2050 scenario analysis using the EU CTI 2050 Roadmap Tool

POWER sector documentation

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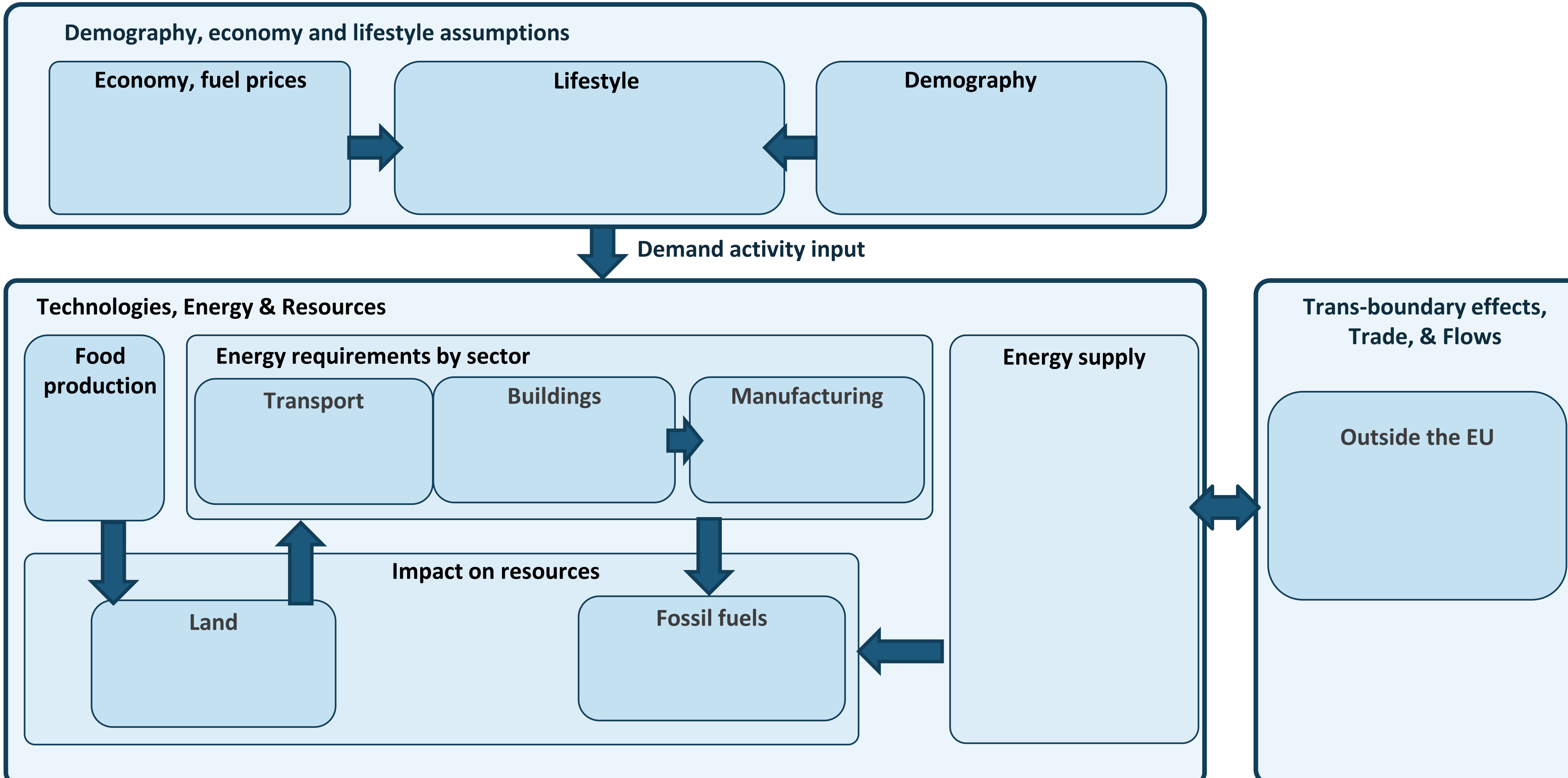
Content

Structure of the ECF EU CTI 2050 Roadmap model



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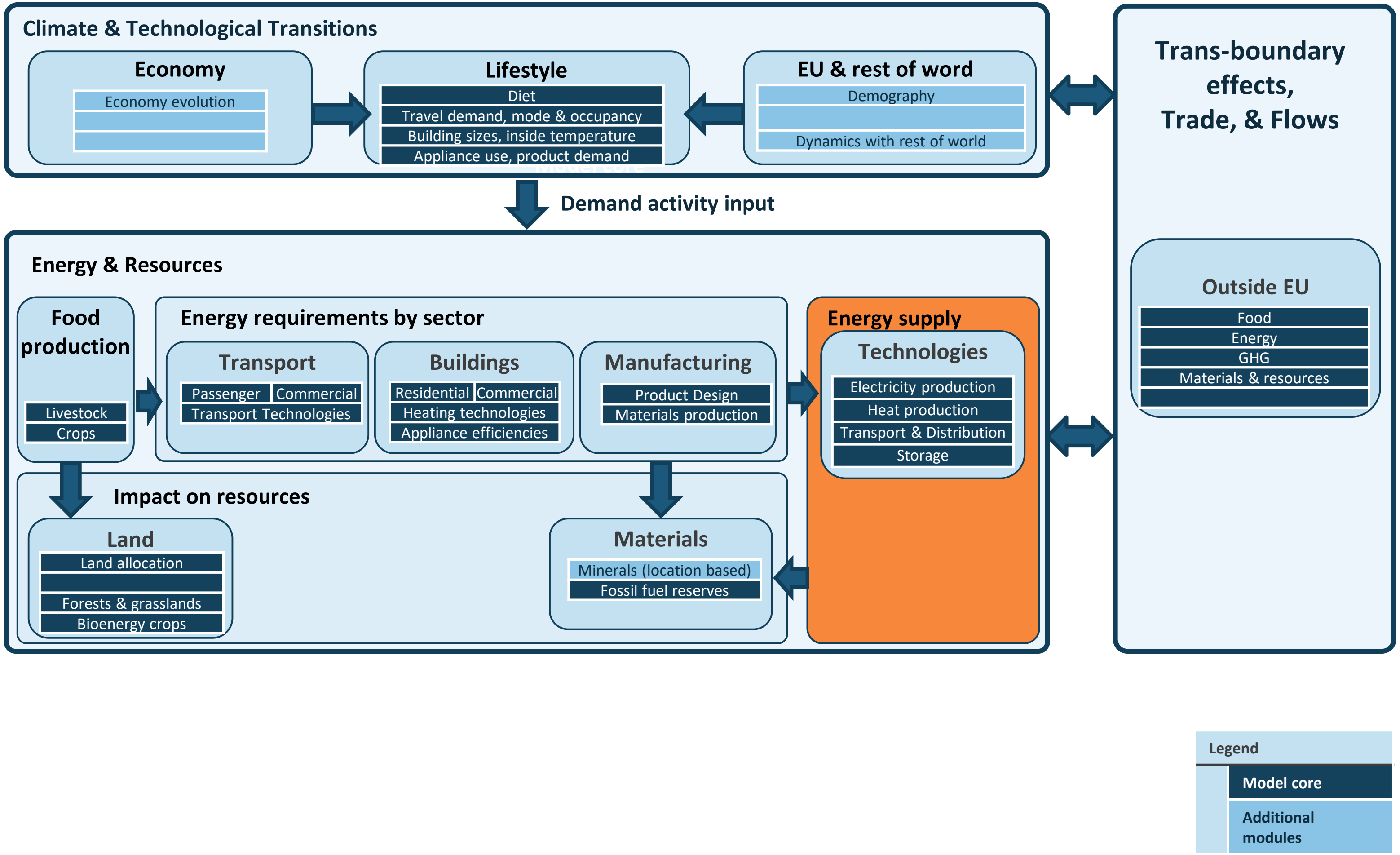

4 ambition levels are used as boundaries to create scenarios
Any value can be chosen in between

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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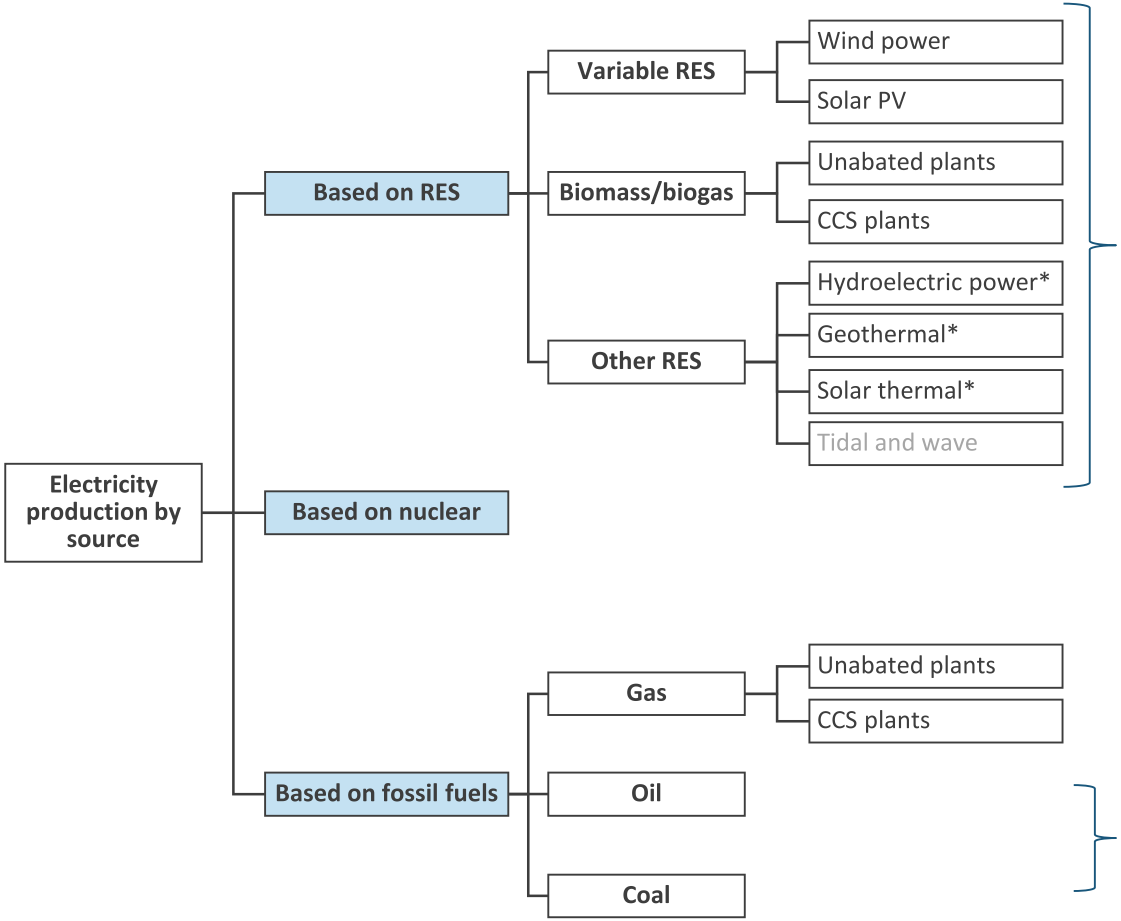
Project context

The approach for the power sector

Description of the levers

Electricity production – simplified logic

Electricity demand is defined based on the sector choices



- Electricity production is computed independently for each RES source based on their potential and scenario choices
- It is then summed up and subtracted from the required electricity demand
- CCS is applied on biogas and biomass based on user choice

- Nuclear production is defined based on user input

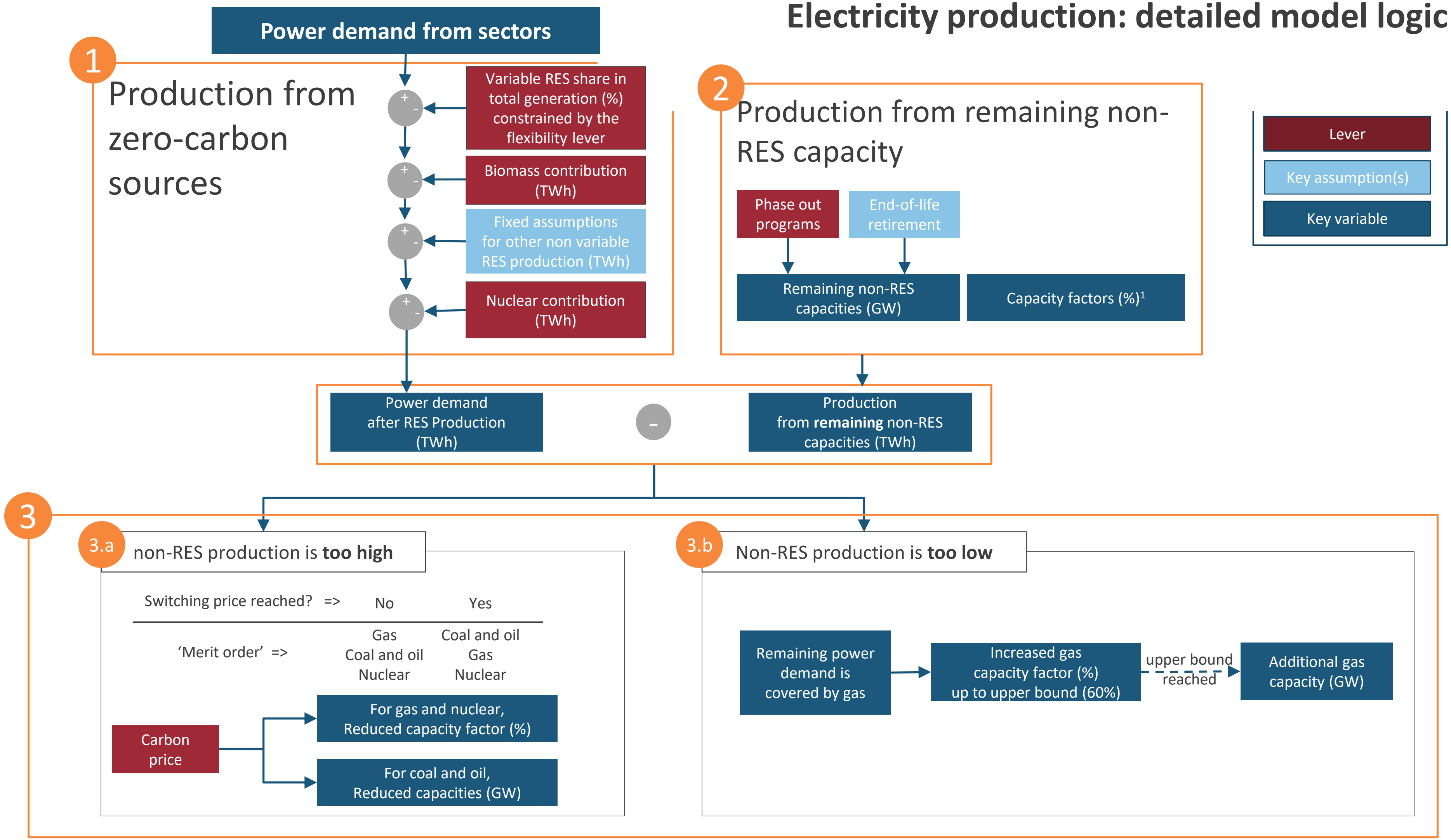
- After exploiting all resources above, any production still required is being covered with gas plants, potentially with CCS

- Oil and coal-firing power plants are progressively removed following user inputs (phase out) and downward balancing between production and demand
- No increase in their contribution is considered

* Currently set as pre-defined trajectories, not levers

SOURCE: Climact

Electricity production: detailed model logic



[1] This is only a fuel switch, has no impact on total production

Levers defined in the EU CTI model

Lever name	Units	Comment	Level 0	Level 3
EU coal phase out(*)	Coal capacities that phase out [%]		Retirements driven by end-of-life only	100% phase out by 2025
EU nuclear Context(*)	Nuclear capacities that phase out [GW]	Nuclear is defined as 4 possible trajectories (A,B,C,D), not ambition levels	Trajectory A: Full Phase out	Trajectory D: COM's delayed CCS scenario (R2050-2011)
EU vRES framework(*)	Variable RES in total generation [%]	S-curve based on policy assessment Can be split in 2 levers to reflect wind and solar more precisely, as well as in centralized vs decentralized	24% by 2030 30% by 2050	61% by 2030 80% by 2050
Zero-carbon flexibility solutions	Contribution of zero-carbon solutions to flexibility needs [%]	Considered zero-carbon flexibility solutions are: DSM, storage, interconnexions and biomass-based flexible generation	Flexibility 100% based on gas flexible generation	Flexibility based on a mix of zero-carbon flexibility solutions
Biomass and biogas contribution	Biomass and biogas power generation [TWh]		No more biomass by 2030	Biomass production considered in EU REF2016
CCS	[% of gas- and biomass-firing production where CCS is used]	Focus on biomass and gas as coal is assumed to be phased out. CCS on biomass leads to BECSS	0% of new assets	100% of new assets

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

What the model does and doesn't do

What the model allows:

- A technology mix is user/expert-defined based on certain scenario options
- The models reflects well the impact of high electrification and reflect the need for higher or lower electricity build-out
- The timing of the implementation of the technology options can be adapted
- Assumptions on the technology costs are predefined, independent from the ambition levels (but a [low – high] costs range is predefined)

Work in progress:

- Requirements for flexibility/storage/DSM**:** Models a link between vRES and flexibility needs

A series of constraints are not explicitly modeled. They should be considered by the expert in the design of the scenario:

- Inertia of the system/energy infrastructure development costs: no abrupt change, while steep slopes possible (considered in design of scenarios)
- Costs are an output of the scenario, they don't drive the technology mix
- Dispatch mechanism and varying capacity factors
- Learning curves
- Electricity infrastructure choices
- Links to the gas infrastructure system

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Coal phase out ambition levels are structured around binding pledges

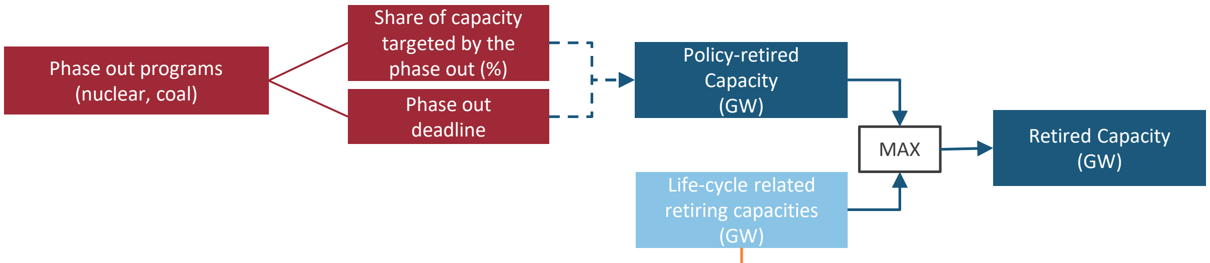
Coal

Country	Share of coal capacity in 2017	no policy scenario	Level 0: Current policy - binding	Level 1: Current policy - binding/ non binding	Level 2	Level 3
Austria	1%	-	-	2025	All phase out by at latest 2040	All phase out by at latest 2025
Bulgaria	3%	-	-	-		
Croatia	0%	-	-	-		
Czech Republic	6%	-	-	-		
Denmark	2%	-	-	2050		
Finland	1%	-	2030	2030		
France	2%	-	-	2023		
Germany	32%	-	-	2050		
Greece	3%	-	-	-		
Hungary	1%	-	-	-		
Ireland	1%	-	-	-		
Italy	6%	-	-	-		
Netherlands	4%	-	-	2025		
Poland	19%	-	-	-		
Portugal	1%	-	-	2020		
Romania	3%	-	-	-		
Slovakia	1%	-	-	-		
Slovenia	1%	-	-	-		
Spain	7%	-	-	-		
Sweden	0%	-	-	2030		
United Kingdom	8%	-	-	2025		

Assumptions:

- Assumed linear progression for annual retired capacity
- Coal capacity trajectory is also linked to carbon price specified in CTI model
  (see slides on balancing production and demand)

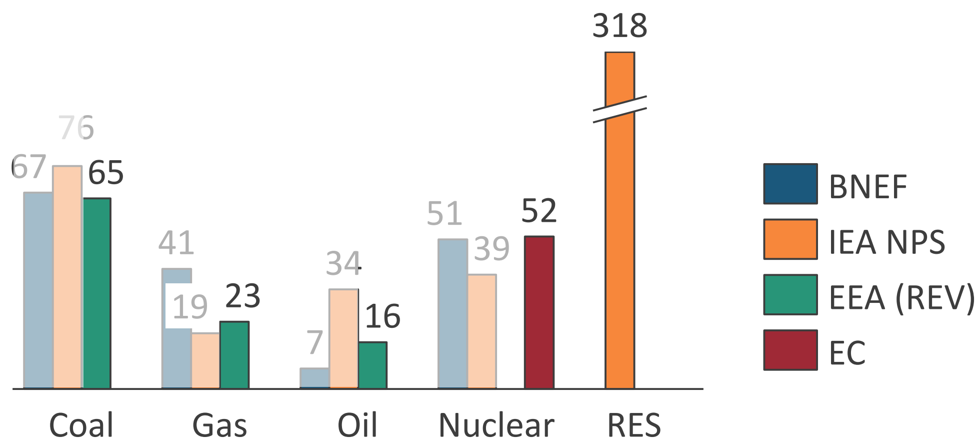
Taking into account end-of-life retiring plants, early retirements should translate into higher costs



Note:
Additional coal plant retirement can results from downward-revised production balanced to demand combined to high carbon price

End-of-life retiring capacity scenario

Cumulative power plant capacity retirements 2016-2030 (GW)



- **EEA (REV) scenario is chosen for coal, gas and oil** plant retirement. It accounts for investments in the efficiency of some plants
- The **EC scenario is chosen for nuclear** end-of-life retirement. It accounts for long term operation programs
- The IEA NPS scenario is used to account for RES end-of-life retirement. This has no impact on the total results

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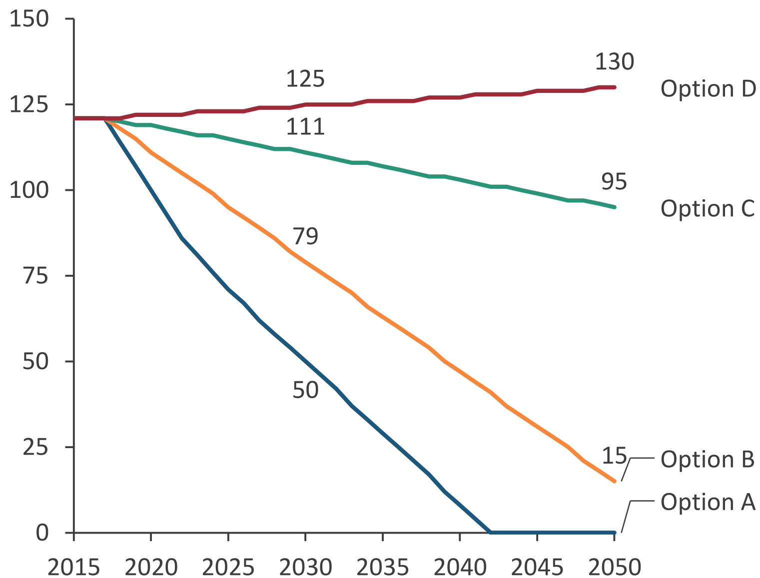
A range of nuclear contributions can be tested in the scenarios

GW of nuclear power plants at EU level



Rationale for the 2050 target value in the four levels:

- **Option A**:
  Full nuclear Phase out decided by 2020, reached by 2042. No new nuclear
- **Option B**: Level of the COM's R2050 2011 low nuclear scenario, corresponding to long-term operations of current plants without new investments
- **Option C**: Lower range of the projected capacity presented in the Nuclear Illustrative Programme of the Commission
- **Option D**:
  Nuclear assets increase to the max observed among the COM's PRIMES R2050 2011 scenarios, i.e. 130MWe in the **delayed CCS scenario**

In addition, the nuclear power generation is dependant on the evolution of the power demand as the capacity factor

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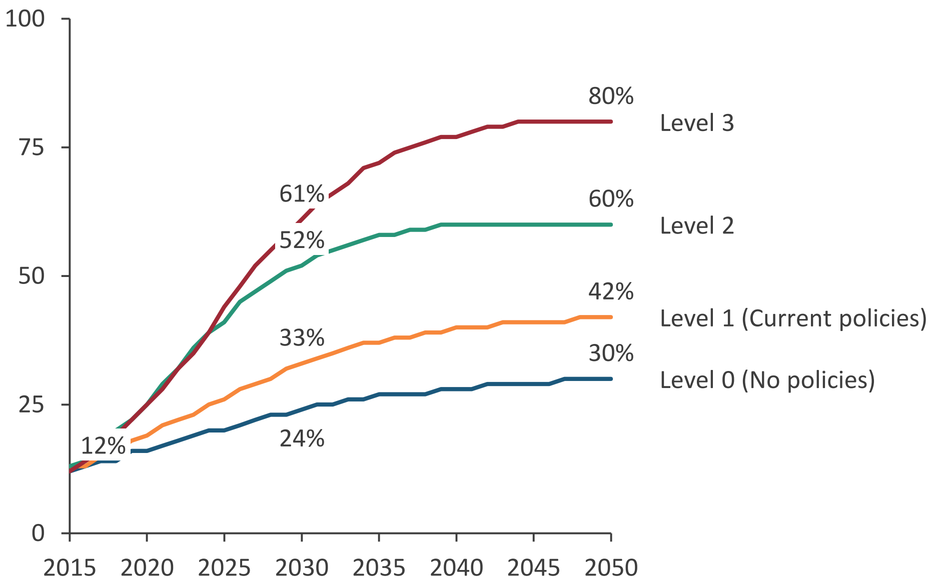
The EU level for the “EU vRES framework” lever is based on a MS-level analysis of the support to RES and the corresponding uptake

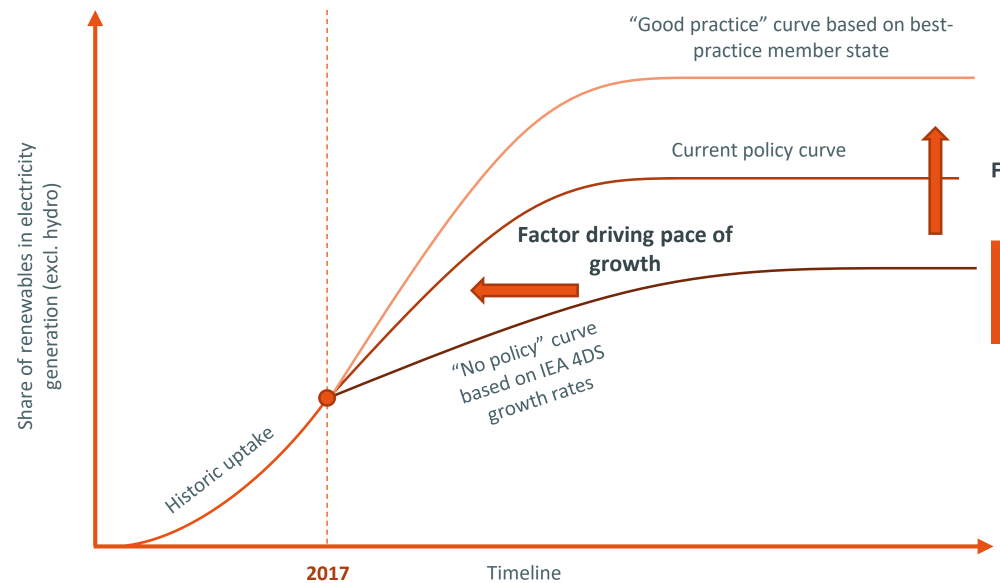
% share of **wind and solar** in electricity generation (EU-level aggregated result)



- The methodology based on deploying the best observed practices (Denmark) leads to a ceiling value of 61% for the contribution of vRES in the power production mix in 2030. Considering the pace of deployment in Denmark leads to reaching that upper limit by 2030.
- By 2050, it is assumed that increased flexibility alternatives will allow this upper limit to be increased to 80% based on various constraints (see next lever on Flexibility options)
- Fixed assumptions on hydro and geothermal lead to 430TWh by 2050. Reaching 100% RES by 2050 with a 80% share of wind and solar, thereby requires the power demand to be limited to 2.150TWh (of which 430TWh amounts to 20%), i.e. a reduction by 33% w.r.t. 2015 level

General idea for determining policy impact

- General idea to model RE uptake based on “s-curve” market dynamics
- Adapt s-curve parameters based on policy assessment with **factor driving pace of growth** and **factor defining the ceiling**



Please find detailed explanations of the **factor driving pace of growth** and the **factor defining ceiling** on the following slides.

* Based on IEA (2016), *Energy Technology Perspectives 2016*, 2016 Edition, International Energy Agency

Source: New Climate Institute

Factor driving pace of growth - Overview

(N = 4)

Metric M	Measured in	Unit	Weight w *	Lower bound M_l	Representing	Upper bound M_u	Representing	Source
Level of support from RES scheme(s)	Ratio accumulated incentives to total RE generation according to good practice curve	%	60%	0%	No or very unambitious incentive	100%	RES schemes totally aligned with good practice development	Own calculations based on RES Legal Database (2017), Agora Energiewende (2017), IEA RE Policy Updates (2016, 2017), Ofgem (2017)
Long-term implications	Ratio of long-term target to good practice curve	%	40%	0%	No or very unambitious long term target	100%	Long-term target totally aligned with good practice development	REN21 Global Status Report 2016
Barriers reducing the factor								
Permit granting procedures	Existence of One-Stop-Shop, online application, maximum time limit for procedures, automatic permission after deadline and facilitated procedures for small-scale producers	[-]	-15%	0	None of administrative services exists	2	All administrative services exists in country	EU Commission (2017), Öko-Institut (2014), Ecofys (2014)
Siting/Zoning	Administrative identification of geographical sites	[-]	-15%	0	No administrative identification of geographical sites	1	Existing administrative identification of geographical sites	EU Commission (2017), Öko-Institut (2014), Ecofys (2014)

* Weights assigned based on expert judgement with input from studies

Source: New Climate Institute

Factor defining ceiling

$(N = 4)$

Metric M	Measured in	Unit	Weight w *	Lower bound M_l	Representing	Upper bound M_u	Representing	Sources
Grid transmission and distribution and interconnection	Total connection capacity as share of electricity generation	in % share of GWh/d	10%	0%	No transmission and interconnection	100%	Full transmission and interconnection	Own calculation based on Entsog (2016) and IEA Energy Balance (2016)
Markets supporting integration of variable RE sources	None (0), Flexible markets OR Capacity mechanism (1), Flexible markets and capacity mechanism (2)	[-]	40%	0	No efforts around markets to increase flexibility	2	Both measure to increase flexibility of markets and capacity markets are introduced	Coding of capacity mechanism based on Energinet.dk (2017);
Demand side management (DSM)	Extend to which DSM is enabled in each MS	[-]	40%	1	Group 1: Those who have yet to seriously engage with Demand Response reforms.	3	Group 3: Enables both Demand Response and independent aggregation.	Coding based on EU Commission JCR (2016)
Storage capacities	Storage capacity (existing/planned) as share of total installed capacity	% share installed electricity generatio n capacity	10%	0%	No storage capacity	100%	Full storage capacity	Own calculations based on PLATTS Database (2016) and Eurostat (2017)

* Weights assigned based on expert judgement with input from studies

Source: New Climate Institute

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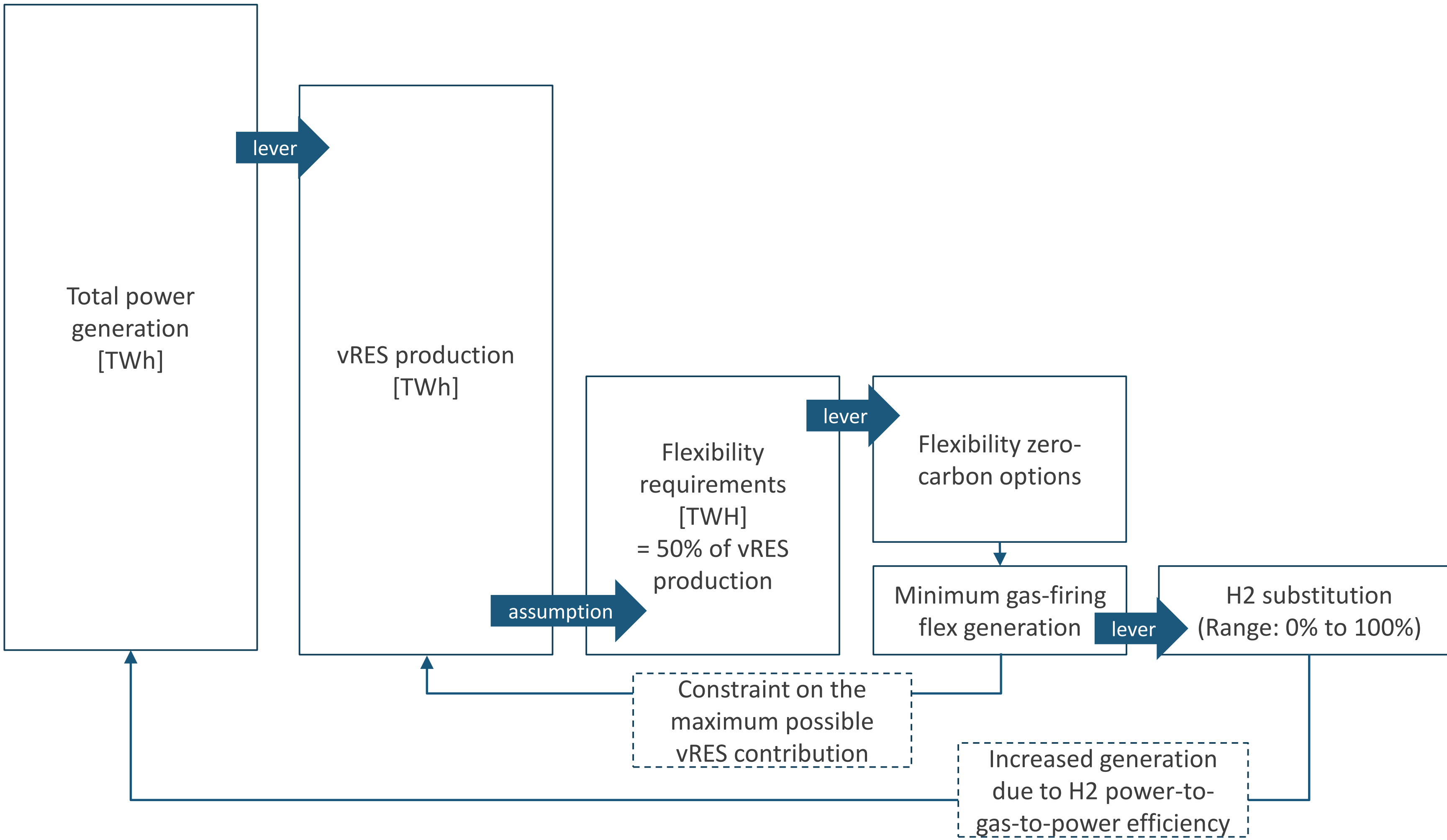
Zero-carbon flexibility solutions: model logic



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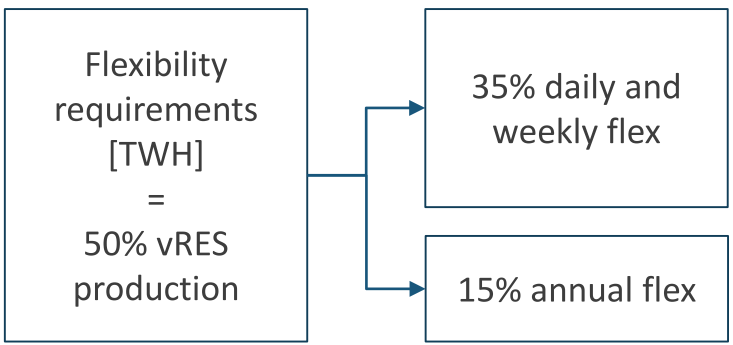
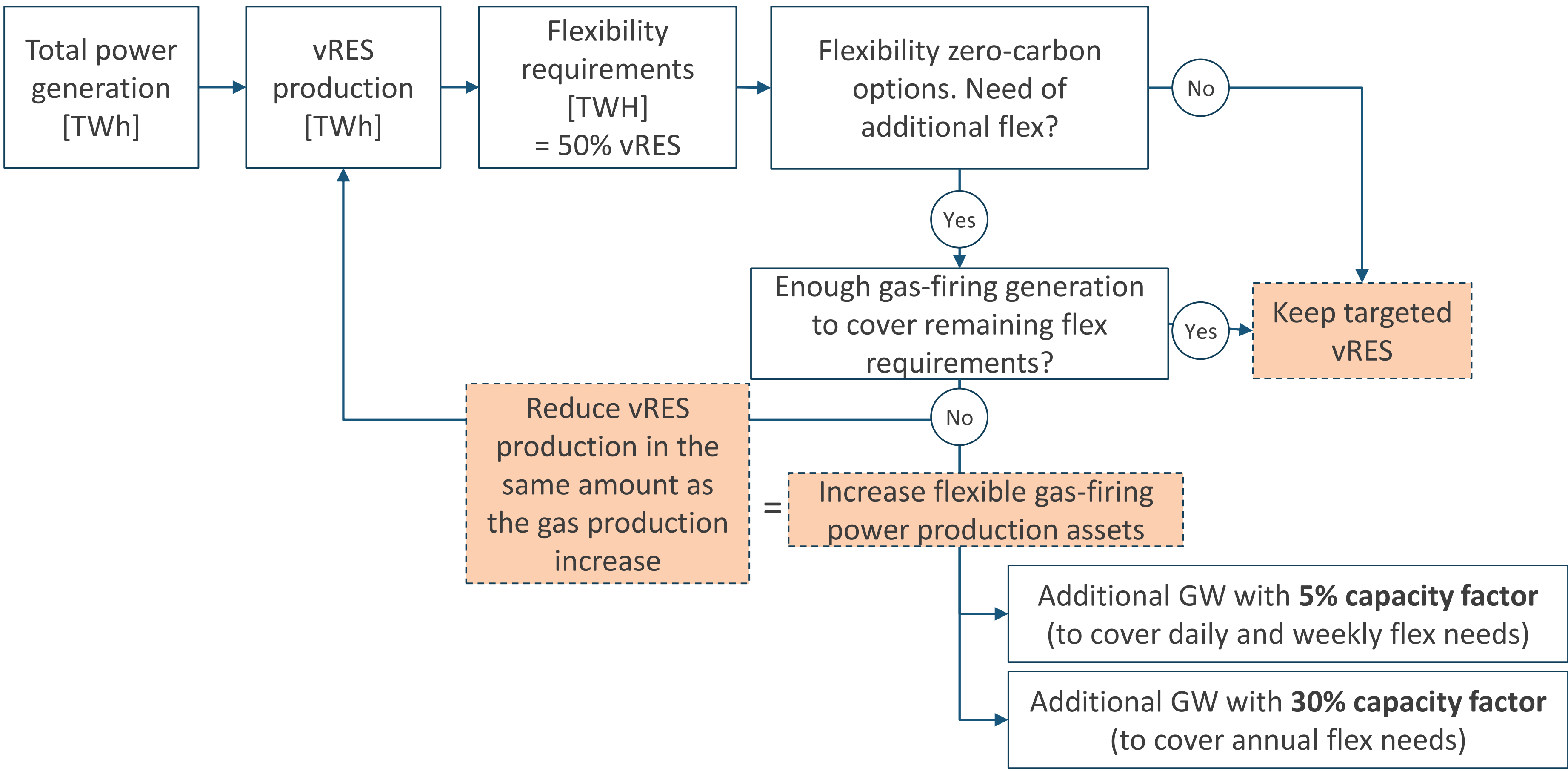
The flexibility requirements are expressed in TWh



- Flexibility needs (in TWh) are considered to amount to 50% of vRES generation and are split between daily (20%), weekly (15%) and annual (15%) needs (based on Artelys’ study “Mainstreaming RES: Flexibility portfolios”)
- Upward and downward activations of that flexibility are not distinguished

If required, vRES production is lowered and gas is increased



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The ‘flexibility’ lever allows to test different portfolios of flexibility solutions

	Level 0 Max carbon flex	Level 1	Level 2	Level 3 Zero carbon flex
Daily and weekly flex solutions:				
DSM (max potential depends on EV, HP and e-processes)	0%	Capture 25% of the potential	Capture 50% of the potential	Capture full potential (*)
Biomass-based dispatchable generation (***) (****)	0%	5%	10%	25%
Interconnections (***)	0%	5%	10%	25%
Storage (***)	0%	5%	10%	Remaining
Gas-based dispatchable generation (***)	100%	Remaining	Remaining	0%
Annual flex solutions:				
Biomass-based dispatchable generation	0% of available generation			100% of available generation (**)
Gas-based dispatchable generation	Remaining	Remaining	Remaining	Remaining

- The modeled implications are:
  - vRES power production limited to the available flexibility solutions
  - costs of flexibility
- There are no additional GHG emissions accounted for flexibility solutions. They are considered in the annual power production mix

(*) The max potential might be limited to a certain % of the connected loads (GW) (**) Subtracting the one used in daily and weekly flex from the available generation
(***) In % of remaining needs (****) Capped by available generation (depends on biomass power lever)

Assumptions for the potential of DSM within the electrical load of demand sectors

Maximum potential of dispatchable electricity consumption in demand sectors
[% of electricity consumption]

Space heating (residential & services)	100%
Transportation (now limited to e-LDVs)	75%
Industrial processes	20%

- The maximal potential of dispatchable electricity consumption in demand sectors is a fixed assumption
- The *zero-carbon flexibility* lever allows to define the share of that potential that is used to answer the flexibility requirements under the tested scenario, as well as the timing within which the targeted potential is reached

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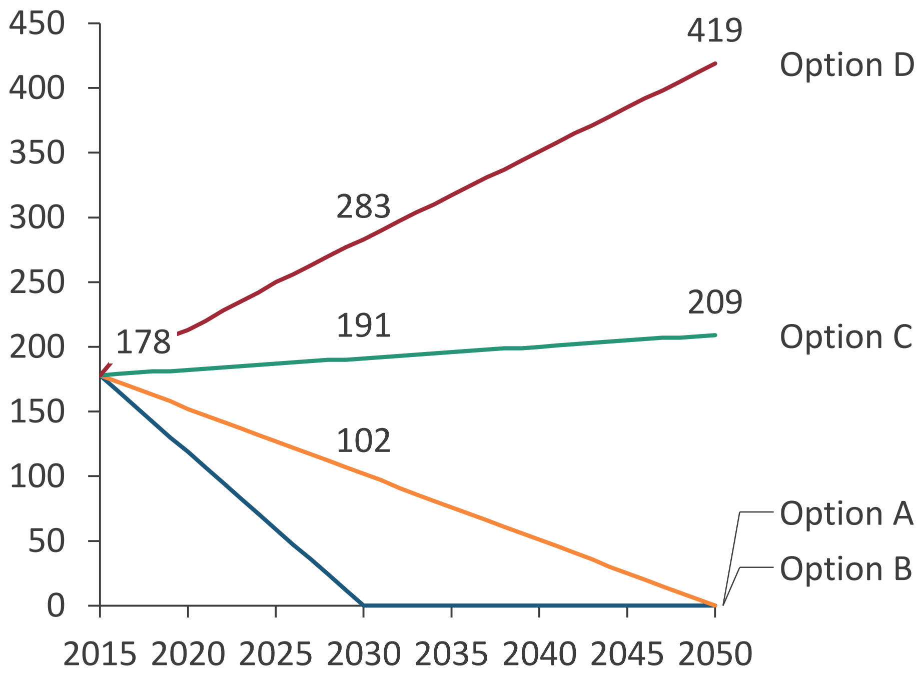
A range of bioenergy contributions can be tested in the scenarios

Power production based on bioenergy [TWh]



Rationale for the levels:

- Option A: No more bioenergy by 2030
- Option B: No more bioenergy by 2050
- Option C: Intermediate between B and D
- Option D: Power production from bioenergy suggested in the COM's Reference scenario (2016)

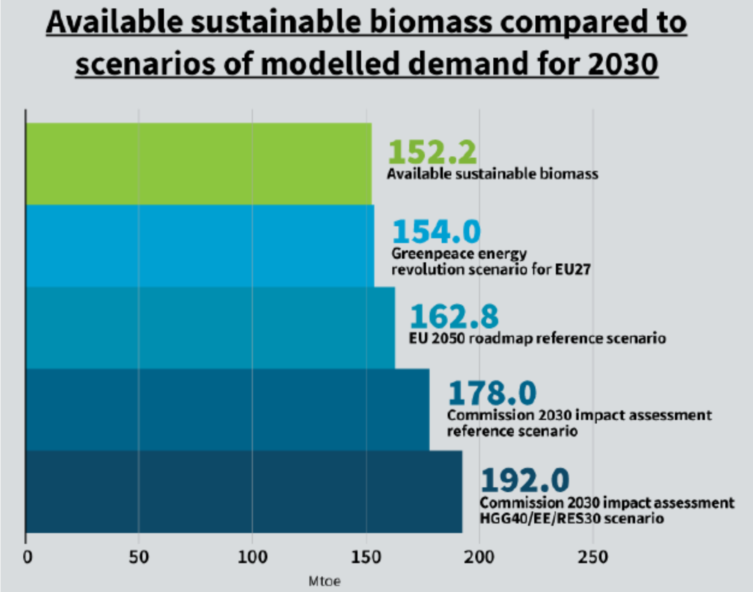
Existing scenarios generally exceed the sustainable potential of bioenergy assessed by BRE for the NGO steering group

Technical potential, Potential for energy use and sustainable potential of bioenergy in the EU [Mtoe]

Mtoe	2020	2030
Technical potential	527.3	521.8
Technical energy potential	354.1	335.5
Sustainable potential	171.9	152.2

Table 1. The sustainable potential is approximately 32.6% of the 2020 technical potential; 29.2% of the 2030 technical potential.

Source: BRE - 2015 - Potential and Implications of using biomass



Source: Transport&Environment - 2016

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A lever allows to test assumptions on the deployment of CCS on new gas- and biomass-firing power plants

- It is suggested that CCS be applied only on a share of new assets, not on legacy ones
- The lever allows to define that share in the range between 0% and 100%
- CCS applied to biomass-firing production is reported under BECSS. It impacts results only in lever settings resulting in an increasing volume of biomass-firing power production
- CCS with gas-firing power production only applies if the gas-firing power production (considered as a buffer to balance production to demand) increases such that legacy assets (with end-of-life retirements subtracted) are not sufficient to match the power demand
- Notes :
  - When additional production is required, the EU fleet-wide gas capacity factor is first increased up to a maximum limit of 60%. New assets are considered only when that upper limit is reached
  - Gas-firing power plant are shut down only based on end-of-life retirements. There is no gas plant closure modelled following low capacity factors, considering that they might be required to provide flexibility services. This could be improved along with the lever on the flexibility solutions