STRATEGIC PERSPECTIVES

CLIMACT

1st June 2023

FACTSHEETS on pathways to 2040

Rationale to explore the post-2030 emission reduction trajectories

Implementing the climate laws of the European Green Deal turns into the smartest economic and security choice. The findings of our "Turning the European Green Deal into Reality" report are clear: implementing the 2030 laws will reduce gas consumption by a third by 2030, deploy renewable energy 3.2 times faster than in the last 20 years and reduce energy bills for consumers by more than a quarter. **Reducing its fossil fuel dependence is also creating greater economic and geopolitical resilience as fossil fuels have contributed to high inflation in Europe.** The net-zero transition ensures affordable energy, which is a major competitive advantage for the European economy and citizens. The additional investments are estimated around 351 billion Euro by 2030, a significant proportion of which will come from carbon market revenues. It will deliver significant savings on gas and oil import bills for the European Union.

Acceleration of the energy transition has become the strategic response to both pandemic and the Russian war. The growing competition between the US and China for leadership in zero carbon technology manufacturing point to their alignment in seeing the economic, geopolitical and security advantages of decarbonising their economies. **The European Union can choose for a path that builds on an open single market with clear standards, on diversified supply chains and a reinvigorated domestic industry.** It is in Europe's interest to create a framework and new economic partnerships that incentivise other economies to decarbonise as well.

Agreeing the post- 2030 climate targets provides additional predictability to businesses and financial actors about the smart investment choices and areas that need further innovation. **Strategic Perspectives recommends agreeing the 2035 and 2040 climate targets already in the first half of 2024 as they can then be instrumental to guide the mandate of the next European Commission.** The Commission will be able to factor them in when proposing a new financial architecture, including the next Multiannual Financial Framework (MFF), as well as the legislative framework to implement the 2040 targets across the economy.

The recent scale and speed of energy efficiency gains, zero-carbon technologies manufacturing and renewable energy deployment turn into the new norm also beyond 2030. The anticipated transformation through electrification, circular economy and modernising European industry has a longer economic cycle though. **Planning for the net zero transition beyond 2030 is the natural next step and provides the necessary clarity on the milestones towards achieving climate neutrality at the latest by 2050.**

The analysis on the next pages has been undertaken by Climact and Strategic Perspectives. Climact provided the modelling on the trajectories towards 2040 with the Pathways Explorer, an open-source energy simulation model.

Overview of trajectories to 2035 and to 2040

Climact has modelled -85%, -90% and -95% net emission reduction scenarios for 2040 and deducted a net-target for 2035 for each of them. **Strategic Perspectives considers the -90% scenario a feasible pathway that provides a strong effort of the European Union in the global effort to fight climate change.** This scenario would require the EU to maintain the same pace of decarbonisation after 2030. This acceleration is realistic as the EU already has many sectors with decarbonisation paths beyond 2030, which is a strong asset for the next steps. This scenario maximises the electrification potential across sectors, sets clear phase out milestones for gas consumption and endorses circularity. It relies on technological innovation driven through policies while keeping a conservative approach on societal choices.

Based on the modelling and analysis, Strategic Perspectives will publish a full report on the priorities for the next European Commission mandate (2024-2029) in July. The results and conclusions derived in the upcoming report are those of Strategic Perspectives and do not necessarily represent those of Climact or the organisations that supported this research.

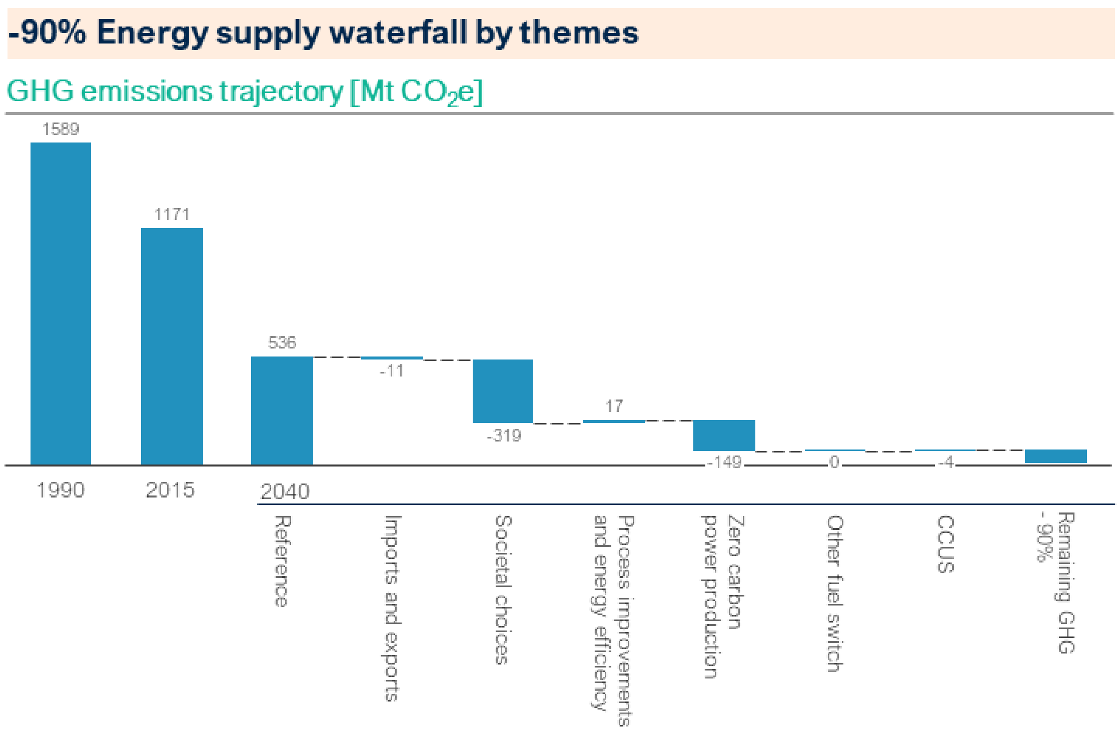
Scenario	Unit	Net emissions 2040	Excluding			Milestone 2035
				Removals		
		Base scope[1]	International bunkers	Natural sinks	Tech.[3]	Base scope[2]
-95% net	**%**	**-95.5%**	**-96.9%**	**-85.7%**	**-84.9%**	**-82.2%**
	Mt CO2e	210.4	97.3	-471.0	-35.51	843.17
-90% net	**%**	**-90.2%**	**-92.8%**	**-81.8%**	**-80.6%**	**-79.2%**
	Mt CO2e	462.5	155.4	-412.5	-61.35	1031.78
-85% net	**%**	**-85.4%**	**-88.3%**	**-78.2%**	**-77.0%**	**-73.2%**
	Mt CO2e	690.9	176.3	-369.3	-59.37	1270.14

[1] Percent reductions are expressed in 2040 vs 1990, on the net GHG emissions
The net includes removals (both natural sinks and technical removals) and international bunkers
The international bunkers include an approximation of the allocable emissions from international aviation & maritime, based on a departure-based logic.
1990 baseline is 4727 Mt net, 4940 Mt excluding natural sinks, and 4940 Mt excluding all sinks
[2] Includes biogenic CO2 from the upgrade of biogas to biomethane (assuming 60% of biogas upgrade to biomethane for scenario -95% (27.6Mt), 50% for scenario -90%(23Mt) and 40% for scenario -85%(18.4Mt) □ Not modelled in the online webtool
[3] The indicative target for 2035 is extracted as an intermediary point of the respective emission trajectories

Overview of energy trajectory to 2040

Key findings

- Demand reduction and energy efficiency are the most impactful measures to reduce emissions in the energy sector and limit additional energy needs. A high degree of electrification across sectors leads to an overall increase in electricity demand. Only through adding zero-carbon energy can the decarbonisation of sectors succeed.
- The installed capacity of solar photovoltaics and wind energy is envisaged to be nearly multiplied by a factor of 7 between 2020 and 2040, keeping almost trend as the deployment required for the 2030 renewable target. This rate allows for a full decarbonisation of the power sector as of 2035 in line with the G7 pledges and capping the use of biomass for power at current levels.
- A key task for policymakers remains to design an orderly phase down of coal and gas use with just transition efforts. While the carbon market will reduce fossil fuel use for power substantially, accompanying measures are needed to secure job prospects for the workforce.
- The main applications for green hydrogen are ammonia, steel and e-fuel production (for maritime and aviation sectors). The decarbonisation of the international transport sectors requires the biggest amount of hydrogen in 2040. The associate electricity demand is equivalent to 14% of total electricity demand in the -90% scenario.
- Careful policy choices are necessary between Carbon Capture and Storage (CCS) and e-fuels production to avoid incentivizing CO2 capture when other decarbonisation routes are preferable. Direct Air Capture (DAC) is considered too energy-intensive and expensive until 2040 and thus plays an insignificant role in the present analysis.



Key assumptions for the energy supply sector

Evolution to 2040		2019	-95%	-90%	-85%
Electricity demand		2.65 TWh	3.82 TWh	3.74 TWh	3.84 TWh
Phase-out Gas (excl. CHP)		123.38 GW	0% by 2034	0% by 2037	Out by 2040
Phase-out Coal		116.54 GW	Out by 2030[1]	Out by 2030[1]	Out by 2030[1]
CCS in electricity generation		None	None	None	None
Nuclear evolution		117.66 GW	Capacity decreases by 10% by 2040	Capacity decreases by 10% by 2040	Capacity decreases by 10% by 2040
Solar PV		85.15 GW	Increase to 1060 GW	Increase to 862 GW	Increase to 862 GW
Wind	On shore capacity	121.35 GW	Expand to 652 GW	Expand to 571 GW	Expand to 571 GW
	Off-shore capacity	5.9 GW	Expand to 195 GW	Expand to 195 GW	Expand to 195 GW
Phase-out of Biomass (by 2050)		6.53 GW	67.7% decrease to 2.11 GW	67.7% decrease to 2.11 GW	67.7% decrease to 2.11 GW

Main differences between the scenarios[4]:

- More ambitious assumptions on societal choices and energy efficiency lead to a smaller but more electric energy demand in the more ambitious scenarios. This allows a faster phase-out of fossil fuels, increasing the EU's energy independence. Lower energy demand also allows to limit the need for additional renewables capacities, reducing pressure on costs, resources and additional planetary boundaries.
- More ambitious scenarios accelerate the decarbonisation of sectors (aviation, maritime,…) relying on synthetic fuels (H2, e-fuels, NH3 …) to decarbonize, leading to additional needs in terms of renewable power production.

[4] Limitations and comments on the model

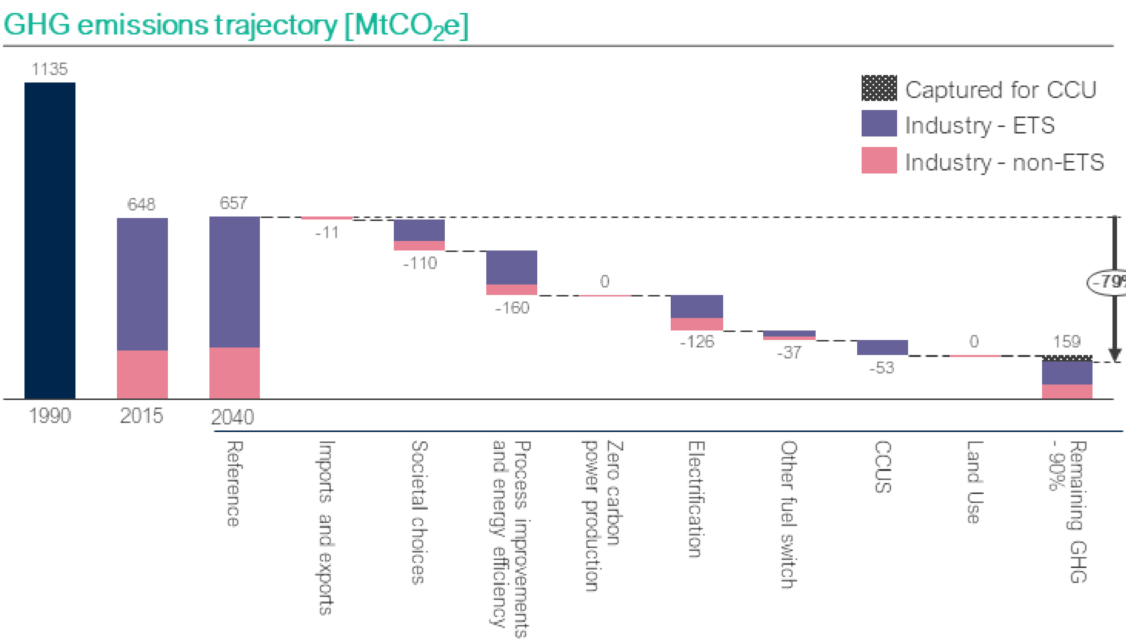
- The time resolution of the model is 1 year, with a set of simplified assumptions to model the intermittency, flexibility, and back-up narrative. The model is mainly oriented towards ensuring sufficient base load energy production to meet demand for every 1 year step.
- Storage of electricity and thermal heat is not modelled.
- The pathways cannot be considered cost-optimal solutions and figures are not the results of a cost-optimization of the energy sector. They reflect a set of assumptions taken by Strategic Perspective in order to meet the demand in energy.
- Impacts on minerals, water and air pollution have not been modelled in this exercise. Further developments of the model will allow such analysis in the course of this year.
- At this stage, only scope 1 emissions are modelled in the scenarios. Integrating scope 2 and 3 emissions will be possible later this year.

Overview of industry trajectory to 2040

Key findings

- Emissions in the industry sector can be substantially reduced by using raw materials with efficiency and promoting circularity. Lowering material production can reduce emissions by 20%. In addition, material efficiency (less cement for the same building, lighter cars, etc.), material longevity (reuse and repair) and switching to sustainable alternatives (clay instead of cement, wood instead of steel) are key measures to be implemented.
- Increase in recycling completes the industrial circularity and allows for an additional 25% of emissions reduction, thus resulting in almost 50% emissions reductions through the "reduce-reuse-recycle" scheme. A potential driver is to switch from an economy of goods to an economy of services as it incentivises companies to produce long-lasting and reparable products to the benefit of consumers.
- Indirect and direct electrification of industrial processes is key and enables the industry to reach an additional 25% emissions reduction. Low- and mid-temperature heat demand can promptly be supplied by heat pumps (i.e. for the food industry), so can some high temperature demand via electric heating (i.e. glass). When direct electrification is not possible, green hydrogen and low-carbon technologies can be deployed (i.e. for steel, green ammonia).
- Alternative fuels will likely be used for feedstock production and limited for energy supply. Decarbonisation through bio and e-fuel energy switches is prioritised for feedstock production (i.e. plastic) and this substitution allows to compensate downstream emissions in waste treatment.
- Carbon capture is only applied to the remaining process emissions, sequestering 56 million tonnes and utilising 35 million tonnes for e-fuel production (i.e. for maritime and aviation). The necessary infrastructure can already be planned now. The narrow application of carbon capture ensures that the main efforts and investments go into emission reductions.

-90% Industry waterfall by themes



Key assumptions for the industry sector

Evolution to 2040			2019	-95%	-90%	-85%
Production level*	Steel		150 Mt	-17%	-17%	-15%
	Aluminium		5Mt	maintained	maintained	+2%
	Cement		173 Mt	-25%	-22%	-17%
	Chemicals olefin & ammonia		80Mt & 47Mt	-28%	-28%	-25%
Secondary share	Steel		41%	76%	68%	60%
	Aluminium		46%	81%	75.4%	72.4%
	Cement non-clinker		25%	39%	36%	34%
	Chemicals olefin		6%	47%	41%	35%
Technology and fuels	Primary steel	H2-DRI	0%	82%	65%	54%
		BF-BOF	100%	18%	35%	46%
	Industry electrification (excl. feedstock)		32%	75%	63%	57%
Carbon Capture	2030		0MtCO2	18Mt	18Mt	20Mt
	2040		0MtCO2	36Mt	36Mt	45Mt

Main differences between the scenarios[5]:

- More ambitious assumptions on societal choices and circularity lead to production levels which are smaller in volume but higher in value. This is materialised by the production of longer lasting goods, the use of more sustainable material to produce them and broader sharing economy (cars, products …).
- A higher share of material is produced through recycling in the more ambitious scenario, leading to a smaller demand in energy and resources as well as smaller GHG emissions.
- More ambitious scenarios rely on faster electrification and quicker developments of breakthrough technologies like H-DRI steel. This allows it to decarbonize faster while relying less on still debated CCS technologies.

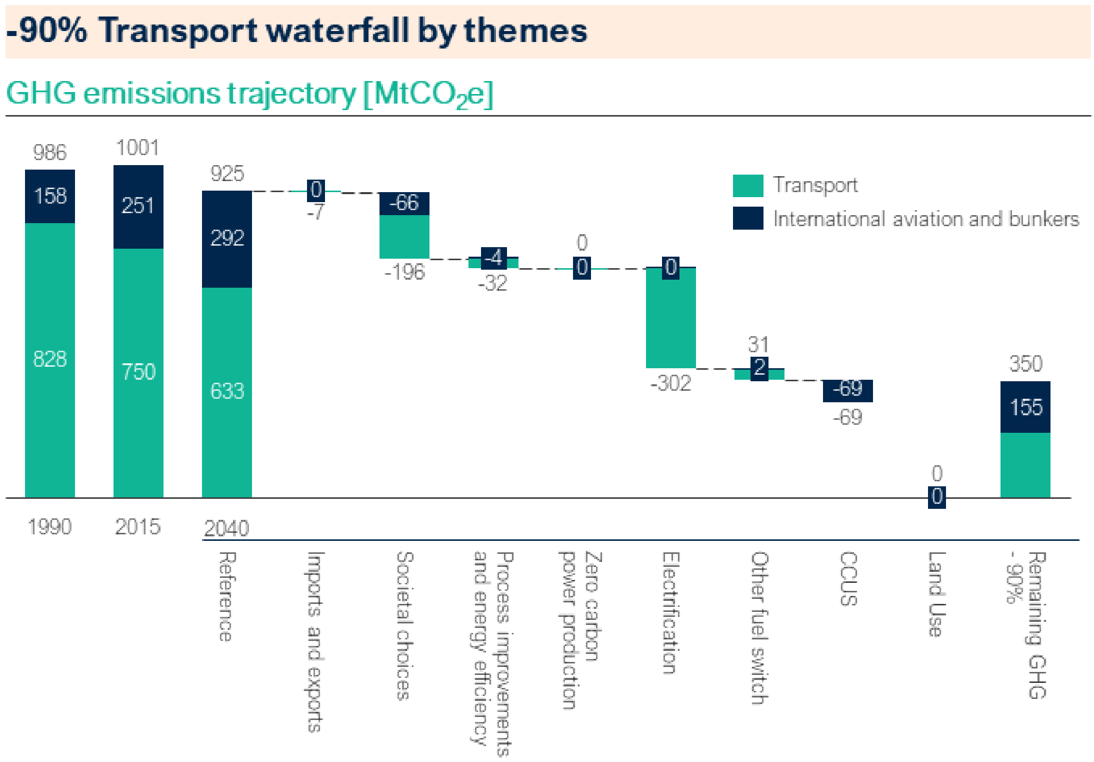
[5]Limitations and comments on the model

- The scenarios are based on exogenous projections for the demand in material. In future, those could be calculated by the model by taking into account the product demand of demand sectors (transport, buildings, etc) , imports/exports and assumption on the manufacturing processes (material efficiency, material switch, etc.).
- The list of technology and fuel switches allowed by the model is not exhaustive and some new technologies might not be possible to model at this stage. The full list of technologies is available through the assumption's descriptions on the webtool.
- At this stage, only scope 1 emissions are modelled in the scenarios. Integrating scope 2 and 3 emissions will be possible later this year.
- Impacts on minerals, water and air pollution have not been modelled in this exercise. Further developments of the model will allow such analysis later this year.

Overview of transport trajectory to 2040

Key findings

- Electrification of car and truck fleets has the potential to cut domestic transport emissions by 50% and significantly reduce oil consumption. By 2040, at least 84% of the total car fleet will be electric and 46% of the truck fleet will be electric and 6% hydrogen powered.
- Emissions gains will be maximised if new cars, trucks and their batteries are designed to be more efficient, lighter and smaller. For instance, eco-design measures for batteries can increase efficiency, limit its weight and ensure a sustainable use of minerals.
- Shifting to other modes of transport, with public transport and “mobility as a service” can reduce the car fleet by 20% while increasing mobility options. This requires the implementation of new infrastructures in urban and rural areas, such as cycle paths, railways, intermodal connections and a system of shared cars. For international travel, air travel will be slightly reduced and replaced by trains, local tourism, or remote meetings for example.
- Increasing the freight modal shift of railways and waterways will contribute to reducing the number of trucks by 30% while maintaining the objectives of European reindustrialisation.
- Switching to alternative fuels is the solution to decarbonise the remaining 50% of international transport emissions. As biofuel and e-fuel supplies are limited, safeguards and priorities could be established to ensure a sustainable use.



Key assumptions for the transport sector

Evolution to 2040 (vs 2015 for relative)				2019	-95%	-90%	-85%
Passenger	Car usage	car occupancy		1.6 people by car	1.72	1.72	1.72
Passenger	Car usage	car utilization		11200 vkm/veh/y	+25%	+25%	+25%
Passenger	Transport demand	inland		12000 pkm/cap/y	+20%	+20%	+35%
Passenger	Transport demand	aviation		3325 pkm/cap/y	-20%	-1%	+10%
Passenger	Modal share	urban	car & 2wheels	65% & 6%	54% 7%	58% 6.5%	58% 6.5%
Passenger	Modal share	urban	public	14%	20%	18.5%	18.5%
Passenger	Modal share	urban	bike & walk	4% & 11%	7% & 12%	5.5% & 11.5%	5.5% & 11.5%
Passenger	Modal share	Non-urban	car	80%	76%	77.5%	77.5%
Passenger	Modal share	Non-urban	rail	11%	13%	12.5%	12.5%
Passenger	Modal share	Non-urban	bus	9%	11%	10%	10%
Passenger	Technology share	BEV cars	New sales	12% (2022)	98% (2030)	95%	86%
Passenger	Technology share	BEV cars	Fleet	3M (2022) (1%)	166M (90%)	162M (84%)	162M (75%)

Key assumptions for the transport sector

Evolution to 2040 (vs 2015 for relative)				2019	-95%	-90%	-85%
Freight	Demand	inland		2390 billion tkm	-20%	-10%	-5%
Freight	Demand	Intern. bunkers		13180 billion tkm	-13%	-6%	-4%
Freight	Territory Modal share	road		71%	61%	63%	66%
Freight	Territory Modal share	rail		17%	23%	22%	20%
Freight	Territory Modal share	IWW		12%	16%	15%	14%
Freight	Technology share (road)	diesel		100%	39% (1.47M)	48% (2M)	55% (2.4M)
Freight	Technology share (road)	electric		0%	54% (2.07M)	46% (1.92M)	39% (1.7M)
Freight	Technology share (road)	hydrogen		0%	7% (0.27M)	6% (0.27M)	7% (0.3M)
Freight & passenger	Fuel switch	aviation	biofuel	0%	22%	22%	22%
Freight & passenger	Fuel switch	aviation	e-fuel	0%	41%	24%	24%
Freight & passenger	Fuel switch	marine	biofuel	0%	0%	0%	0%
Freight & passenger	Fuel switch	marine	e-fuel	0%	50%	30%	20%

Main differences between the scenarios[6]:

- The more ambitious scenario has a smaller global transport demand, both for passenger and freight. This is driven by more sustainable choices, the development of circularity and a change in the territory planning to facilitate more local travel.
- More developed public transportations and infrastructures allow for a more rapid shift from cars to active modes and public transports in the more ambitious scenarios.
- More ambitious scenarios also rely on a faster technological switch, to BEV for road transport and e-fuels for the maritime and aviation sectors.

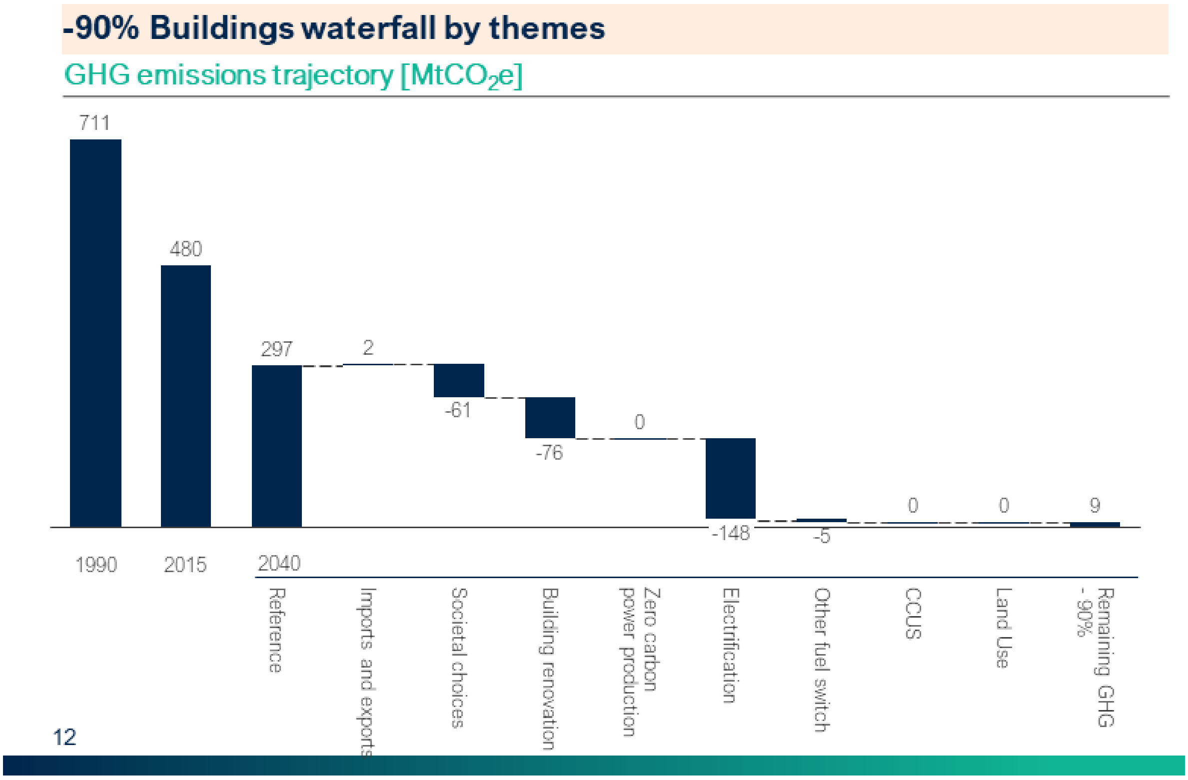
[6]Limitations and comments on the model

- The model uses simplified assumptions in the stock of the vehicle fleet.
- At this stage, only scope 1 emissions are modelled in the scenarios. Integrating scope 2 and 3 emissions will be possible later this year.

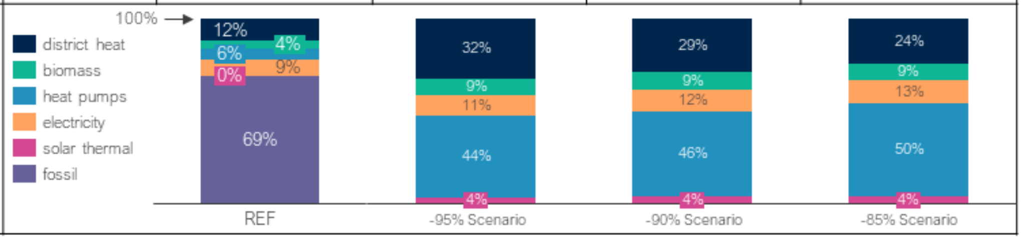
Overview of buildings trajectory to 2040

Key findings

- The pathways presented in this analysis are in line with an overall phase out of fossil fuels in the building sector by 2040 as envisaged in the Energy Performance of Buildings Directive. The energy renovation rate of building stocks needs to increase significantly to 3% from 2030 to 2040.
- Most of these renovations should be energy+ pr 0-emissions buildings, respectively defined as an energy requirement below 85kWh/ m² and below 15kWh/m².
- All new constructions should be 0-emission buildings from 2030. Deep renovation of buildings and a significant deployment of low-carbon heating systems go hand in hand.
- For the renewable share for heating to reach 100% in 2040, half of the energy demand will be covered by heat pumps and a third by district heating. The heat pump installation rate thus also increases to 3% in line with the building renovation rate.
- Society can contribute to the efforts in the sector also by maintaining efforts to reduce energy demand as effectively implemented in response to the Russian war.



Key assumptions for the building sector

Evolution to 2040 (vs 2015 for relative)		2019	-95% net	-90%	-85%
Floor areas	residential	▪ 40 m^2/cap	▪ +10% to 44m^2/cap	▪ +16% to 46 m2/cap	
	services	▪ 1370 billion m^2	▪ Keep floor area stable		
New construction		▪ /	▪ 0-emission buildings[1] from 2030		
Renovations	rate	▪ 1.3% (residential) & 2.4% (services)	▪ Renovation rate: 3% by 2030		
	Depth	▪ 80% of shallow (<25% energy savings vs average of the stock)	▪ 70% of 0-emission buildings[0,1] ▪ 18% of energy+ buildings[0,2]	▪ 65% of 0-emission buildings ▪ 16% of energy+ buildings	▪ 55% of 0-emission buildings ▪ 15% of energy+ buildings
Technological mix of residential space heating					

NOTES: 0. Renovation depths are constant between 2030 and 2040
1. energy+ buildings are defined as <15kWh/m²
2. 0-emission buildings are defined as <85kWh/m²

Main differences between the scenarios[7]:

- The pace of renovation is similar in all scenarios, but their depths vary, leading to a building stock with smaller heating and cooling needs for the more ambitious scenarios. New construction rates are limited in all scenarios to favour less energy and resource consuming renovations.
- The installation of heat-pumps also accelerates in more ambitious scenarios, in line with a wider development of deep renovations.
- District heating develops more quickly in the more ambitious pathways.

[7]Limitations and comments on the model

- Assumptions on the renovation of buildings are simplified and translated for all buildings, their complete renovations occur in one-year steps. Those renovations could happen through multiple iterations in a timespan of more than a year.
- Buildings of the same granularity are considered to have the same average energy consumption, based on the average consumption for the reference year (2019). The granularity is the following:
  - Residential buildings: single family housing and multi-family housing.
  - Services: education, health, public offices, private offices, trade, others.

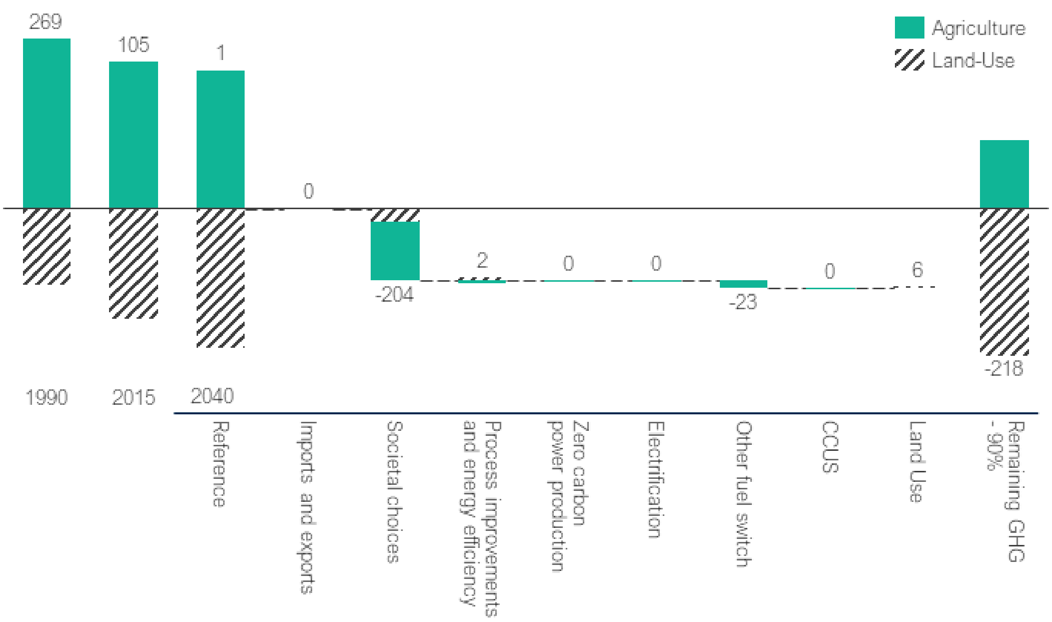
Overview of agriculture, forestry and land use trajectory to 2040

Key findings

- Reducing food waste by 35-40% can lower food production by 5% and thus reduce emissions and pressure on land.
- Shifting to a healthier and plant-based diet can contribute to reducing food demand by 12%. Reducing meat consumption in line with recommendations of the World Health Organisation has a significant impact on direct emissions of methane and nitrous oxide emissions, but also indirectly on pressure for land and deforestation for feed imports.
- Agriculture and forestry-waste can contribute to energy production.
- Afforestation, better forest management and restoration of natural habitats, such as peatlands, bring many benefits. They allow for an increased carbon sequestration and storage through natural sinks and provide a habitat for biodiversity and improve air quality.

-90% AFOLU waterfall by themes

GHG emissions trajectory [$MtCO_2e$]



Main differences between the scenarios[8]:

- The quantity of freed-up land that can be allocated to carbon sequestration increases in the more ambitious scenarios. The main driver behind this is a progressive change of diet (consume less and more plant-based food) and a reduction of food waste.
- More ambitious scenarios go further in terms of sustainable agriculture practices and livestock management.

Improved farming practices can reduce agricultural emissions

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	-95%	-90%	-85%
Reduce food waste	Improved food chain efficiency		
	-40%	-35%	-35%
Afforestation of freed up lands	Change in social patterns and agricultural practices can free-up land for carbon sequestration (reduced food waste and food consumption per capita, switched diet, land management…)		
	+16 Mha	+12 Mha	+11Mha
Reduce fertilizer use	-24% N / -24% P / -24% K / -19% pesticides		
Reduce fodder needs of livestock	Traditional fodder is replaced by alternative proteins for		
	18%	17%	16%
	Traditional fodder is replaced by grazing for		
	9%	9%	9%
Reduce enteric fermentation	On average CH_4 emissions from enteric fermentation decreases by		
	7%	7%	6%
Reduce emissions from manure (CH_4 & N_2O)	On average CH_4 and N_2O emissions from manure management decreases by		
	22%	22%	21%

[8]Limitations of the model

- The forest and land sink capacity does not consider yet the impact of externalities such as wildfires, drought or bark beetles for instance.). The carbon sequestration potential of land-use should be taken with highest caution, as it relies on assumptions on the overall land management that are hard to enforce and control over the territory.
- At this stage, only scope 1 emissions are modelled in the scenarios. Integrating scope 2& 3 emissions will be possible later this year.
- Impacts on minerals, water and air pollution have not been modelled in this exercise. Further developments of the model will allow such analysis later this year.

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CLIMACT

The modelling work behind those scenarios has been conducted by Climact. Feel free to reach out for more details or to build on this exercise for further analysis (national scenarios, extra-analysis,...)

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