2050 scenario analysis using the EU CTI 2050 Roadmap Tool

Documentation on costs assumptions

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Agenda

- Overall methodology
- Buildings sector
- Transport sector
- Industry sector
- Power sector
- AFOLU sector

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- **Overall methodology**
- Buildings sector
- Transport sector
- Industry sector
- Power sector
- AFOLU sector

What this model brings

- A solid modelling **approach which captures assumptions from a wide range of sources, supporting co-creation and transparency**.
- A model of **intermediate complexity to facilitate the evaluation of trade-offs and synergies** at sectoral, EU (and with EU Calc at country) level.
- **Strong cross-sectoral links** which allow to better understand the impact of e.g., innovation (autonomous vehicles), lifestyle levers or the circular economy
- Flexible enough to **replicate and compare existing pathways from other institutions**
- A web-version of the model which **allows users to explore the impacts arising from existing pathways or their own pathways.**

This study is focused on the development of low carbon scenarios, assessing their techno-economical implications

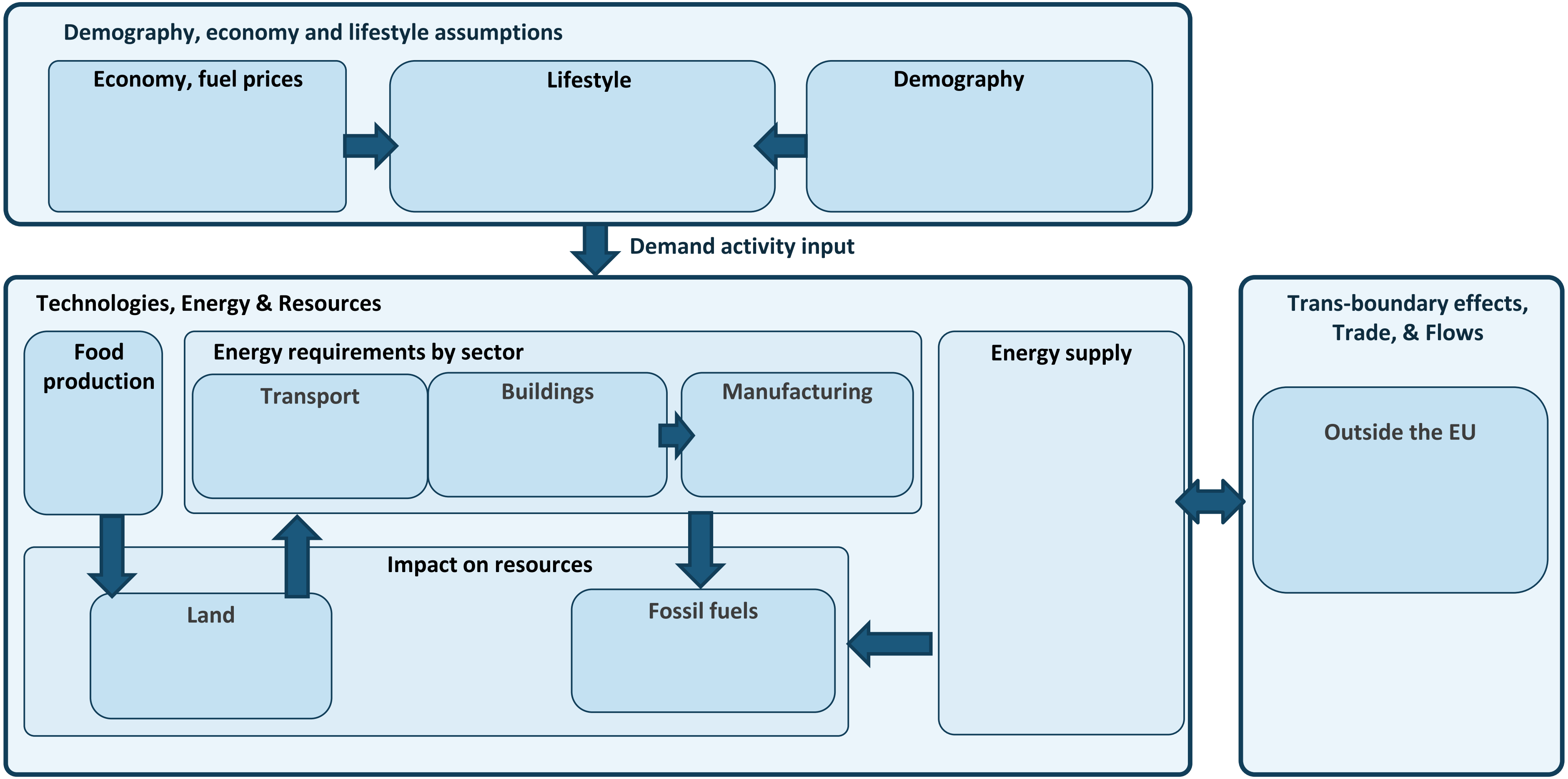
What it covers

- The development of low carbon scenarios based on realistic and transparent assumptions
- An open and dynamic model, with an online version to increase reach and use
- The engagement of a wide group of experts on sector findings
- The identification of the key decision points, and of timing implications
- A good view on the direct cost implications (capex/opex/fuels)

What it does NOT do

- Scenarios are not projections, and the launch of the model will not include the choice of an ideal scenario. A report is scheduled for September with a set of potential credible net-zero scenarios.
- The model does not optimize on costs, but does give a view on cost implications
- There is no macro-economic analysis, nor a view on social implications
- Co-benefits are not included, nor the economic impact of climate change

Structure of the ECF EU CTI 2050 Roadmap model



Demography, economy and lifestyle assumptions

Economy, fuel prices

Lifestyle

Demography

Demand activity input

Technologies, Energy & Resources

Food production

Energy requirements by sector

Transport

Buildings

Manufacturing

Energy supply

Impact on resources

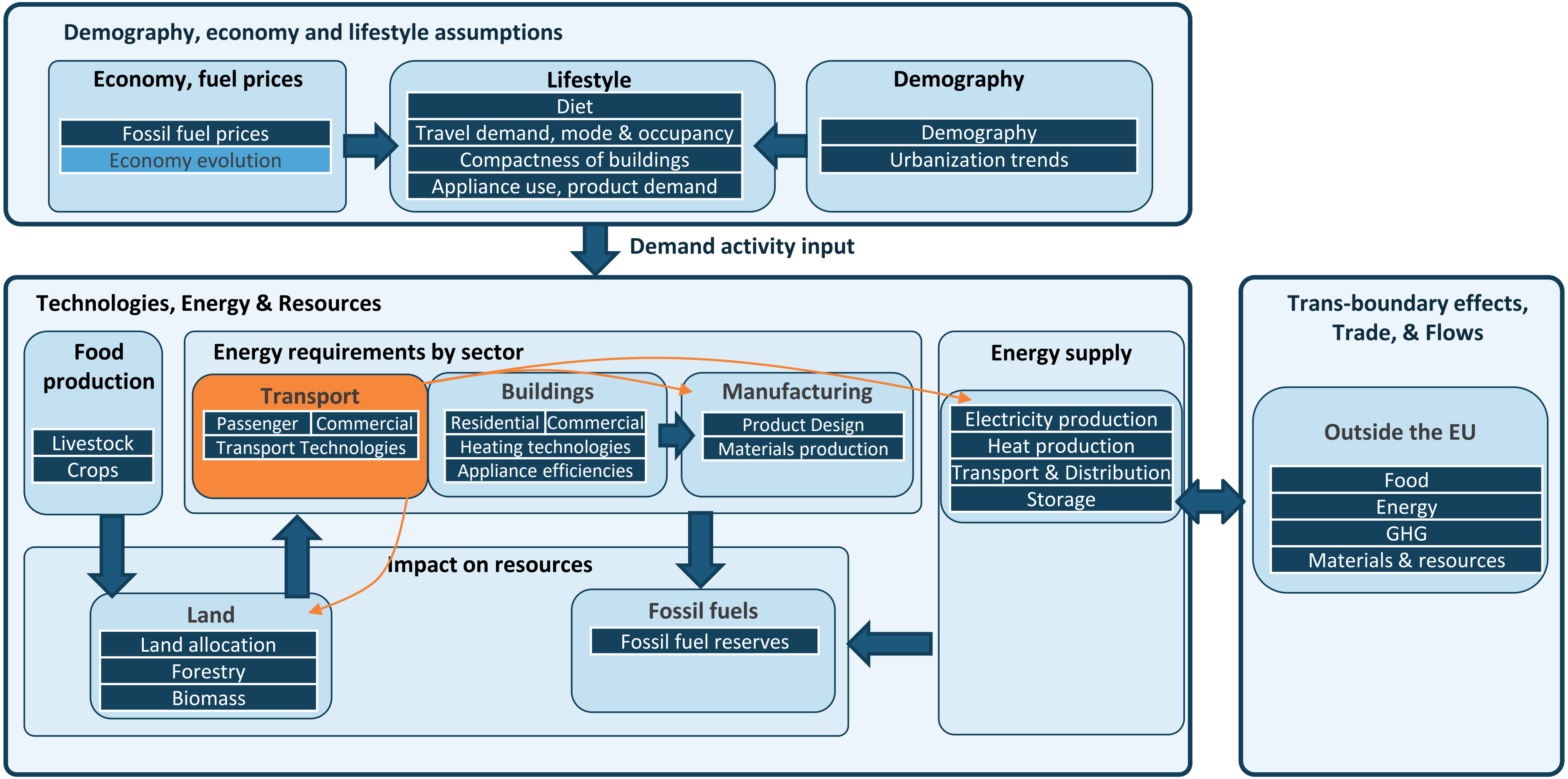
Land

Fossil fuels

Trans-boundary effects, Trade, & Flows

Outside the EU

Structure of the ECF EU CTI 2050 Roadmap model



Demography, economy and lifestyle assumptions

Economy, fuel prices
- Fossil fuel prices
- Economy evolution

Lifestyle
- Diet
- Travel demand, mode & occupancy
- Compactness of buildings
- Appliance use, product demand

Demography
- Demography
- Urbanization trends

Demand activity input

Technologies, Energy & Resources

Food production
- Livestock
- Crops

Energy requirements by sector

Transport
- Passenger | Commercial
- Transport Technologies

Buildings
- Residential | Commercial
- Heating technologies
- Appliance efficiencies

Manufacturing
- Product Design
- Materials production

Energy supply
- Electricity production
- Heat production
- Transport & Distribution
- Storage

Impact on resources

Land
- Land allocation
- Forestry
- Biomass

Fossil fuels
- Fossil fuel reserves

Trans-boundary effects, Trade, & Flows

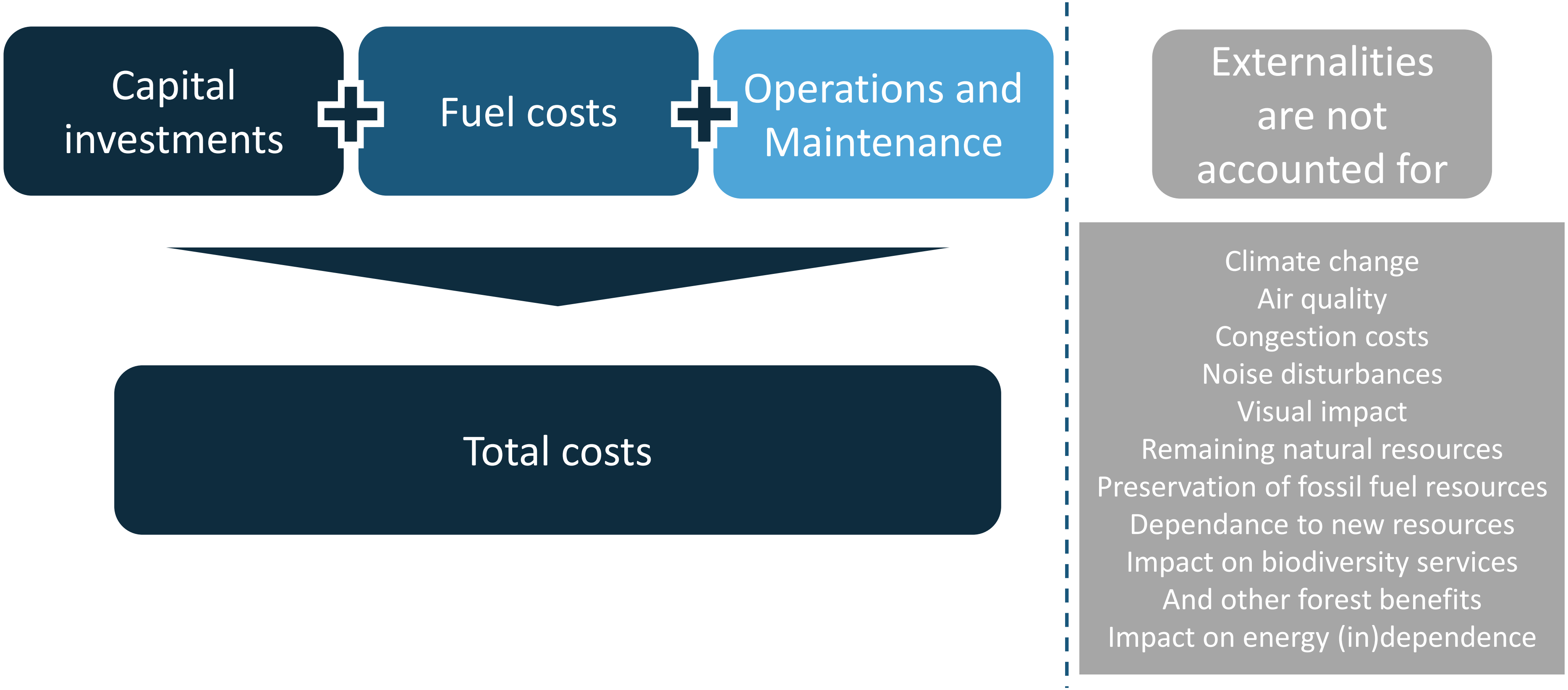
Outside the EU
- Food
- Energy
- GHG
- Materials & resources

4 ambition levels are used as boundaries to create scenarios

Level 0	Level 1	Level 2	Level 3
• **Current ambition**	• **Increased ambition**	• **Ambitious**	• **Transformational**
• Current legal measures, “BAU”	• More extensive use of existing technologies	• Significant effort based on high implementation of available technologies	• Max implementation requiring fast deployment and, in some cases, some type of innovation

Any value can be chosen in between

Structure of the cost modeling



Capital investments + Fuel costs + Operations and Maintenance

Total costs

Externalities are not accounted for

Climate change
Air quality
Congestion costs
Noise disturbances
Visual impact
Remaining natural resources
Preservation of fossil fuel resources
Dependance to new resources
Impact on biodiversity services
And other forest benefits
Impact on energy (in)dependence

And remember this is not accounting for the cost of all the externalities

				Not in the model
	Investments	**O&M**	**Fuels**	**Externalities**
Behaviour changes	n/a	- Maintenance based on technology distribution - Information campaigns, trainings,…	- Consumption volumes - Takes fuel shift into account - Taxes on fuels	- Impact of climate change - Air quality (cost on health and reduction in life expectancy) - Congestion costs (transport) - Reduction in noise disturbances (transport) - Visual impact (éoliennes) - Impact on required resources - Preservation of fossil fuel ressources - Dependance on new ressources - Impact on biodiversity services - Reduction/increase in nuclear risk - Impact of energy (in)dependence (reducing the impact of oil crises, etc.)
Energy efficiency	■ Refurbishing (insulation, windows, etc.) ■ Replacing heaters/boilers ■ Replacing electric appliances ▫ Improvements of appliances by manufacturers (R&D)			
Electrification	■ Replacing boilers			
Behaviour changes / evolution of the organization of society	■ Vehicles (cars, buses, trains, trucks, boats) ■ Rail infrastructure ▫ Costs related to the structure of the territory (for example a reduction in the cost of maintaining roads)	- Maintenance based on technology distribution - Information campaigns, trainings,…	- Consumption volumes - Takes fuel shift into account - Taxes on fuels	
Energy efficiency	■ Cost of the replacement of the fleet over time ■ Improvement of fleet efficiency by manufacturers (R&D)			
Electrification	■ Replacement by electric vehicles (batteries included) ■ Cost of the electric charging infrastructure			
Carbon intensity	■ Investments to improve carbon intensity (new products or processes, energy efficiency, cogeneration, etc.)	- Maintenance based on technology distribution	- Consumption volumes - Takes fuel shift into account -Funcioning of CCS	
CCS	■ Equipment to capture, transmit and store CO2 ▫ Cost of R&D of developing CCS			
Electricity	■ All production plants (wind or gaz turbines, etc.) ■ Electric transmission network, back-up plants ■ Distribution network (simplified approach) ■ Cost of CCS for electricity ▫ Cost of R&D for geothermal systems	- Maintenance based on technology distribution	- Biomass, fossil fuels and electricity imports - Cost of producing biomass	
Biomass	■ Biomass transformation plants			

■ Included

▫ Non-included

SOURCE: Climact

Potential impacts of non-action on the climate are not included in ‘business-as-usual’ scenarios

1) Cost of damages from climate change

- IPCC highlights the potential negative impacts linked to rising temperatures (such as increased damages from floods, water restriction, extreme heat events and wildfires)

2) Impact of climate change on economic growth

- OCDE highlights the potential negative impacts of climate changes on economic growth (such as productivity of various sectors, damages to capital, changes in demand for healthcare or energy)

Literature provides evaluation of the potential costs related to those impacts but uncertainties and methodological limitations still remain important

Potential co-benefits of climate action are also not covered

Evaluation of potential monetary impact

Air pollution

- Fossil fuel use is the main factor of air pollution and impacts public health
- Climate policy can enable **savings in air pollution policies and public health**

up to **~4% of GDP** (BE)(1)

Congestion and road accidents

- Growth of congestion and accidents impact **productivity of the overall economy**
- Climate policy is expected to encourage the shift to more collective transport

up to **~3 to 4% of GDP** (BE)(2)

Living environment

- Weak insulation and ventilation of homes has impact on **health and comfort of inhabitants**
- Climate policy is expected to accelerate the retrofit of large number of houses and buildings with higher standard of energy efficiency

up to **~1 to 2% of GDP** (EU)(3)

Healthy diet

- Unbalanced healthy diet is source of diseases (cardiovascular and cancer)
- Climate policy is expected to encourage a shift from animal proteins towards a mix of sustainably produced animal and vegetal proteins

up to **~6% of GDP** (UK)(4)

Sources: (1) OCDE (2014) – (2) van Hessen et al. (2011) + Christidis et al (2012) – (3) IEA (2014) – (4) Scarborough et al. (2012)

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- **Buildings sector**
  - **Scope of the cost assessment**
  - Cost assumptions
  - Illustrative results
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Costs covered, units and data sources

Lever category	Lever name	Units of CAPEX	Units of OPEX	Levers impacting cost results	Sources of data
Buildings envelope	New build	€/m²	-	Demography, household size, floor area req., demolition rate	Expert inputs
	Renovation (EE)	€/saved kWh	-	Renovation (rate, depth), demolition rate	Literature review[1]
Systems	Space heating	€/new kW	€/total kW	Demography and household size => # of installation Renovation (rate, depth) => size of installations Decarbonizing heat, Mix of technologies => type of installations	European Commission[2]
	Water heating	€/install.	€/kWh	Not included yet	Global calculator[3]
	Cooling	€/install.	€/kWh	Not included yet	Global calculator[3]
Appliances	Lighting, appliances, cooking	€/install.	€/kWh	Not included yet	Global calculator[3]

Assumption: similar specific costs are considered for residential and non-residential buildings

Notes:

(1) Including: Ecofys, Sia Partners, P. Sweatman, CLIMACT, OpenExp

(2) European Commission, 2016 - Mapping and analyses of the current and future heating-cooling fuel deployment

(3) Based on data from UCL-TIAM

Links between levers and costs

	Lever name	CAPEX	OPEX	FUELS
Compactness	Floor area requirements	New build	-	Energy consumption volume to cover heating and cooling demand
Buildings efficiency	Household size => # dwellings (Only for residential)	New H&C systems [€/kW]	H&C systems stock [€/kW]	Energy consumption mix to cover heating and cooling demand
	Depth of renovations	Investments in renovation [€/saved kWh]	-	
	Renovation rate	idem	-	
	Demolition rate	Impacts costs of new build	-	
Decarbonized Heat	Decarbonized Heat	New/replaced H&C systems [€/kW]	H&C systems stock [€/kW]	
Mix of technologies	Heat districts	DHC vs individual heating (source + network + substation)	DHC vs individual heating (based on large gas boiler)	0 for RES, covered in CAPEX & OPEX Cost of gas for non-RES
	RES-based individual heating			
	Heat pumps	HP vs other systems	HP vs other systems	Lower volume, electrification
	Bioenergy	Solid vs other systems	Solid vs other systems	Bioenergy vs other fuels
Appliances	Appliance utilization growth rate	Drives volume where €/savings applies	-	Electricity
	Appliance standards	Drives savings. Global invest: [€/kWh]	-	Electricity
	Cooking electrification	-	-	Electricity vs fossil-fuels

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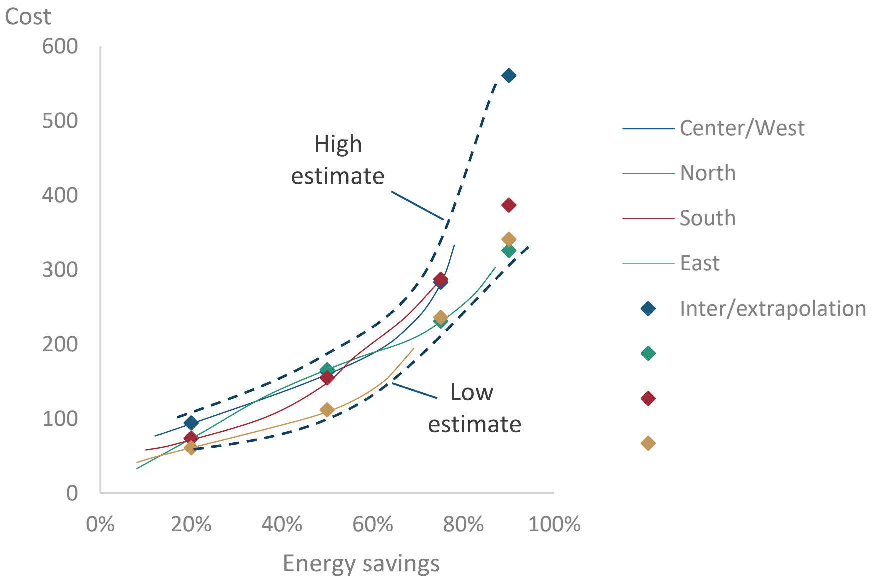
Costs assumptions: Investments in buildings energy efficiency are based on PRIMES

Buildings EE investment costs considered in PRIMES in function of the energy savings[1]
[€/m²]



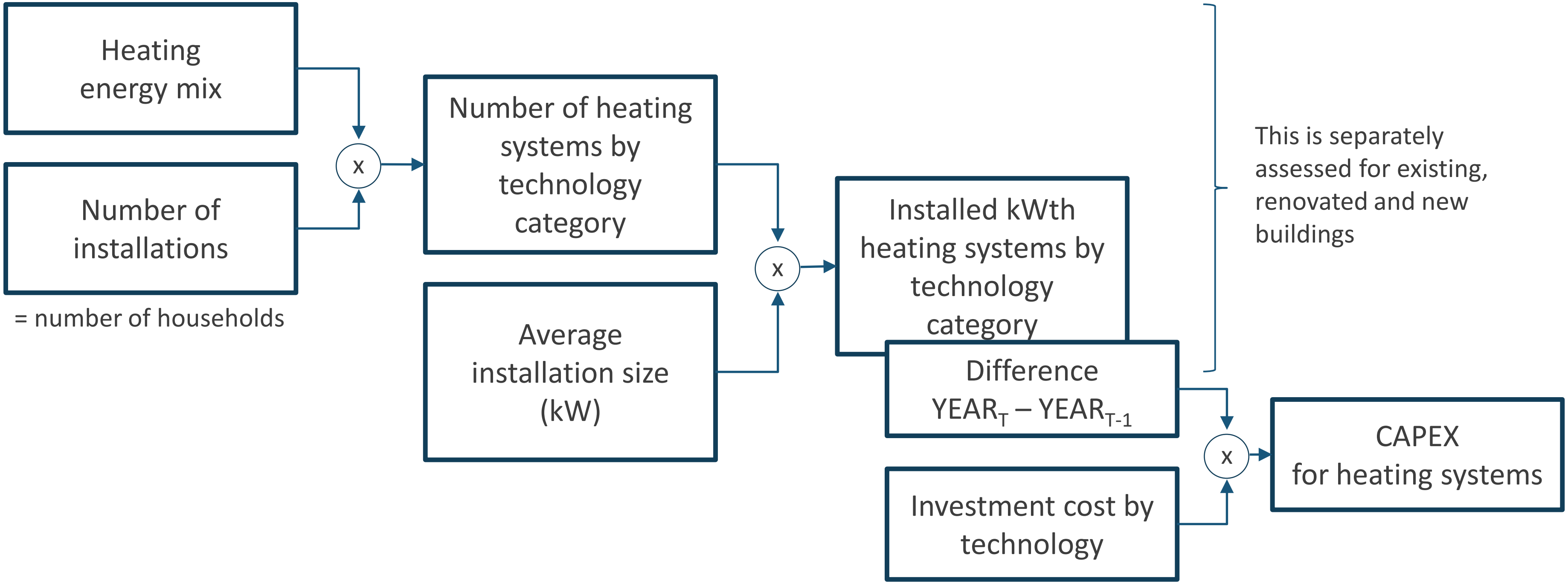
Deriving buildings EE investment costs considered in the CTI
[€/m²]

Average energy savings	Average cost €/m²	for a 90m² dwelling	for a 120 m² dwelling
20%	75	7k€	9k€
50%	150	14k€	18k€
75%	260	23k€	31k€
90%	400	36k€	48k€

Notes: (i) Similar costs are considered for residential and non-residential buildings. (ii) These are energy-related costs

(1) https://ec.europa.eu/energy/sites/ener/files/documents/2018_06_27_technology_pathways_-_finalreportmain2.pdf

Heating system CAPEX
are driven by the energy mix and the total system size



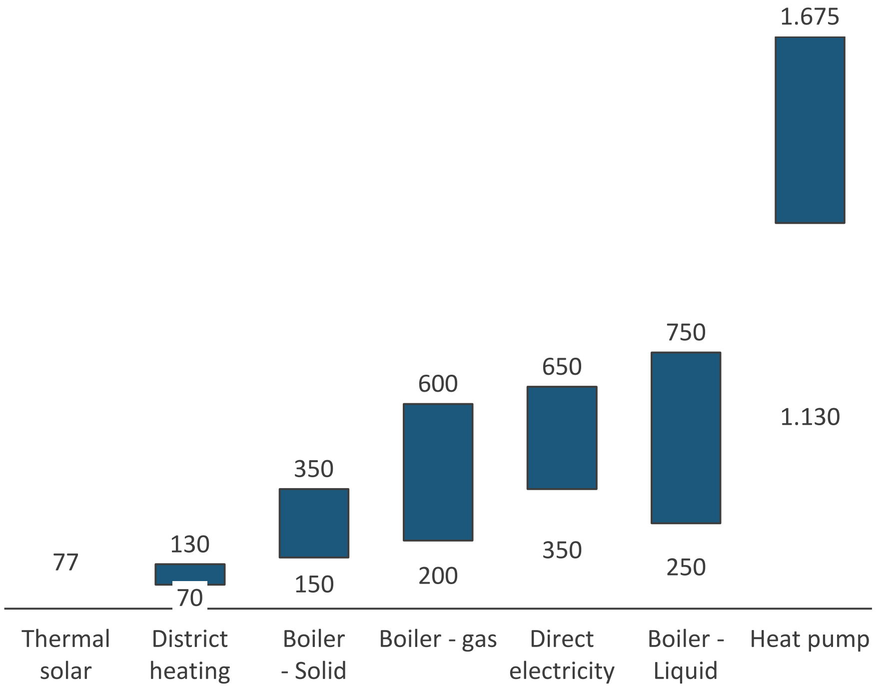
Main assumptions:

- The energy mix (% of energy) reflects the mix of systems (% of installations)
- Costs as a function of kW better allow to illustrate the cost of decarb. heat for different envelope EE levels
- The average installation size is proportional to the average consumption: in 2015, 10kWth for existing buildings, 8kWth for renovated buildings and 5kWth for new buildings

Space heating systems – CAPEX
Investment cost by technology

Space heating system CAPEX

[€/kWth, low and high estimates]

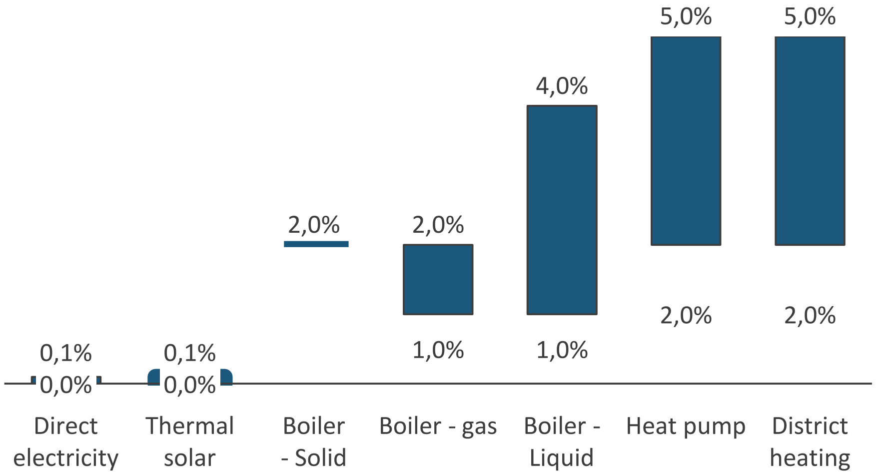


- Costs are expressed as a function of the installed (new/retrofit) heating power
- 10kW is considered for an average residential installation, and expressed as a function of the energy efficiency (i.e. the lower the heat demand, the lower the installed power)
- Data source:
  European Commission, 2016 - Mapping and analyses of the current and future heating-cooling fuel deployment
- 20% cost reduction by ’50 w.r.t. ’15
  are considered for district heating and heat pumps

Space heating systems - OPEX

Space heating system OPEX

[% of CAPEX, low and high estimates]



Data source:

- European Commission, 2016 - Mapping and analyses of the current and future heating-cooling fuel deployment
- Data to be identified for heat pump OPEX, now taken equal to district heating

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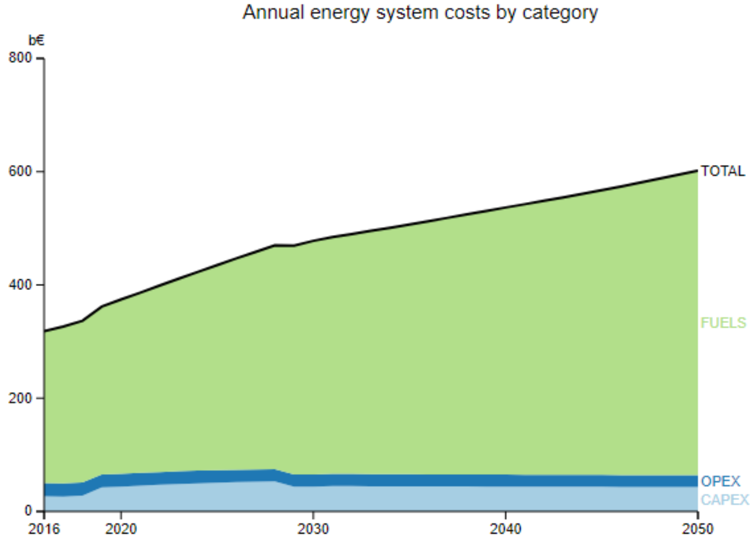
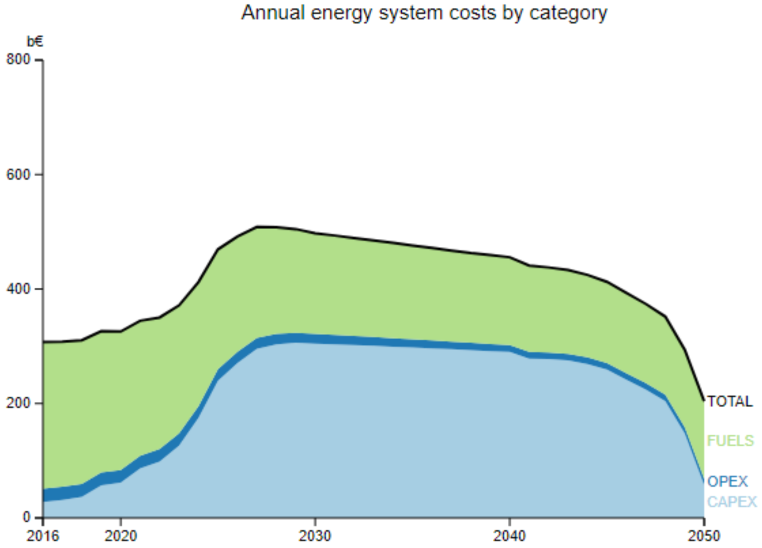
Illustrative results

Time evolution of costs in buildings
for selected scenarios [billion €]

EUREF16



**Net-zero ambition
(balanced scenario)**



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Scope of costs included in the model for transport

Type of costs	Cost unit	LDVs	2Ws	Buses	HDVs	Trains	Planes	Boats
CAPEX	*EUR/new vehicle*	v		v	v			
OPEX	*EUR/vkm or EUR/vehicle (buses)*	v		v	v			
FUELS	EUR/TWh	v	v	v	v	v	v	v
INFRASTRUCTURES CAPEX	EUR/unit	Only charging stations for BEV and FCEV		Only charging stations for BEV and FCEV + kilometers of e-highways				

Notes :

(1) CAPEX & OPEX for vehicles are differentiated by technology:
  - (a) LDVs : Liquid fuel, CNG, PHEV, FCEV, BEV
  - (b) Buses Liquid fuel, CNG, BEV
  - (c) HDV : Gasoline, diesel, CNG, PHEV or Trolley, FCEV, BEV with differentiation between light, medium or heavy HDV

(2) Categories of fuels taken into account : conventional liquid fuels, liquid bioenergy, gas, electricity, hydrogen

(3) No infrastructure OPEX is taken into account

Infrastructure development 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

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Average vehicle CAPEX

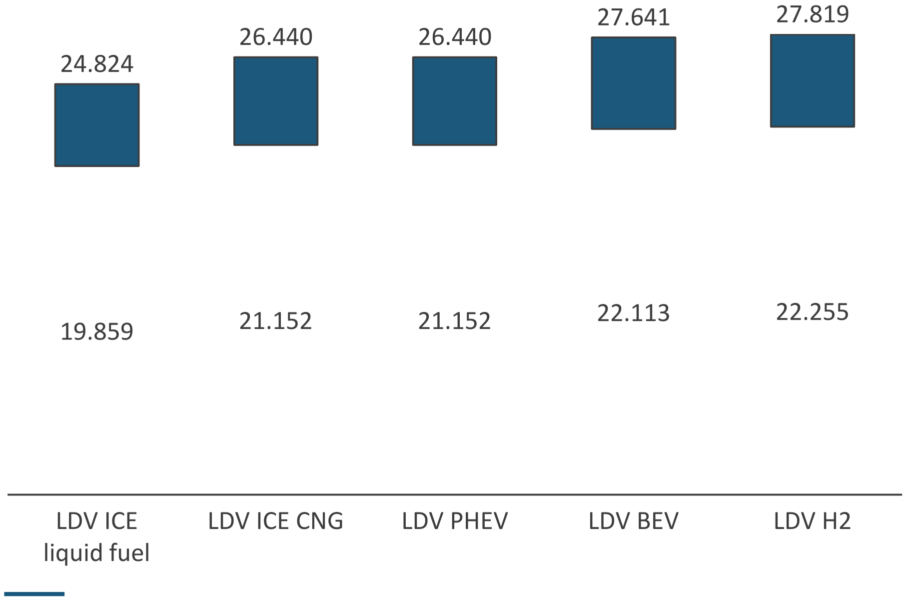
Type of cost	Type of vehicle	Units	2015	2050	Source & hypothesis
CAPEX	LDV ICE liquid fuel	*EUR/new vehicle*	25 300	24 824	Fueling Europe's Future (2018) - TECH Scenario for 2020, 2030, 2050 & interpolation in between Except for CNG : 2015 based on Global calc hypothesis and assumed to evolve ate the same rate than BEV
	LDV ICE CNG	*EUR/new vehicle*	28 083	26 440	
	LDV PHEV	*EUR/new vehicle*	27 989	26 440	
	LDV BEV	*EUR/new vehicle*	31 087	27 641	
	LDV H2	*EUR/new vehicle*	39 696	27 819	
	Bus ICE liquid fuel	*EUR/new vehicle*	232 000	227 633	2015 data is based on FCH (2015) data, then costs are assumed to evolve at the same rate than same technology for cars
	Bus ICE CNG	*EUR/new vehicle*	257 520	242 451	
	Bus PHEV	*EUR/new vehicle*	331 000	312 685	
	Bus BEV	*EUR/new vehicle*	285 058	253 459	
	Bus H2	*EUR/new vehicle*	700 000	490 555	
	HDV ICE liquid fuel	*EUR/new vehicle*	136 321	121 856	Based on an upcoming study on trucks (*confidential*) for 2025, 2030, 2040, 2050 & interpolation in between. Except for ICE trucks : based on Global Calc hypothesis Those are the costs of Medium & Heavy trucks, light trucks are assumed to have CAPEX 65% lower (assumption from Global Calc)
	HDV ICE CNG	*EUR/new vehicle*	152 802	139 948	
	HDV PHEV (trolley)	*EUR/new vehicle*	150 807	129 789	
	HDV PHEV	*EUR/new vehicle*	169 142	146 303	
	HDV BEV	*EUR/new vehicle*	214 293	147 324	
	HDV H2	*EUR/new vehicle*	186 887	139 340	

Vehicles : LDV - CAPEX

- High cost scenario = 120% of average cost
- Low cost scenario = 80% of average cost

LDV CAPEX in 2050

[€/vehicle, low and high estimates]

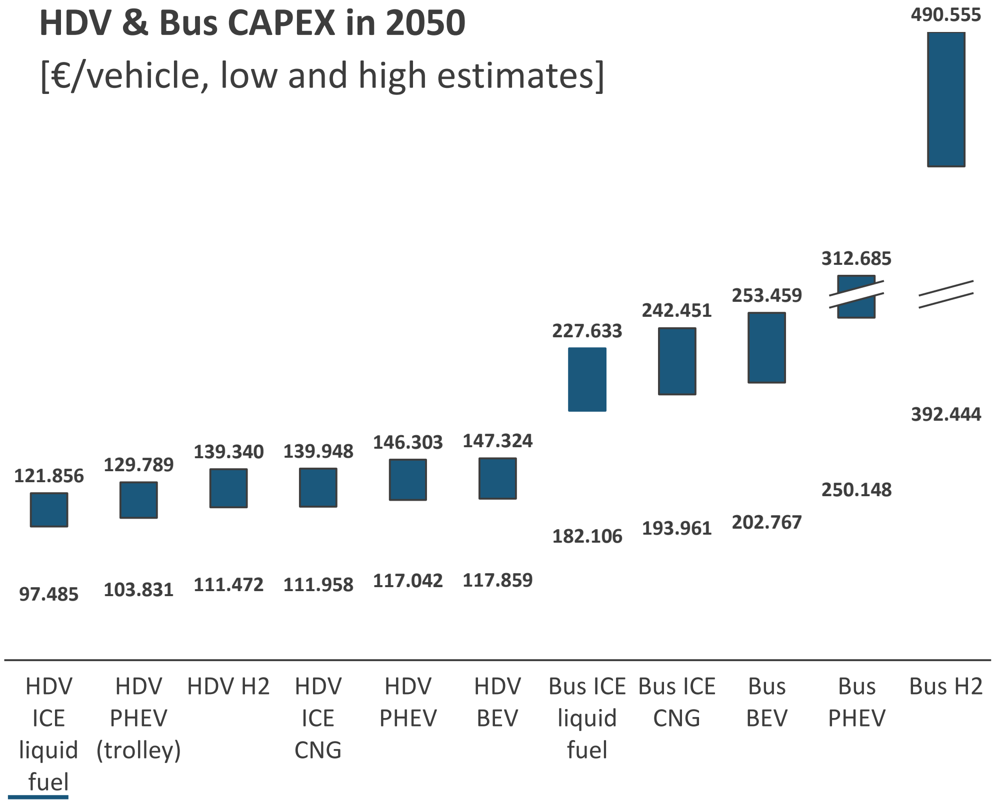


Vehicles : HDV & Bus – CAPEX

- High cost scenario = 120% of average cost
- Low cost scenario = 80% of average cost

HDV & Bus CAPEX in 2050

[€/vehicle, low and high estimates]



Average vehicle OPEX

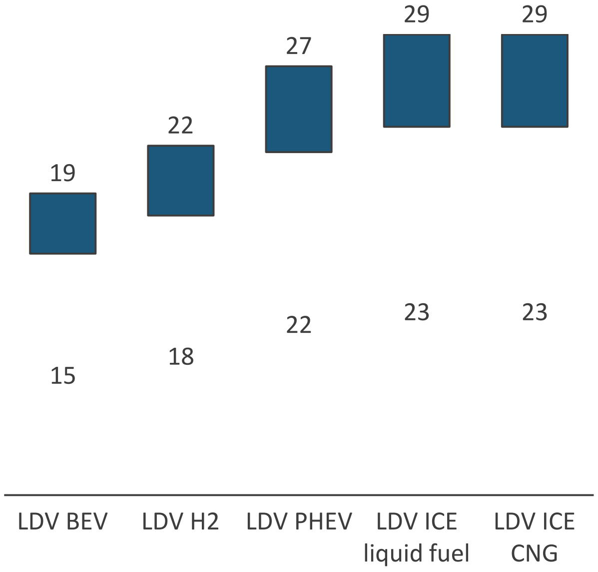
Type of cost	Type of vehicle	Units	2015	2050	Source & hypothesis
OPEX	LDV ICE liquid fuel	*EUR/km*	0,031	0,029	EESI (2015) for 2020, 2030 & 2050 & interpolation in between
	LDV ICE CNG	*EUR/km*	0,031	0,029	
	LDV PHEV	*EUR/km*	0,027	0,027	
	LDV BEV	*EUR/km*	0,021	0,019	
	LDV H2	*EUR/km*	0,026	0,022	
	Bus ICE liquid fuel	*EUR/vehicle/year*	5 021	4 810	Based on Global Calc assumption
	Bus ICE CNG	*EUR/vehicle/year*	5 585	4 981	
	Bus PHEV	*EUR/vehicle/year*	4 350	4 398	
	Bus BEV	*EUR/vehicle/year*	3 345	3 207	
	Bus H2	*EUR/vehicle/year*	14 907	3 315	
	HDV ICE liquid fuel	*EUR/km*	0,22	0,22	Based on ICCT (2017) assumptions
	HDV ICE CNG	*EUR/km*	0,22	0,22	
	HDV PHEV (trolley)	*EUR/km*	0,22	0,22	
	HDV PHEV	*EUR/km*	0,20	0,20	
	HDV BEV	*EUR/km*	0,20	0,20	
	HDV H2	*EUR/km*	0,20	0,20	

Vehicles : LDV & HDV - OPEX

- High cost scenario = 120% of average cost
- Low cost scenario = 80% of average cost

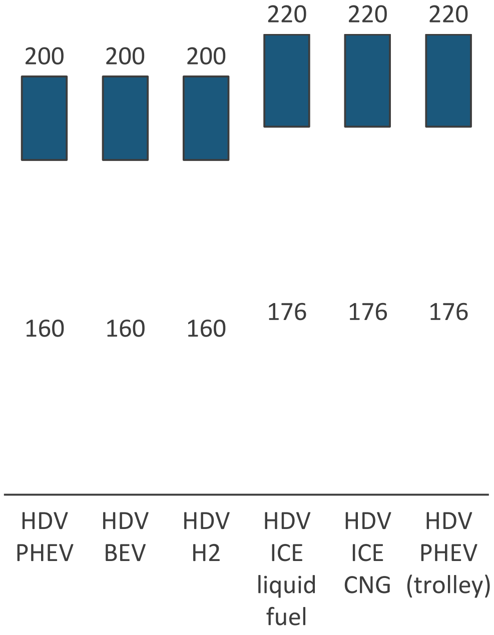
LDV OPEX in 2050

[€/1000 vkm, low and high estimates]



HDV OPEX in 2050

[€/1000 vkm, low and high estimates]

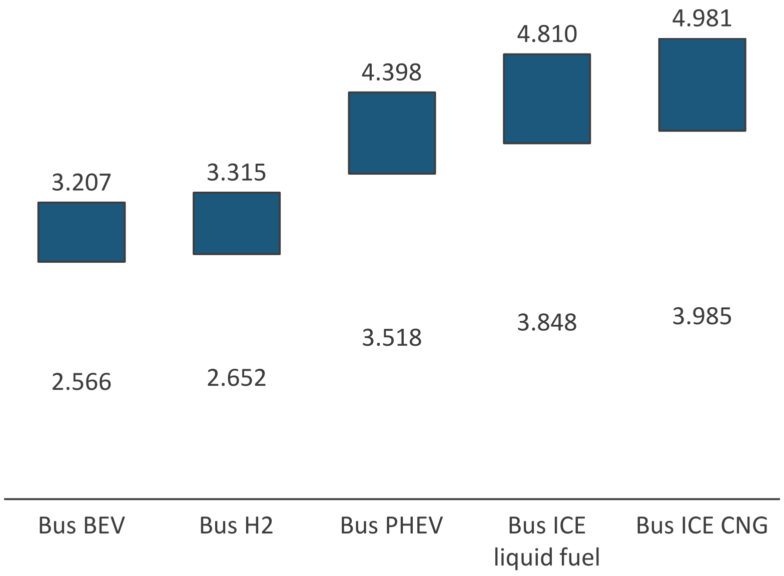


Vehicles : Bus- OPEX

- High cost scenario = 120% of average cost
- Low cost scenario = 80% of average cost

Bus OPEX in 2050

[€/vehicle, low and high estimates]



Average infrastructure CAPEX

Type of cost	Type	Units	2015	2050	Source & hypothesis
CAPEX	New km of e-highways	*EUR/km*	2 498 333	2 020 000	Based on Fueling Europe's Future (2018) - TECH Scenario, for LDVs infrastructures Truck infrastructure costs are based on an upcoming study on truck (*confidential*)
	New private charging stations - BEV LDV	*EUR/unit*	1 146	800	
	New public charging stations - BEV LDV	*EUR/unit*	7 669	6 400	
	New fast charging stations - BEV LDV	*EUR/unit*	67 923	46 000	
	New charging stations - FCEV LDV	*EUR/unit*	2 000 000	1 000 000	
	New charging stations - BEV HDV	*EUR/unit*	69 005	67 352	
	New depot stations - BEV HDV	*EUR/unit*	454 708	660 625	
	New charging stations - FCEV HDV	*EUR/unit*	1 611 548	1 386 108	

Infrastructure description :

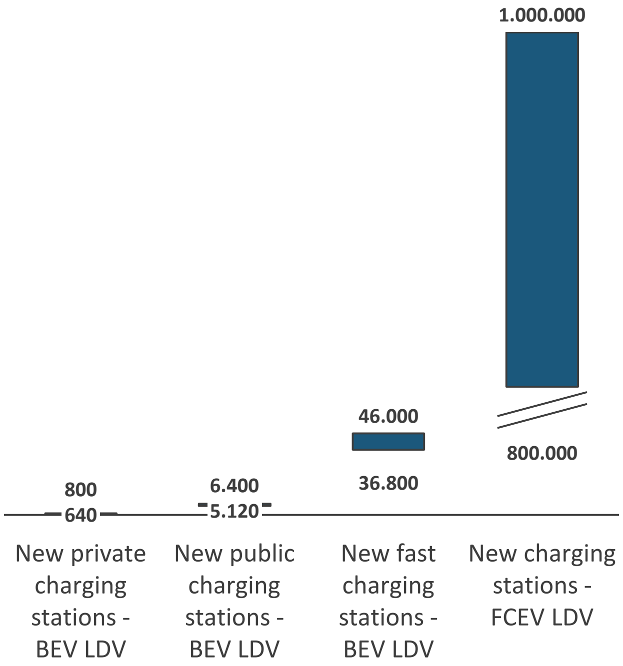
- Private / public & fast charging station for LDV : single charging point
- FCEV charging station for LDV : 500kg/day H2 charging station (can support 1 000 cars charging/day)
- Charging station for HDV : single charger
- Depot station for HDV : 8 or more chargers
- Charging station FCEV for HDV : 1 dispenser

Infrastructures - CAPEX

- High cost scenario = 120% of average cost
- Low cost scenario = 80% of average cost

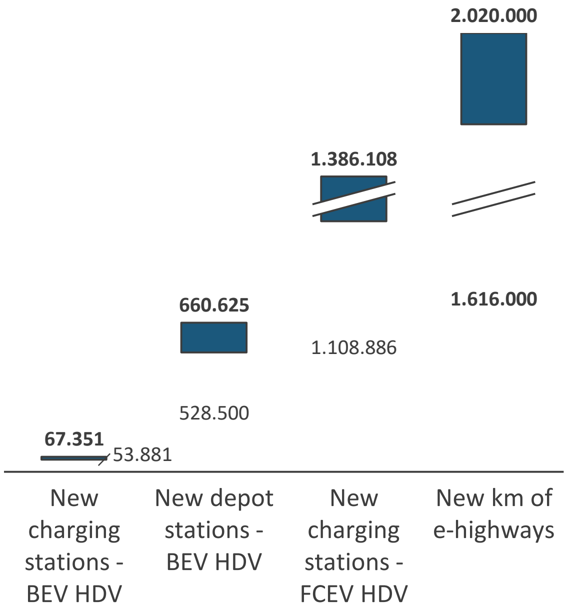
Infrastructure CAPEX in 2050 for LDVs

[€/unit, low and high estimates]



Infrastructure CAPEX in 2050 for HDVs

[€/unit, low and high estimates]



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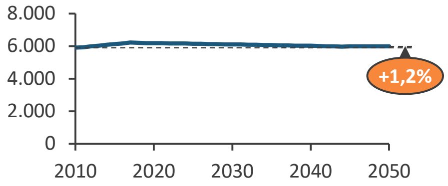
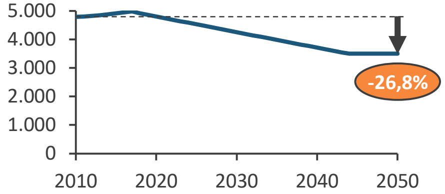
Impact of societal changes on the transport sector

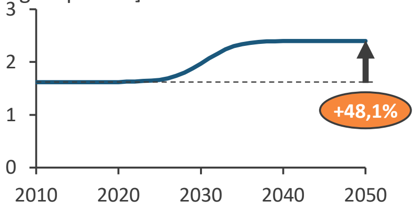
Total transport passenger demand
[Bn km.**passengers**]



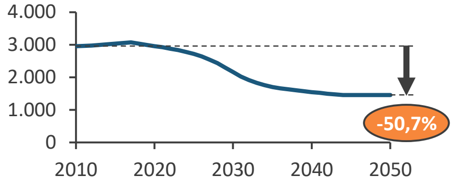
Share of LDVs in transport passenger demand
[Bn km.**passengers**]



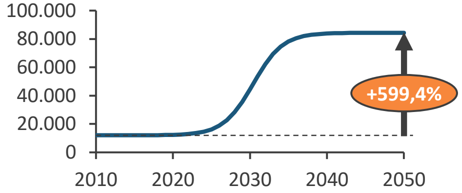
Evolution of LDV occupancy
[passengers per car]



Transport demand for LDVs
[Bn km.**vehicles**]

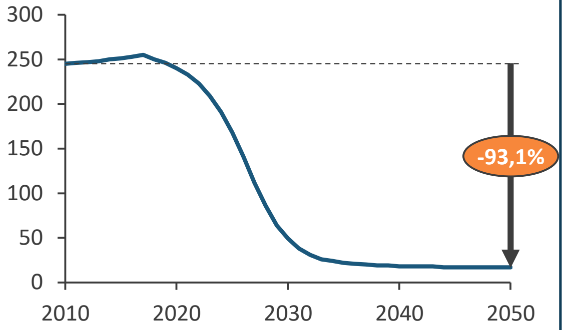


LDV utilization
[km per vehicle]

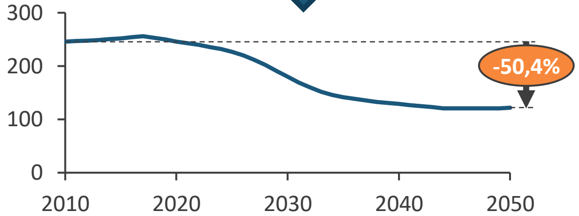


Assumptions in the balanced scenario

Number of private cars (LDVs)
[Mios of vehicles]



Compared to assuming utilization stays at 12000 km per LDV per year

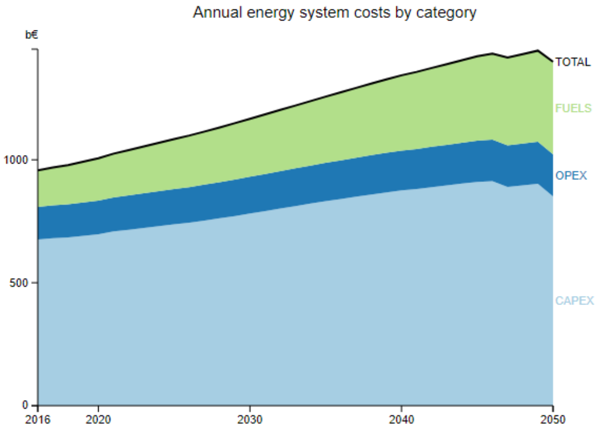


Illustrative costs results

Time evolution of costs in transport for selected scenarios [billion €]

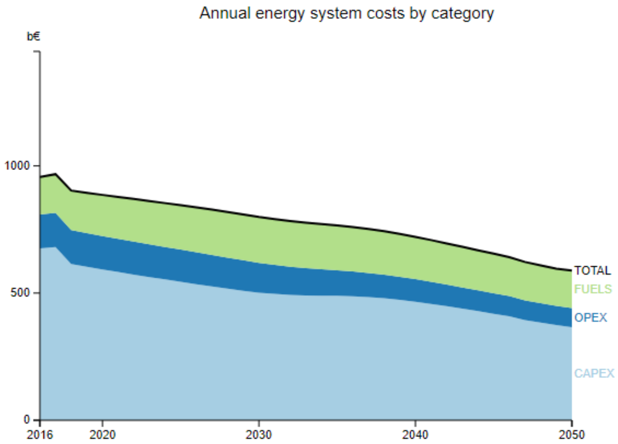
EUREF16

- in transport this is equal to all levers at level 0



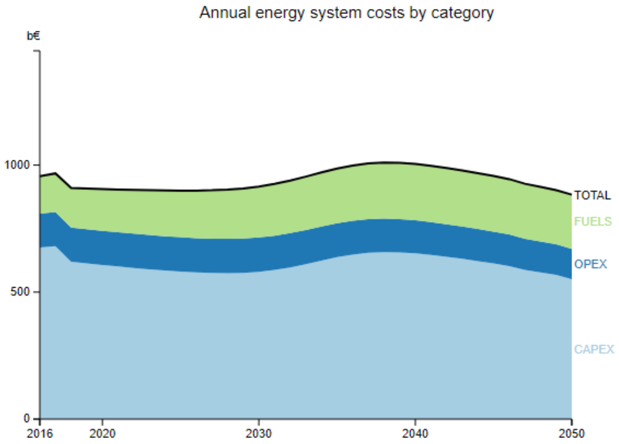
Net-zero - Balanced scenario

- Transport demand at level 2,4
- Utilization and occupancy at level 1,4



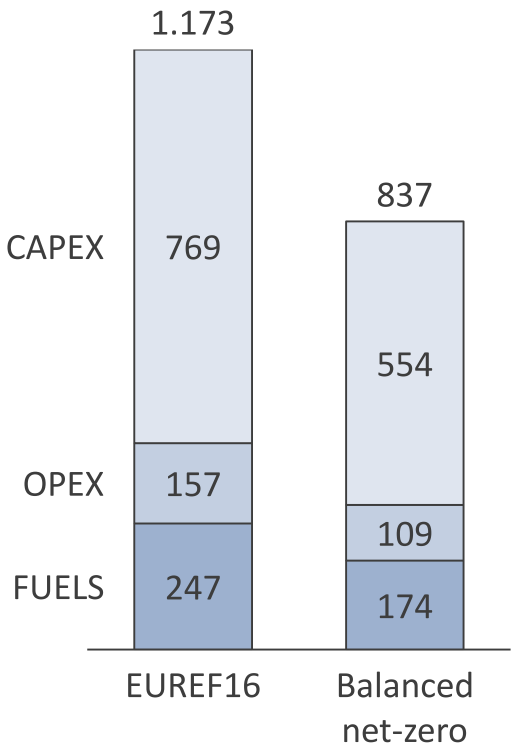
Net-zero - Balanced scenario but with

- Transport demand at level 0
- Utilization and occupancy at level 0

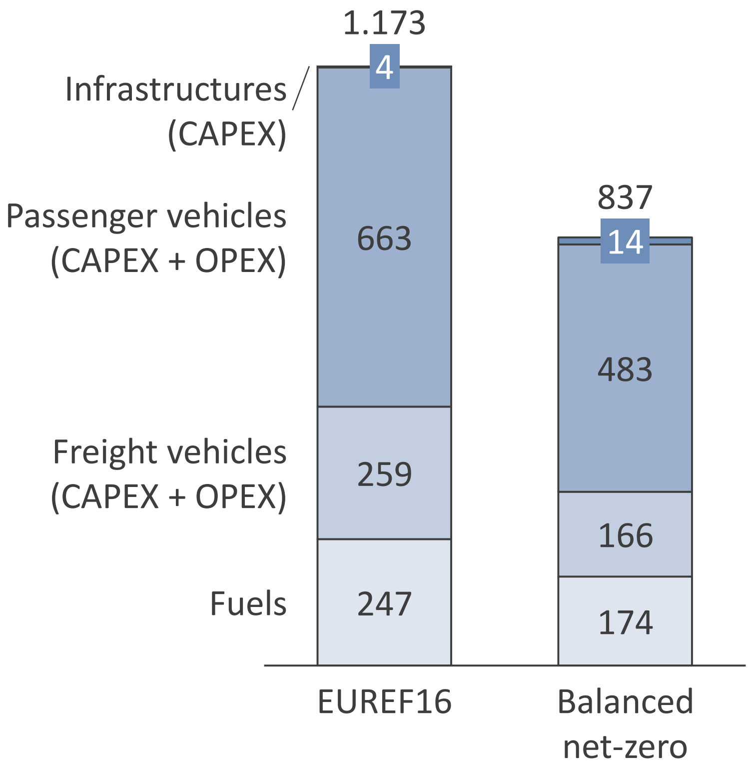


Illustrative results: Average annual undiscounted

Average annual expenditures by type
for selected scenarios [undiscounted b€]



Average annual expenditures by type
for selected scenarios [undiscounted b€]



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For industry, we only model energy system costs, these only cover part of the manufacturing costs

In scope	Out of scope
• Existing capacity costs (in current technology/process) • Part of the transition costs to another technology • Fuel costs • Maintenance costs	• R&D • Marketing • Opportunity costs • Part of the transition costs • Impact on costs at other stages of the supply chain (1)

NOTES: (1) e.g. Composed cement takes longer to dry and will therefore make some construction building processes longer

SOURCE: Climact analysis

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We assess the cost of the 8 levers of the manufacturing sector

Cost implications and modelling rationale per lever

Lever		Why it has a cost implication	How it is modelled	Sources
1	Reduce (reduce activity, increase lifetime, increase imports)	• These levers reduce product demand, therefore require less materials production (& related costs)	• Production capacity capex & opex are covered • Fuel costs to produce the required materials are covered. • The manufacturing from materials to products, the R&D and the overheads are not covered. • The opportunity cost related to what activities could have been enabled with the avoided/purchased product is not modelled	• Through the model • Capacity costs from literature or Climact assumptions
2	Material switch	• Using other materials for the same products changes the energy requirements to produce the materials	• The cost of manufacturing through another material is modelled (capacity, opex & fuel) • The design and manufacturing costs related to the transition are not modelled	• Through the model
3	Design	• The lever enables to manufacture the same products with less materials (& related production costs)	• The induced material production is covered • The R&D costs to manufacture with less materials, and the transition to the new manufacturing production line are not modelled	• Through the model
4	Recycle	• Manufacturing recycled materials instead of new materials requires less energy but requires a waste collection stream	• For steel, the cost of the recycled steel (through EAF or DRI) are specified • For chemicals, costs are independent of the recycling rates • For cement, recycling is modelled through the zero emission by products which has specified costs • The transition costs are not modelled (it is assumed that the revenues generated by the collection correspond to their costs)	• Through the model • Costs for recycled technologies are provided for steel, aluminium & paper
5	Process	• Changing processes requires investments and then changes the consumption profiles	• Process costs are obtained from literature when available, other process improvements are assessed as energy efficiency	• Capacity costs from literature
6	Energy efficiency	• Investments in energy efficiency enable to reduce the specific consumption	• Capex are assumed to have a 2-20 years payback compared to annual energy savings. The 2-20 years payback time is specified through a lever	• Climact estimate on average payback and link to capex
7	Fuel Switch	• Changing the fuel mix implies a different consumption profile	• Fuel costs are covered. • The transition costs are not modelled (capex & opex modifications)	• Through the model
8	CCS	• CCS requires to build & maintain infrastructures and implies an increased specific energy consumption	• Capex & opex costs are assessed per technology • An additional electricity consumption is modelled	• Costs from literature

SOURCE: Climact analysis

Due to lack of available data, energy efficiency investments are modelled based on energy consumption savings

BACKUP

Rationale

Ideal solution

- X€ for reducing by 1% the energy consumption of Y tons of materials Z

Current work around

- In a market based environment, industries only implement energy efficiency measures with a payback below 3-7 years
- The capex & opex can therefore be assumed in the order of 3-7 years of the energy savings
- The way this is assessed is detailed in an excel

Limitations

Market distortions are not modelled:

- Taxes (e.g. on fuels purchases)
- Supporting mechanisms (e.g. ETS & CDM)

Market distortions are important

- Several countries, including China have strong market distortions
- Distortions are most visible on upcoming critical technologies (e.g. PV) but are present in the materials assessed (steel, aluminum, paper, chemicals, cement, timber)

SOURCE: Climact analysis

The following sources are used to model the costs

	Reduce	Design	Recycle	Process	Fuel Switch	Energy efficiency	CCS
Steel	Eurofer capacity costs	Modelled as material reduction (R&D cost = recycling stream valuation)	Modelled as process change	Eurofer capacity costs	Modelled as fuel costs	Capex = 2-20 years payback on fuel savings	IEA ETP
Chemicals	Global Calculator	same	/	Global Calculator	same	Capex = 2-20 years payback on fuel savings	IEA ETP
Cement	Global Calculator	same	Modelled as process change	Global Calculator	same	Capex = 2-20 years payback on fuel savings	IEA ETP
Others	Climact	same	Modelled as process change	Global Calculator	same	Capex = 2-20 years payback on fuel savings	IEA ETP

SOURCE: Climact analysis

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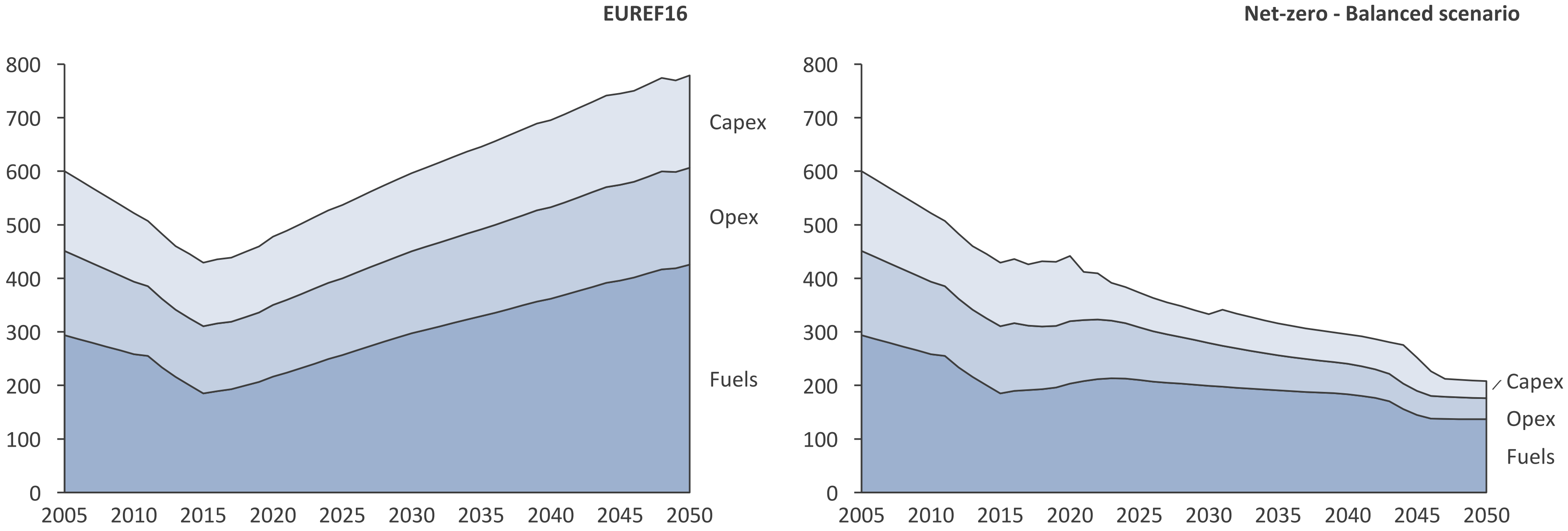
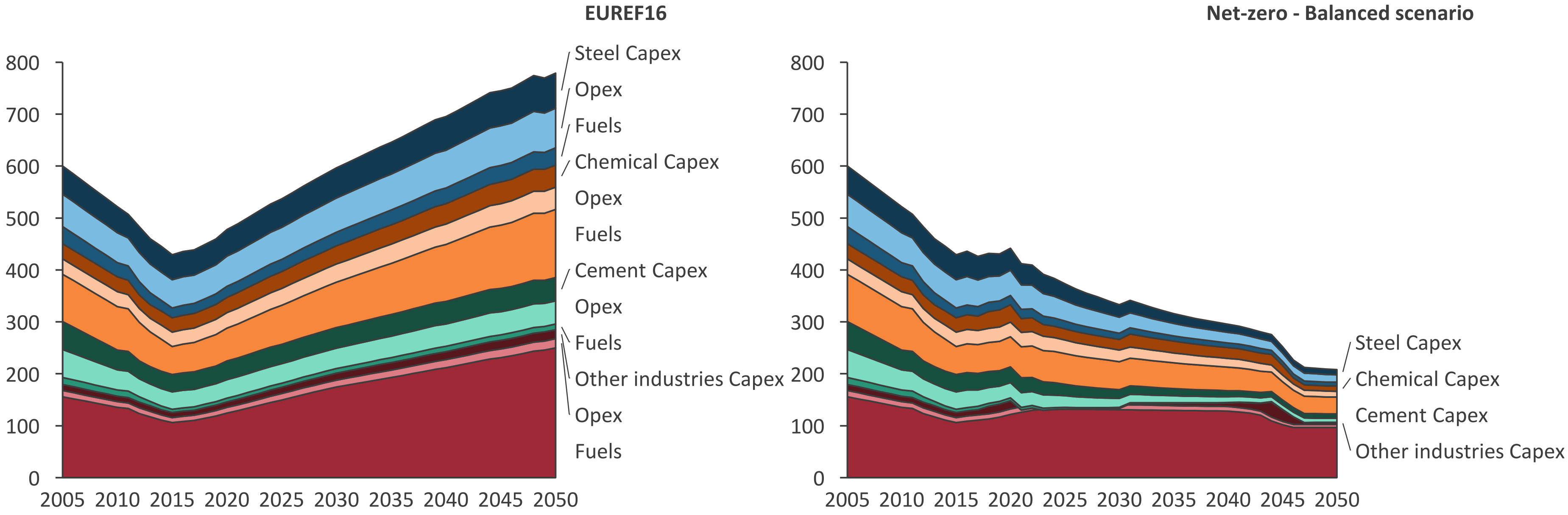
Illustrative results

Time evolution of costs in manufacturing for selected scenarios
[billion €]



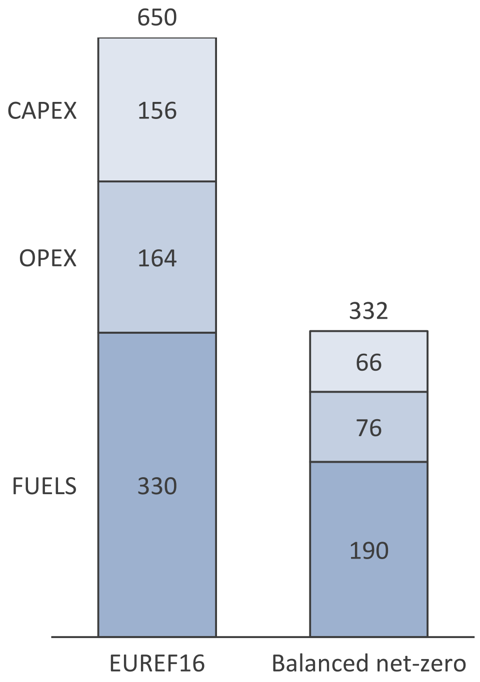
Illustrative results

Time evolution of costs in manufacturing for selected scenarios
[billion €]



Illustrative results: Average annual undiscounted

Average annual expenditures by type for selected scenarios
[undiscounted b€]



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Current levers defined in the EU CTI model

Lever name	Levers impacting cost results	Costs covered	Units	Sources of data
EU coal phase out(*)	• The capacity mix is based on the electricity demand from all sectors, based on user choices • The user than defines the contribution from coal, nuclear and RES options • Depending on the demand-supply balance, the capacity factor of gas, coal and nuclear can be affected, and even the capacity of coal (downward) and gas (upward)	Capex of all new capacity Opex of existing and new capacity Fuel costs of existing and new capacity	Capex in EUR/MW Opex in EUR/MW Fuel in EUR/MWh	Capex and Opex from WEO 2016 Fuel from ETP 2017, RTS, 2DS and B2DS scenarios as levels 0, 2 and 3
EU nuclear Context(*)				
EU vRES framework(*)				
Zero-carbon flexibility solutions				
Biomass and biogas contribution				
CCS				

Note: (*) Ambition level 1 for these levers correspond to current MS policies

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RES and nuclear cost assumptions

Renewables - regional details *Note: average figures at regional level*	Capital cost ($2015 per kW)				Annual O&M Costs ($2015 per kW)				Efficiency (gross, LHV)				Capacity factor (%)			
	2015	2020	2030	2040	2015	2020	2030	2040	2015	2020	2030	2040	2015	2020	2030	2040
Biomass Power plant																
Europe	2400	2350	2300	2250	85	80	80	80	35%	35%	35%	35%	60%	60%	60%	60%
Geothermal																
Europe	2900	2800	2700	2600	60	55	55	50	10%	10%	10%	10%	85%	85%	85%	85%
Hydropower - large-scale																
Europe	2650	2650	2650	2650	70	70	70	70	100%	100%	100%	100%	28%	28%	28%	28%
Hydropower - small-scale																
Europe	3900	3900	3900	3900	80	80	80	80	100%	100%	100%	100%	26%	26%	26%	26%
Solar photovoltaics - Large scale																
Europe	1320	1040	860	780	14	12	12	12	100%	100%	100%	100%	14%	14%	14%	15%
Solar photovoltaics - Buildings																
Europe	1600	1280	1080	980	16	16	14	14	100%	100%	100%	100%	12%	12%	13%	13%
Marine																
Europe	6950	6650	4650	3450	210	200	140	100	100%	100%	100%	100%	25%	25%	25%	25%
Wind onshore																
Europe	1840	1780	1720	1680	46	44	44	44	100%	100%	100%	100%	25%	26%	26%	26%
Wind offshore																
Europe	4600	3850	3200	2900	160	140	120	115	100%	100%	100%	100%	45%	46%	46%	46%

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	Capital costs ($2015 per kW)				Annual O&M Costs ($2015 per kW)				Efficiency (gross, LHV)			
	2015	**2020**	**2030**	**2040**	**2015**	**2020**	**2030**	**2040**	**2015**	**2020**	**2030**	**2040**
Nuclear												
Europe	6600	6000	5100	4500	170	165	165	165	33%	33%	33%	33%

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Gas, Coal, and CCS cost assumptions

	Capital costs ($2015 per kW)				Annual O&M Costs ($2015 per kW)				Efficiency (gross, LHV)			
	2015	2020	2030	2040	2015	2020	2030	2040	2015	2020	2030	2040
CCGT Europe	1000	1000	1000	1000	25	25	25	25	59%	59%	60%	61%
Gas turbine Europe	500	500	500	500	20	20	20	20	40%	40%	41%	42%

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	Capital costs ($2015 per kW)				Annual O&M Costs ($2015 per kW)				Efficiency (gross, LHV)			
	2015	2020	2030	2040	2015	2020	2030	2040	2015	2020	2030	2040
Steam Coal - SUBCRITICAL Europe	1700	1700	1700	1700	45	45	45	45	39%	39%	39%	39%
Steam Coal - SUPERCRITICAL Europe	2000	2000	2000	2000	60	60	60	60	43%	43%	43%	43%
Steam Coal - ULTRASUPERCRITICAL Europe	2200	2200	2200	2200	65	65	65	65	45%	46%	47%	48%
IGCC Europe	2500	2500	2350	2300	90	90	80	80	44%	45%	47%	50%

The average is used

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	Capital costs ($2015 per kW)				Annual O&M Costs ($2015 per kW)				Efficiency (gross, LHV)			
	2015	2020	2030	2040	2015	2020	2030	2040	2015	2020	2030	2040
Coal + CCS Europe	5500	5500	5000	4800	190	190	180	170	36%	37%	39%	40%
Oxyfuel + CCS Europe	5700	5700	5200	5000	200	200	180	180	36%	37%	39%	40%
IGCC + CCS Europe	5850	5850	5250	4950	210	210	190	180	36%	37%	40%	43%
CCGT + CCS Europe	3100	3100	2800	2650	100	100	90	80	52%	52%	53%	54%

The average is used

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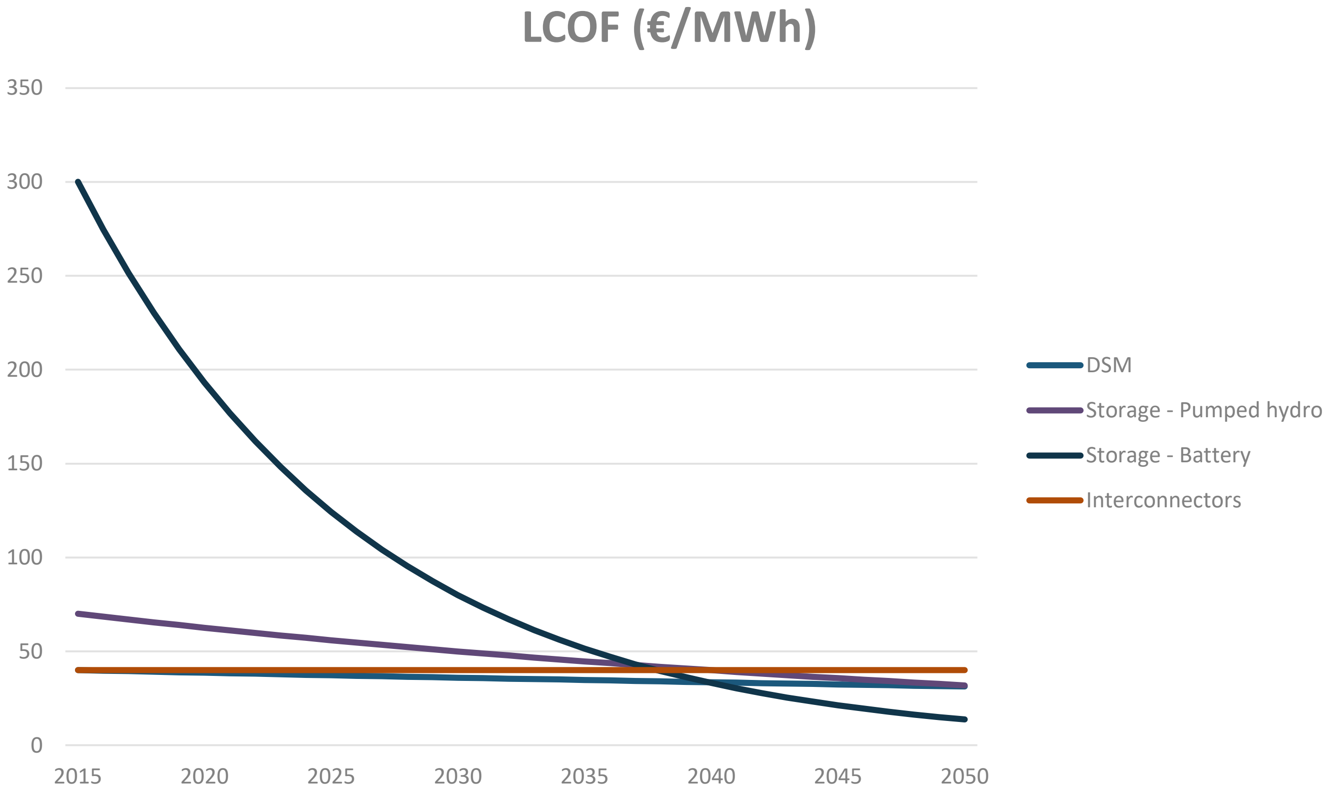
The cost of handling intermittency
is assessed based on the least cost of flexibility by flexibility option

LCOF (€/MWh)	IEA	Other literature	Level considered in the CTI
Flexible generation	5 – 10		Already accounted in the power production mix
Interconnections			40
- **Distribution grid**	1 – 10		
- **Transmission grid**	5 – 30		
Storage			
- **Hydro**	50 – 150	50 ('30) – 70 (today)	50
- **Li-Ion**	300 – 800	84 ('30) – 303 (today)	300
DSM			
- **Buildings heat**	10 – 40	40	40
- **e-Transport**		30	30
- **Industry**	60 – 75	40	40
H2 conversion		232 ('30) – 309 (today)	Accounted via the increased power production required

The cost of handling intermittency
is assessed based on the least cost of flexibility by flexibility option



Note: for storage, only the costs of pumped hydro is considered in the model

Fuel price assumptions

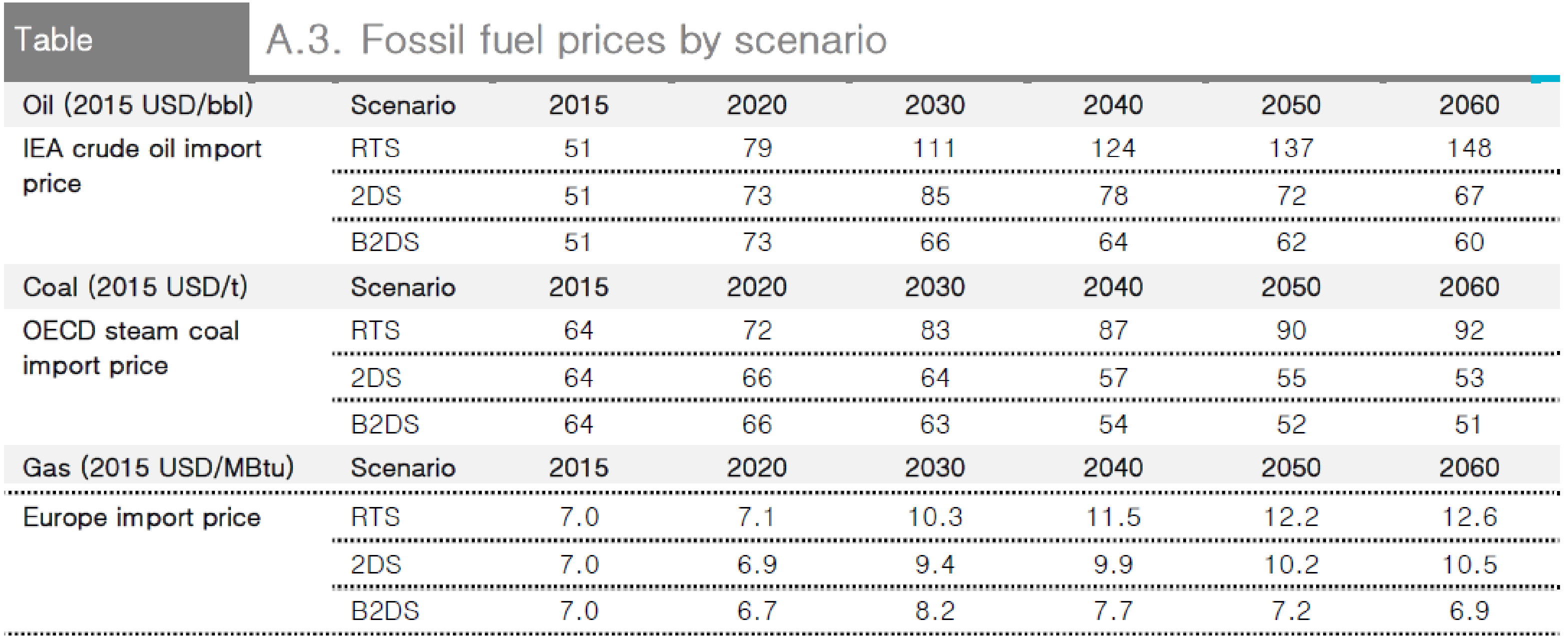


Table A.3. Fossil fuel prices by scenario

Oil (2015 USD/bbl)	Scenario	2015	2020	2030	2040	2050	2060
IEA crude oil import price	RTS	51	79	111	124	137	148
	2DS	51	73	85	78	72	67
	B2DS	51	73	66	64	62	60
Coal (2015 USD/t)	**Scenario**	**2015**	**2020**	**2030**	**2040**	**2050**	**2060**
OECD steam coal import price	RTS	64	72	83	87	90	92
	2DS	64	66	64	57	55	53
	B2DS	64	66	63	54	52	51
Gas (2015 USD/MBtu)	**Scenario**	**2015**	**2020**	**2030**	**2040**	**2050**	**2060**
Europe import price	RTS	7.0	7.1	10.3	11.5	12.2	12.6
	2DS	7.0	6.9	9.4	9.9	10.2	10.5
	B2DS	7.0	6.7	8.2	7.7	7.2	6.9

Source: IEA Energy Technology Perspectives 2017

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Only afforestation opex are modelled for AFOLU

Categories	Levers	Costs modelled
Diet Pattern	Food calories	
	Meat calories	-
	Meat Types	
Efficiency	Feedlot systems (cattle / sheep & goats)	
	Livestock conversion ratio	
	Animal density on pasture	
	Crops yields	-
	Waste - production	
	Waste/Residues - Collection	
	Bioenergy yields	
Land-use	Land Multi-use	-
	Bioenergy types	-
	Land Degradation	-
	Level of self-sufficiency in food & meat	-
	Land Surplus allocation	OPEX: 5000 € per ha of afforestation
	Use of dedicated bioenergy crops (yes/no)	-
	Reduce forestry intensity	-

1. Climact

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Afforestation is assume to cost 5k€/ha

Sources:

1. Land Life Company: https://www.landlifecompany.com/
2. Société Royale Forestière de Belgique http://www.srfb.be/
3. Zanchi et al., *Afforestation in Europe - Final Version*, EU FP6 research project MEACAP, WP4, Jan.2007

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Afforestation cost illustration