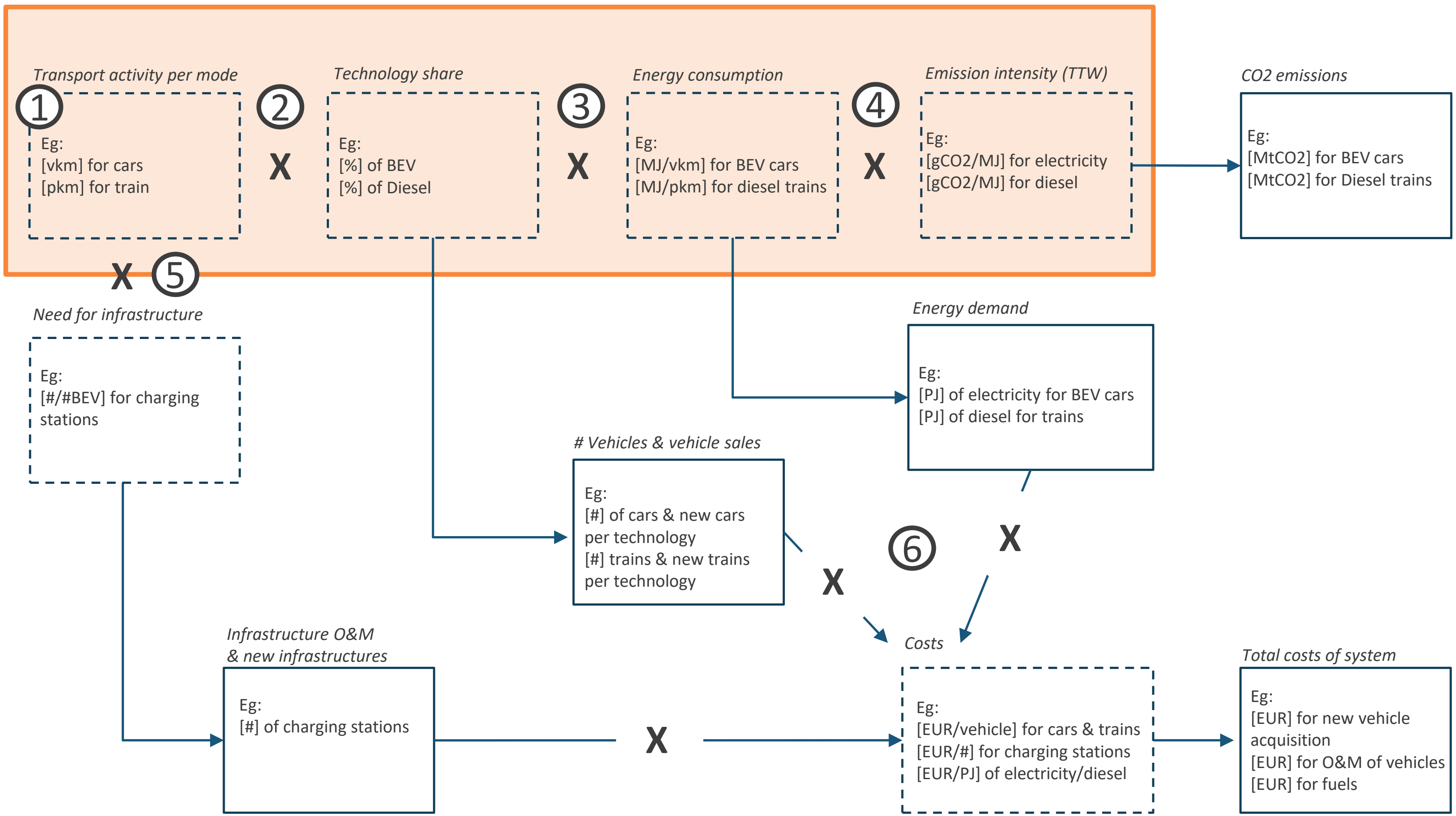
General calculation logic of transport modules (both passenger & freight)

Calculation steps

Output



The avoid/reduce-shift-improve approach is used to structure the levers used to reduce transport energy demand and GHG emissions

- **Avoid** vehicle activity by:
  - reducing transport demand
  - increasing vehicle occupancy/load factor
- Further **reduce** the number of vehicles needed by:
  - increasing the utilization rate of vehicles
  - increasing the mileage lifetime of vehicles
- **Shift** to more efficient/environmentally friendly modes (e.g. active modes or public transport)
- **Improve** efficiency of transport by:
  - making more efficient new vehicles
  - shifting to more efficient fuels and technologies

In practice, we use 8 types of levers

	Lever type	Granularity of the levers for the user
1.	Transport demand [pkm/capita] or [tkm]	Passenger: land transport demand, aviation demand Freight: total demand
2.	Occupancy/load factor [passenger/vehicle] or [ton/vehicle]	Passenger: occupancy for LDV & bus Freight: load factor for trucks
3.	Utilization rates [km/vehicle/year]	Passenger: utilization rate for LDV & 2W Freight: utilization rate for trucks
4.	Modal share [%/mode]	Passenger: modal share for LDV, 2W, Bus Freight: modal share for trucks, rail, maritime
5.	Vehicle efficiency [MJ/km] or [MJ/pkm] or [MJ/tkm]	Passenger & freight bundled as one lever: energy efficiency for cars, rail, aviation and navigation
6.	Low Emission Technology development [% of new vehicles/technology]	Passenger: - ZEV share (with an additional priority lever between BEV and FCEV) - LEV share Freight: - ZEV share - LEV share Passenger & freight together: short-haul flights electrification & shipping electrification
7.	Fuel mix [%/fuel type]	Passenger & freight together: Biofuels, e-fuels
8.	Lifetime of vehicles [total km/vehicle]	Passenger: total kms travelled over vehicle lifetime Freight: total kms travelled over vehicle lifetime

Scope of the analysis

Modes for passenger transport:
- Light duty vehicles (LDV)
- 2-wheels (2W)
- Bus
- Rail
- Airplane

Modes for freight:
- Heavy Duty Vehicles (HDV)
- Rail
- Aviation
- Inland Waterways (IWW)
- Marine

Types of vehicles/trip:

Airplanes:
- Intra-EU
- Extra-EU

HDV:
- Light
- Medium
- Heavy

LDV, 2W, bus, rail, ships :
No further categorization

Technologies:
LDV, 2W & Bus:
- Internal Combustion Engines (ICE)
- Battery Electric Vehicles (BEV)
- Fuel Cell Electric Vehicles (FCEV)
- Plug-in Hybrid Electric Vehicles (PHEV)

Rail:
- ICE
- Catenary Electric (CE)

Airplane:
- ICE
- BEV

HDV:
- Internal Combustion Engines (ICE)
- Battery Electric Vehicles (BEV)
- Fuel Cell Electric Vehicles (FCEV)
- Plug-in Hybrid Electric Vehicles (PHEV)
- Catenary Electric Vehicles (CEV)

Ships:
- ICE
- BEV

Types of fuels:
- Diesel (for ICE & PHEV)
- Gasoline (for ICE & PHEV)
- Gas (for ICE & PHEV)
- Electricity (for BEV, PHEV, CE)
- Hydrogen (for FCEV)
- Aviation gasoline (for ICE planes)

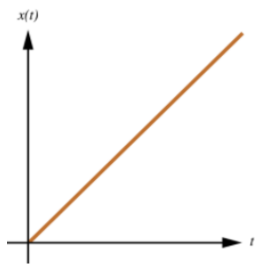
Source of fuels:
- Conventional fossil fuel
- Biofuel (1G & 2G)
- E-fuel / PtX

+ **infrastructures**:
- EV charging stations,
- E-highways,
- Hydrogen charging stations

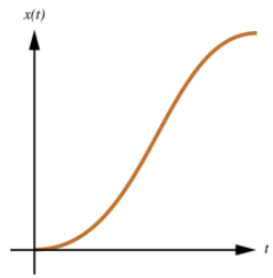
+ **costs (yet to be added)**:
- Fuel costs,
- CAPEX for new vehicles and new infrastructures,
- OPEX for existing vehicles and infrastructures.

Projection trajectories until 2050

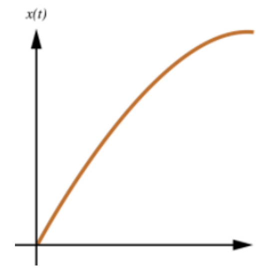
- Different types of curves are used



L-curve



S-curve



HS-curve

- Starting time and duration parameters are also used

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Calculation sequence of levers for the computation of energy and emissions in transport

1 Transport demand
[pkm] & [tkm]

This lever determines the total transport demand

2 Modal share
[%/mode]

This lever determines the share of transport demand for each transport mode
Multiplied by the transport demand, this results in the total transport demand for each mode in [pkm] or [tkm]

3 Occupancy & Utilization rate
[pkm/vkm] & [vkm/veh]

Occupancy lever determines the number person per vehicules and allows to translate [pkm] to [vkm] for cars and buses
Utilization rate determines de number of kilometers per vehicle each year and allows to compute the number of vehicles needed to answer the demand

4 Technology share
[%]

This lever determines the share of each technology in each mode

5 Energy efficiency
[MJ/pkm] or [MJ/vkm] & [MJ/tkm]

This lever sets the energy consumption for each mode & each technology. This allows to translate transport demand into energy consumption

6 Biofuels
[% fuel]

This lever sets the sare of biofuels in the different types **of remaining fuels**

7 E-fuels
[% of "non-bio"fuel]

This lever sets the sare of e-fuels in the different types **of remaining non bio-fuels**

Calculation sequence of modal share sub-levers

1 Modal share – LDV [%]

This lever determines the share of LDV in total transport demand

2 Modal share – 2W [%]

This lever determines the share of 2W **in remaing transport demand** (total – LDV)

3 Modal share – Bus [%]

This lever determines the share of **Bus in remaing transport demand** (total – LDV – 2W)

Calculation sequence of technology sub-levers

1 Technology share – ZEV [%]

This lever determines the share of Zero Emission Vehicles (either Battery Electric Vehicles or Fuel Cell Electric Vehicles) into the total vehicle fleet

2 Share of FCEV in ZEV [%]

This lever determines the share of Fuel Cell Electric Vehicles into the ZEV fleet

3 Technology share – LEV [%]

This lever determines the share of Low Emission Vehicles (mainly Plug-in Hybrid Electric Vehicles) **into the remaining non-ZEV vehicle fleet**

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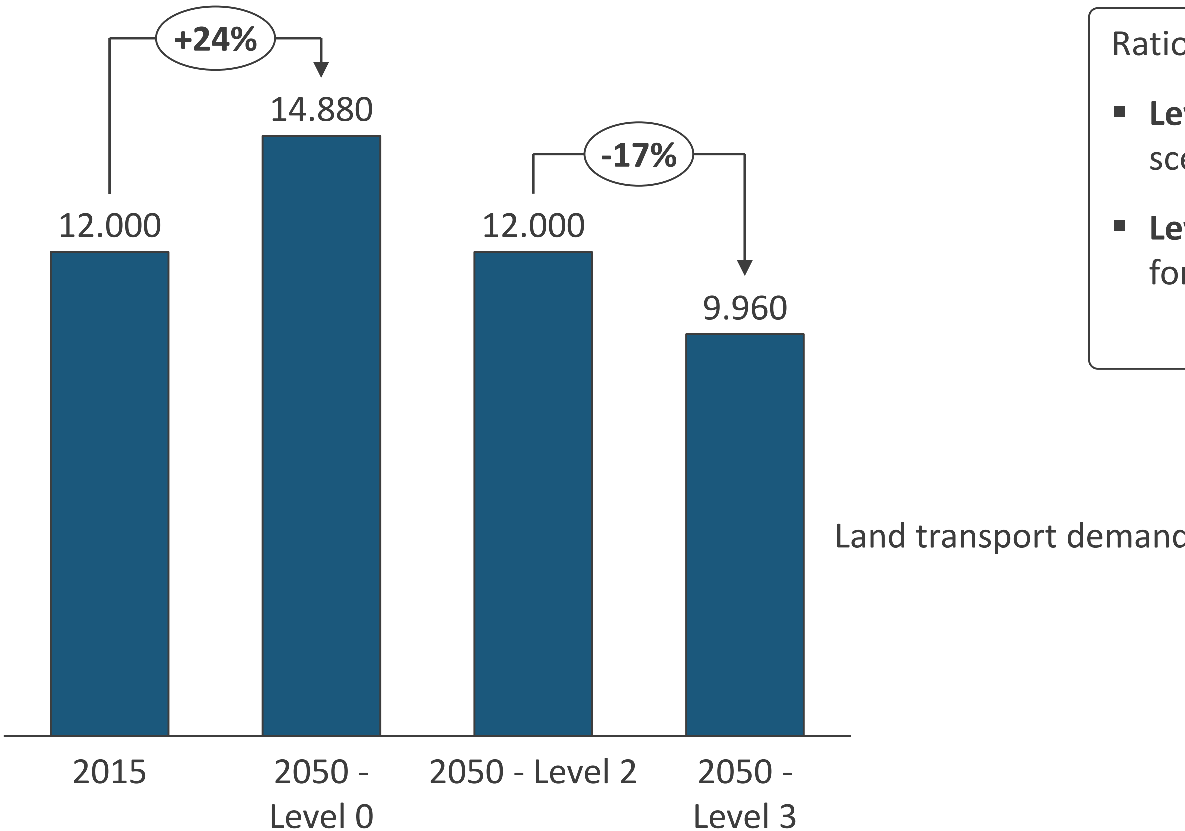
Summary of ambition levels for passenger transport

Lever	Curve shape	2015 situation for EU28	2050 ambition for EU28+CH			Sources
			Level 0	Level 2	Level 3	
Passenger – transport demand	L	12000 pkm/capita for land transport 2400 pkm/capita for aviation of which 1200 are intra-EU	+24% for land transport +84% for aviation	+0% for land transport +0% for aviation	-17% for land transport -23% for aviation	Level 0 aligned with PRIMES REF16 Level 3 considers demand decrease coherent with NegaWatt scenarios
Passenger – Modal share	L	Car: 78% 2W: 4% Bus: 9% Rail: 9%	Car: 75% 2W: 4% Bus: 9% Rail: 12%	Car: 61% 2W: 3% Bus: 17% Rail: 19%	Car: 55% 2W: 2% Bus: 25% Rail: 18%	Level 0 aligned with PRIMES REF16 Level 3 aligned with proximobility scenario of [V.Kaufmann & E.Ravalet, 2016] for France
Passenger - Occupancy	L	Car: 1,6 p/v 2W: 1,1 p/v Bus: 18,8 p/v	Status quo compared to 2015	Car: 2,3 p/v 2W: 1,1 p/v Bus: 24,4 p/v	Car: 2,6 p/v 2W: 1,1 p/v Bus: 27,3 p/v	Level 3 for cars aligned with most optimistic scenario of [TRANSvisions, 2009] for urban transport.
Passenger – Utilization rate	L	Car: 12000 vkm/v 2W: 3200 vkm/v Bus: 42000 vkm/v	Status quo compared to 2015	Car: +400% 2W: +10% Bus: +30%	Car: +900% 2W: +15% Bus: +45%	Level 3 for cars aligned with disruption scenario of [RethinkX, 2017]
Passenger – Energy efficiency (fleet average)	L	Car: 3 MJ/vkm Bus: 17 MJ/vkm Rail: 0,3 MJ/pkm Air: 2 MJ/pkm	Car: -20% Bus: -15% Rail: -10% Aviation: -5%	Car: -30% Bus: -22% Rail: -30% Aviation: -15%	Car: -35% Bus: -25% Rail: -40% Aviation: -22%	Level 0 aligned with Belgium Low carbon (Climact, 2013) Level 3 based on T&E, IEA, UIC, Sustainable aviation
Passenger – Technology share (in new sales for cars & buses, and in total fleet for trains & planes)	S	Car: 3% LEV, 0,1% ZEV Bus: 0,5% LEV, 0,3% ZEV Train: 50% ZEV Air: 0% LEV + ZEV	Car: 8% LEV, 9% ZEV Bus: 0% LEV + ZEV Air: 0% LEV + ZEV	Car: 22% LEV, 69% ZEV Bus: 50% LEV + ZEV Air: 0% LEV + ZEV	Car: 100% ZEV Bus: 100% ZEV Air: 10% ZEV	Level 3 for cars aligned with most optimistic scenario of Fueling Europe's Future 2
Passenger – Lifetime of vehicles	L	Car: 180000 km Bus: 400000 km Train: 30 years Air: 30 years	Status quo compared to 2015	Car: +350% Bus: +20% Train: +20% Air: +20%	Car: +700% Bus: +30% Train: +30% Air: +30%	Level 3 for cars aligned with disruption scenario of [RethinkX, 2017]
Passenger & Freight – Fuel mix	L	Biofuels: 5% of transport liquid or gas fuel demand E-fuels: 0% of transport liquid or gas fuel demand	Biofuels: 7% of transport liquid or gas fuel demand E-fuels: 0% of transport liquid or gas fuel demand	Biofuels: 65% of transport liquid or gas fuel demand E-fuels: 42% of transport liquid or gas fuel demand	Biofuels: 100% of transport liquid or gas fuel demand E-fuels: 60% of transport liquid or gas fuel demand	The transport sector defines a certain amount of biofuels demand which is either produced in the AFOLU Sector or imported

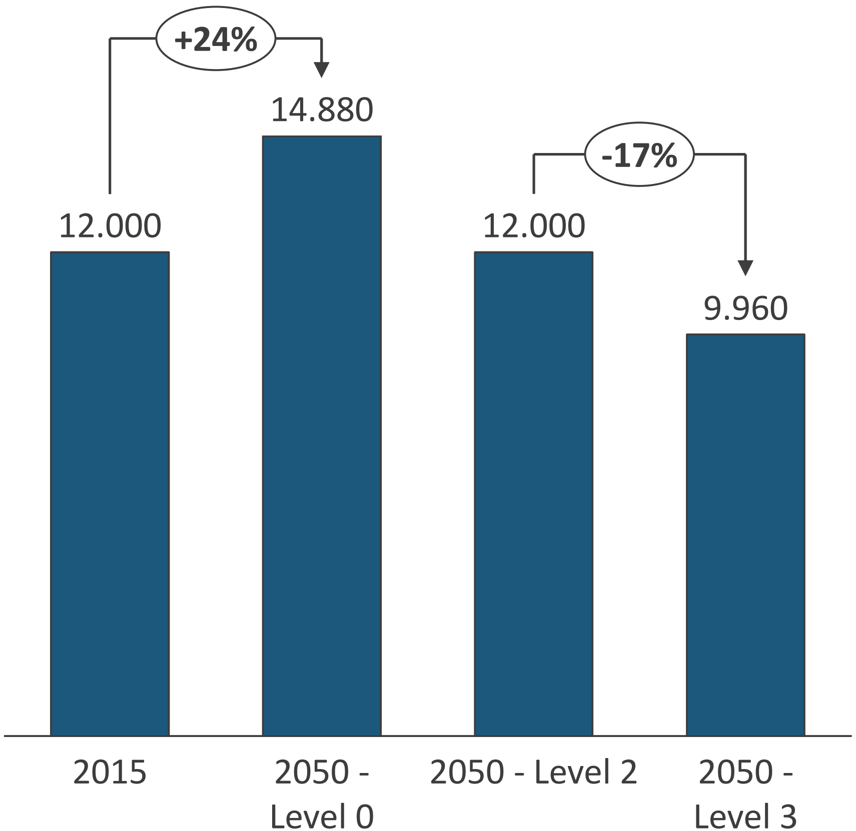
Land transport demand: Ambition levels



Rationale for the levels:

- **Level 0:** Aligned with EURef 2016 scenario
- **Level 3:** based on the Négawatt scénario for France

Land transport demand: Ambition levels



Level 2 is ambitious but realistic:

- It is a status quo scenario and therefore does not require significant change compared to today
- In EU, those country already have lower demand per capita: NL, ES, BG, CZ, etc.

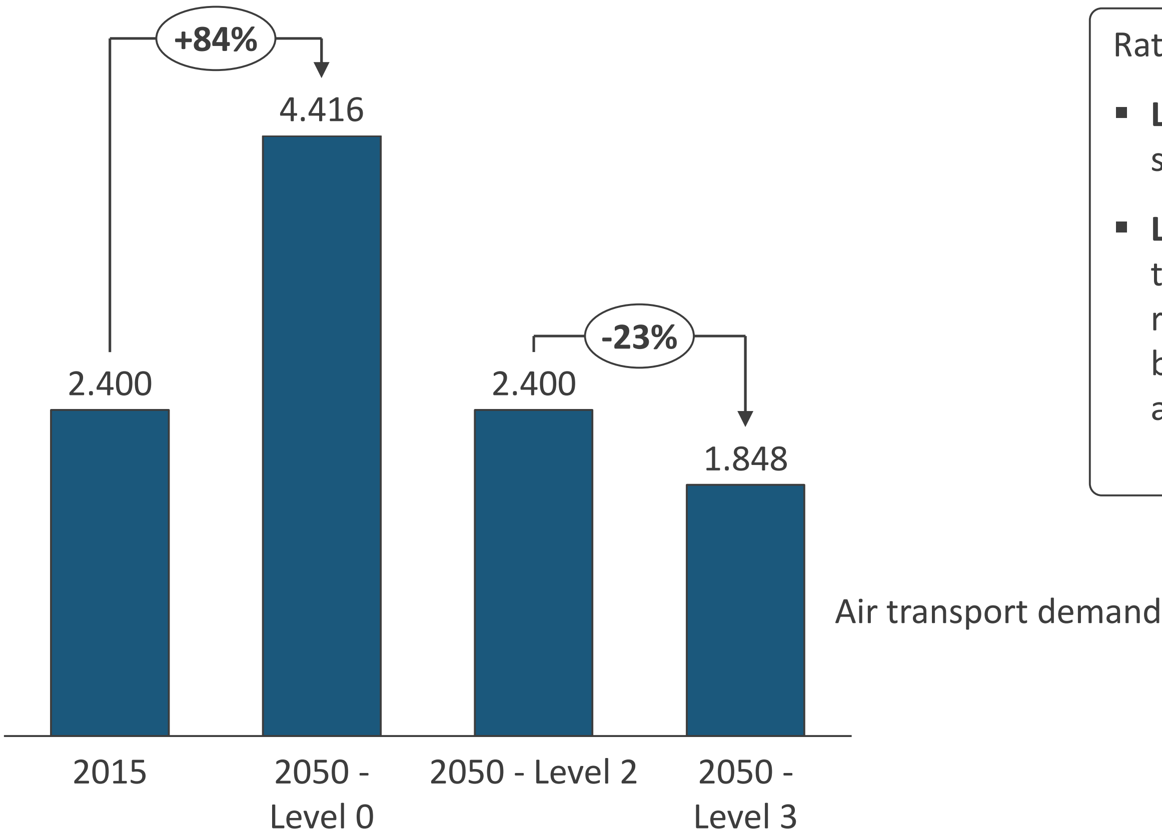
Level 3 requires some additional efforts and changes such as:

- Strong urban policy for "proximobility"
- Change in behaviour to switch to active modes (bike, walk)

But is still realistic:

- Some EU countries already have lower demand: SK, RO, PL, MT, LV, HR

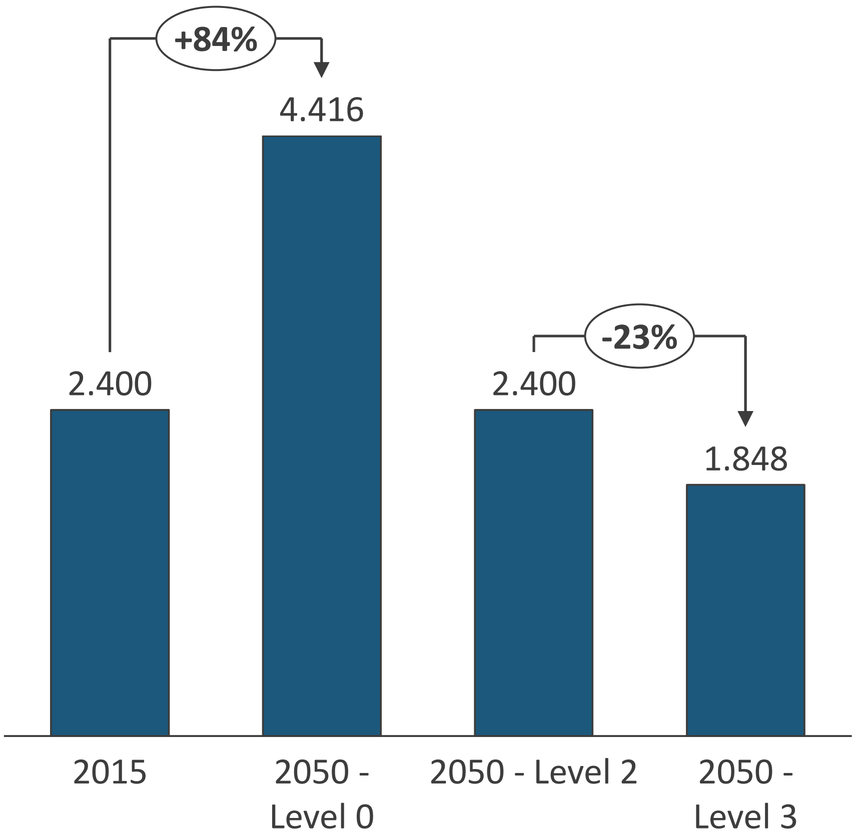
Air transport demand: Ambition levels



Rationale for the levels:

- **Level 0:** Aligned with EURef 2016 scenario
- **Level 3:** based on the observation that the most rapid and efficient way to reduce aviation emissions is to change behaviors and significantly reduce aviation demand [Bows-Larkin, 2015]

Air transport demand: Ambition levels



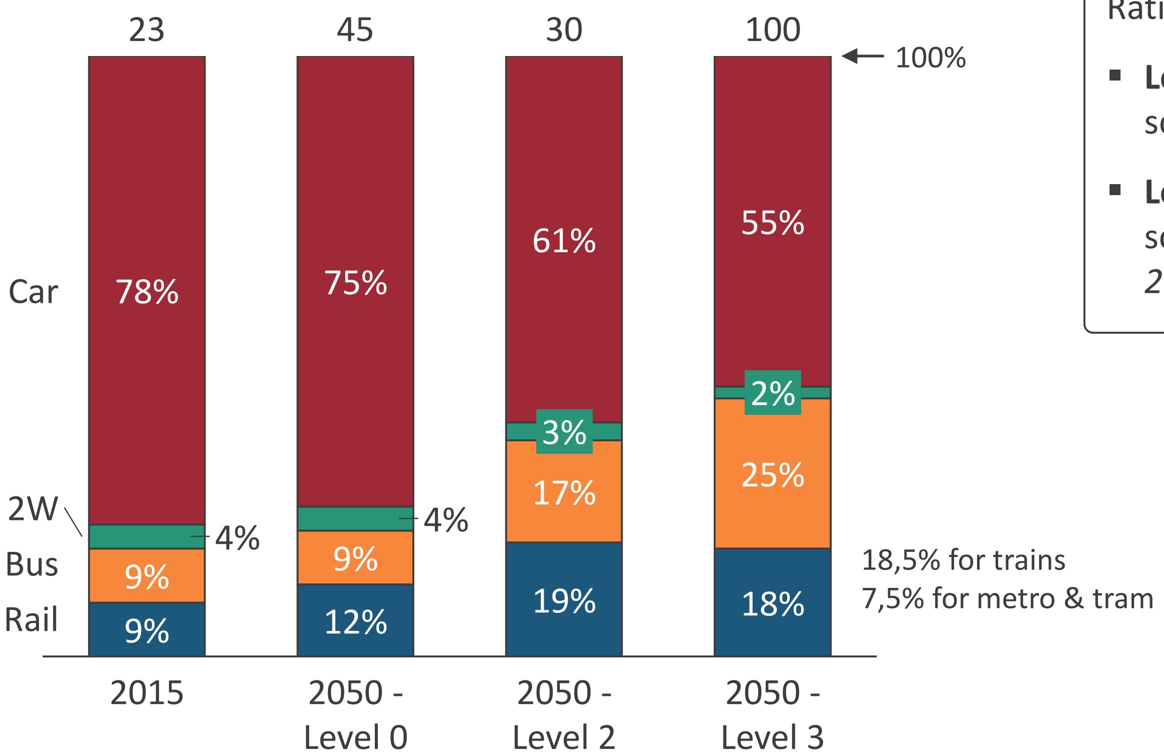
Level 2 is ambitious but realistic:

- It is a status quo scenario and therefore does not require significant change compared to today

Level 3 requires some additional efforts and changes such as:

- Less long-range travels, and behaviour change on travelling
- More Video-conference for international meetings
- High carbon price on aviation

Modal share: Ambition levels

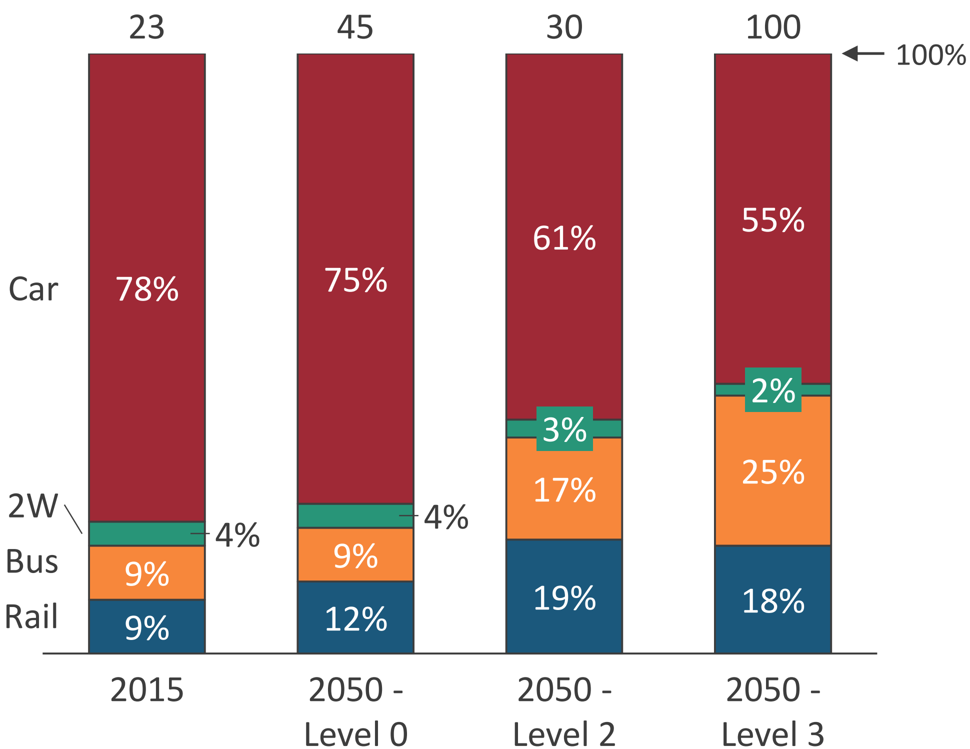


Rationale for the levels:

- **Level 0:** Aligned with EURef 2016 scenario
- **Level 3:** based on the Proximobility scenario of *[V.Kaufmann & E.Ravalet, 2016]* for France

*Rail = metro & tram + train

Modal share: Ambition levels



Level 2 is ambitious but realistic:

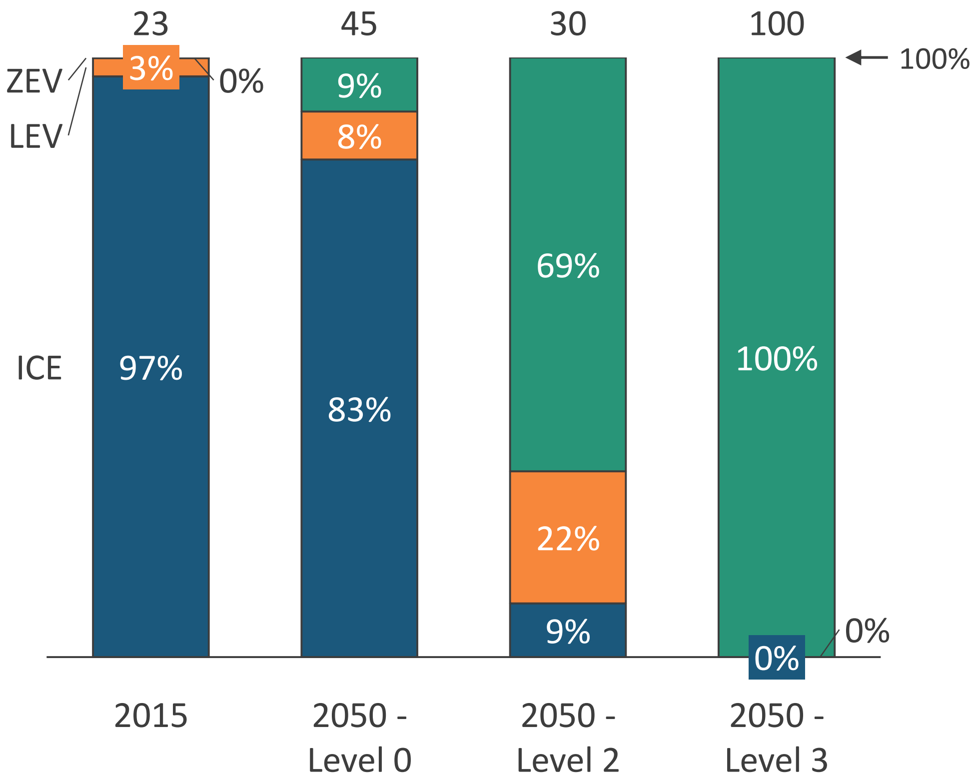
- Some countries already reach a 15% bus share in 2015 (BG, CZ, SK) or even more
- Train share already reaches 17% in 2015 in Switzerland and Japan
- Metro + tram share already reaches more than 5% in somes EU countries in 2015 (CZ, AT, RO)

Level 3 requires some additional efforts and changes, in line with the *[V.Kaufmann & E.Ravalet, 2016] proximobility scenario for France*:

- Strong urban planning policies**
- Decrease in long-range transport demand
- Shift to TGV "because of the quality of the time" it allows

** "In territorial terms, this scenario is characterized by the development of concentrated decentralization. Suburban areas will be less dispersed and reach critical mass in terms of population."

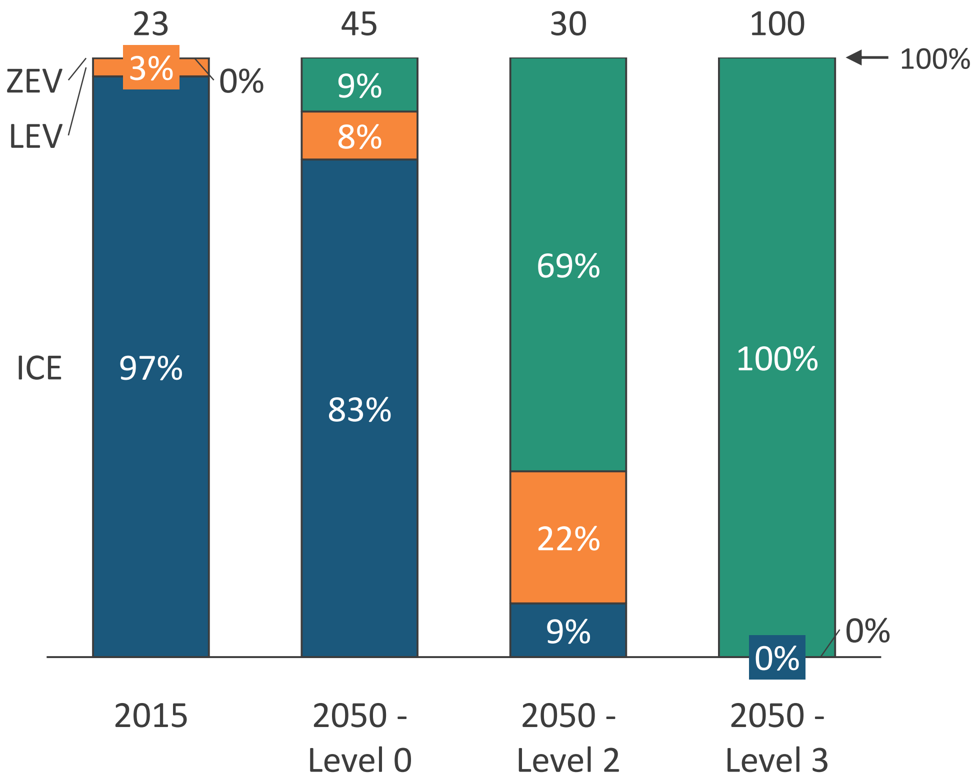
Technology share: Ambition levels



Rationale for the levels:

- **Level 0:** Aligned with EURef 2016 scenario
- **Level 3:** Aligned on Fuelling's Europe Future 2 most optimistic scenario for new car sales

Technology share: Ambition levels for cars



Example of national/local objectives for LDVs [SLoCaT, 2018]:

- Norway: after 2025, all new LDV should be ZEV
- The Netherlands: ban new petrol & diesel cars by 2030
- Germany: only ZEV LDVs will be approved for use in 2030

Manufacturers objectives:

- Volvo: by 2020, 10% of EV
- Honda: by 2030, 2/3 of new sales are EV (PHEV, BEV, etc.)

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Summary of ambition levels for freight

Lever	Curve shape	2015 situation for EU28	2050 ambition for EU28+CH			Sources
			Level 0	Level 2	Level 3	
Freight – transport demand	L	3400 Btkm/year	+1,16%/year	+0%/year	-0,7%/year	Level 0: aligned on PRIMES REF16 Level 3: NegaWatt scenarios
Freight – Modal share	L	Road: 50% Rail: 12% IWW: 4,9% Sea: 33% Air: 0,1%	Road: 51% Rail: 11% IWW:4,9% Sea: 33% Air: 0,1%	Road: 41% Rail: 20,4% IWW: 4,4% Sea: 34,1% Air: 0,1%	Road: 35% Rail: 23% IWW: 4,9% Sea: 37% Air: 0,1%	Level 0 aligned with PRIMES REF16 Level 3 aligned with EC White paper modal shift ambition Level 3 based on NégaWatt scenarios
Freight – Load factor	L	Road: 10,8 tkm/vkm	Status quo compared to 2015	Road: +10%	Road: +15%	Level 2: T&E estimate Level 3: IEA estimate
Freight – Utilization rate	L	Road: 68500 vkm/year	Status quo compared to 2015	Road: +7%	Road: +10%	Climact work in the context of the EU Calculator
Freight – Energy efficiency (fleet average)	L	Light truck: 3MJ/km Medium truck: 6 MJ/vkm Heavy truck: 12 MJ/vkm Boat: 0,3 MJ/tkm Rail: 0,15 MJ/tkm Air: 20 MJ/tkm	Truck: -10% Boat: -5% Rail: -10% Air: -20%	Truck: -33% Boat: -30% Rail: -30% Air: -34%	Truck: -50% Boat: -40% Rail: -40% Air: -40%	Level 0 aligned with Belgium Low carbon (Climact, 2013) Level 3 based on T&E, IEA, UIC, Sustainable aviation, DNV-GL
Freight – Technology share (in new sales for trucks, and in total fleet for boats & planes)	S	Truck: 0,04% LEV, 0,3% ZEV Boat: 0% LEV + ZEV Air: 0% LEV + ZEV	Truck: 26% LEV+ZEV Boat: 0% LEV+ZEV Air: 0% LEV+ZEV	Truck: 70% LEV+ZEV Boat: 70% LEV+ZEV Air: 0% LEV+ZEV	Truck: 100% LEV+ZEV Boat: 20% of SSS & 10% of LSS Air: 10% BEV	Level 3: T&E reports, DNV-GL for boats and expert interviews
Freight – Lifetime of vehicles	L	Truck: 400000km Boat, train, aircraft: 25 years	Status quo compared to 2015	All vehicles: +20%	All vehicles: +30%	Climact work in the context of the EU Calculator

Content

Aviation – Direct emissions mitigation logic & ambition levels

European Climate Foundation | ClimateWorks FOUNDATION

1 Aviation demand
[pkm] & [tkm]

Passenger aviation:
Situation in 2015: 2380 km/capita (50% intra-EU, 50% extra-EU)
2050, Level 0: +1,8% every year (same proportion of intra/extra EU than in 2015)
2050, Level 3: -0,9% every year (same proportion of intra/extra EU than in 2015)
Freight aviation:
0,1% of intra-EU freight modal share (constant for all scenarios)
Extra-EU freight aviation represents 94% of freight aviation demand

2 Energy efficiency
[MJ/pkm] & [MJ/tkm]

Situation in 2015: 2 MJ/pkm & 19 MJ/tkm
2050, Level 0: 20% improvement compared to 2015
2050, Level 3: 40% improvement compared to 2015

This includes technical/design (e.g. Light-weight materials, aerodynamism, etc.) & operational improvement (e.g. shorter routes, bigger planes)

3 Electrification
[% of short hauls]

Situation in 2015: 0%
2050, Level 0: 0% electrification
2050, Level 3: 10% of all intra-EU flight

Starting year: 2040 or after because of R&D process

4 Biofuels
[% kerozene]

Situation in 2015: 0%
2050, Level 0: 0% of bio-kerozene
2050, Level 3: 100% of bio-kerozene

5 E-fuels
[% of "non-bio"kerozene]

Situation in 2015: 0%
2050, Level 0: 0% e-kerozene
2050, Level 3: 100% e-fuels in "non-bio"kerozene

Starting year: 2030 or after because of long fuel registration process

Navigation– Direct emissions mitigation logic & ambition levels

1 Navigation demand
[pkm] & [tkm]

Passenger navigation:
Inland Waterways passenger navigation is kept constant at 2010 level : 40 [Bpkm]
Freight navigation:
Situation in 2015 : 38% of EU freight modal share
2050, Level 0 : 38% of EU freight modal share
2050, Level 3 : 42% of EU freight modal share

2 Energy efficiency
[MJ/pkm] & [MJ/tkm]

Situation in 2015: 0,45 MJ/tkm for IWW* & 0,23 MJ/tkm for maritime
2050, Level 0: 5% improvement compared to 2015
2050, Level 3: 40% improvement compared to 2015

This includes technical/design & operational improvement

3 Electrification
[%]

Situation in 2015: 0%
2050, Level 0: 0% electrification
2050, Level 3: 30% of all SSS* and 15% of all LSS*

4 Biofuels
[% navigation gasoline]

Situation in 2015: 0%
2050, Level 0: 0% of navigation gasoline
2050, Level 3: 100% of navigation gasoline

5 E-fuels
[% of "non-bio" navigation gasoline]

Situation in 2015: 0%
2050, Level 0: 0% of navigation gasoline
2050, Level 3: 100% efuels in non-bio navigation gasoline

IWW: Inland Waterway ; SSS: Short Sea Shipping ; LSS: Long Sea Shipping

Decarbonizing freight shipping

Type of measures	Main measures	Decarbonization potential
Technological	Light materials	0-10% fuel saving
	slender design	10-15% fuel saving
	less friction	1-25% fuel saving
	waste heat recovery	0-4% fuel saving
	Others	4-15% fuel saving
Operational	Lower speed	0-60% CO_2 emissions reduction potential
	ship size	0-30% CO_2 emissions reduction potential
	ship-port interface	1% CO_2 emissions reduction potential
Alternative fuels/energy	Sustainable biofuels, hydrogen, ammonia, electric ships, wind assistance	0 – 100% CO_2 emissions reduction potential

Comment: Those potentials can't be added without considering the interactions between measures
Source: International Transport Forum (2018). Decarbonizing Maritime Transport – Pathways to zero-carbon shipping by 2035

Electrification of shipping: could reach around 10% in 2035 according to ITF (2018)

Infrastructure assumptions

Infrastructure development	Unit	Source	#/1000 veh
LDV - Number of private charging stations per BEV (residential or at workplace)	#/1000 veh	Fuelling Europes Future 2	1000
LDV - Number of public charging stations per BEV (in parkings)	#/1000 veh	Fuelling Europes Future 2	200
LDV - Number of fast charging stations per BEV	#/1000 veh	Fuelling Europes Future 2	3
LDV - Number of FCEV charging stations per FCEV	#/1000 veh	Fuelling Europes Future 2	1
HDV - Number of fast charging stations per BEV	#/1000 veh	Fuelling Europes Future 2	17
HDV - Number of depot station per BEV	#/1000 veh	Fuelling Europes Future 2	1000
HDV - Number of FCEV charging stations per FCEV	#/1000 veh	Fuelling Europes Future 2	2
HDV - km of e-highways per PH-ERS trucks	# km/1000 veh	Fuelling Europes Future 2	3

Content

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