Country profiles

Meta-analysis of country-specific energy scenario studies for neighbouring countries of Germany

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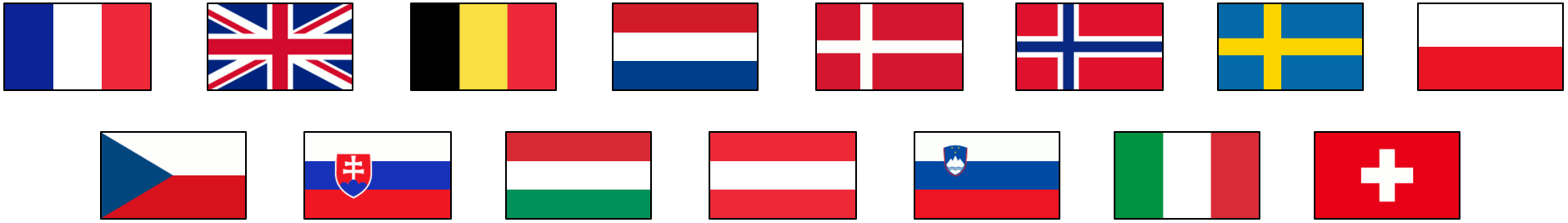


Country-specific scenarios

i) Legend

Name of the institute

Indicator	■ Targets / ■ Causes	■ Requirements / ■ Outcomes
Energy demand	■ *A target concerning the indicator*	■ *Conditions which are needed to be satisfied for reaching the target*
Share of renewable energies	■ *An event/cause relevant to the indicator*	■ *The outcome of the event*
Decarbonization	... ***(name of the specific scenario within the study)***	...
Nuclear targets	...	...
Import / export	...	...

Five aspects that are considered in the scenario analysis

Specific targets or occurences mentioned in the study

Requirements for targets, or outcomes of the occurences mentioned in the study

Navigation across countries

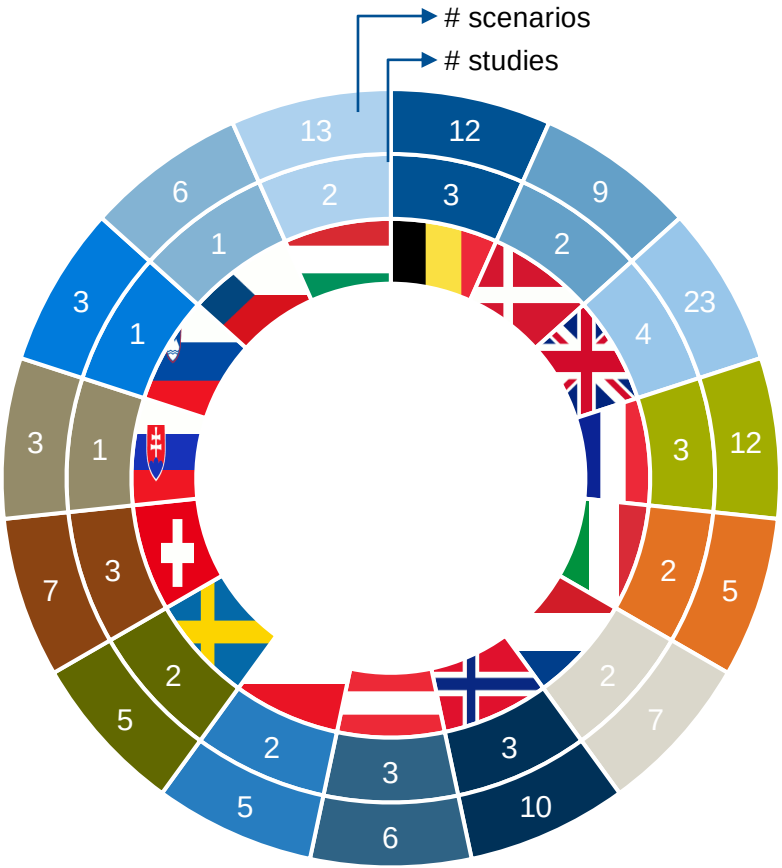
Country-specific scenarios

ii) List of studies

Country	Title	Institution	Contractor	Contractee	Year of study	# Scenarios	Starting year	End year
Belgium	Electricity Scenarios for Belgium Towards 2050	ELIA	Grid operator		2017	6	2016	2050
Belgium	The Belgian energy landscape by 2050: an outlook assuming no changes in policy	Federal Planning Bureau	Public agency		2017	1	2015	2050
Belgium	Energy Transition in Belgium	Energyville	Research institute	Business association	2017	5	2016	2030
Denmark	IDA's Energy Vision 2050	Aalborg Universitet	University	Trade union	2015	1	2015	2050
Denmark	Energiscenarier frem mod 2020, 2035 og 2050 (Energy scenarios from 2020, 2035 and 2050)	Energistyrelsen (Danish Energy Agency)	Public agency		2014	8	2035	2050
Great Britain	Future energy scenarios	National Grid	Grid operator		2018	4	2017	2050
Great Britain	2050 Energy Scenarios	KPMG	Service company	Trade association	2016	4	2014	2050
Great Britain	Whole-system cost of variable renewables in future GB electricity system	Imperial College London	University		2016	7	2015	2030
United Kingdom	The UK energy system in 2050	UKERC	Research institute		2013	8	2015	2050
France	ADEME energy transition scenarios 2030/2050	ADEME	Public agency		2014	2	2030	2050
France	Scénario négaWatt 2017-2050	Association négaWatt	Think-tank	Policymakers	2017	2	2015	2050
France	Bilan prévisionnel - de l'équilibre offre-demande d'électricité en France	Réseau de Transport d'Électricité	Grid operator		2017	8	2016	2035
Italy	Strategia Energetica Nazionale (National energy strategy)	Ministerio dello Sviluppo Economico	Ministry		2017	3	2010	2030
Italy	Una strategia energetica per l'Italia	Associazione Italiana Economisti dell'Energia	Business association	Business association	2017	2	2015	2030
Netherlands	Nationale energieverkenning 2017	Energy Research Center for Netherlands (ECN)	Research institute	Ministry	2017	2	2016	2035
Netherlands	Energy scenarios for 2030	CE Delft	Research institute		2014	5	2012	2030
Norway	CenSES Energy demand projections towards 2050	Centre for Sustainable Energy Studies (CenSES)	Research institute		2014	5	2010	2050
Norway	The Norwegian scenario and action plan presented by NITO Future Climate	The Norwegian Society of Engineers and Technologists	Union in engineering		2009	2	2000	2050
Norway	Det norske energisystemet mot 2030 (The Norwegian energy system in 2030)	UiO:Energi	University		2014	3	2011	2030
Austria	Energie wirtschaftliche Szenarien im Hinblick auf die Klimaziele 2030 und 2050	Umweltbundesamt (Österreich)	Government agency	Ministry	2015	2	2010	2035
Austria	Szenario erneuerbare Energie 2030 und 2050	Umweltbundesamt (Österreich)	Government agency	Business association	2016	1	2010	2050
Austria	Stromzukunft Österreich 2030	Technische Universität Wien	University	Advocacy group	2017	3		2030
Poland	Polish energy sector 2050 - 4 scenarios	Forum Energii	Think-tank		2017	4	2016	2050
Poland	Energy sector in Poland	Polish Information and Foreign Investment Agency	Public agency	Ministry	2013	1	2015	2030
Sweden	Energy Scenario for Sweden 2050	Swedish Environmental Research Institute (IVL)	Research institute	NGO	2011	1	2005	2050
Sweden	Four Futures: The Swedish energy system beyond 2020	Swedish Energy Agency	Public agency		2016	4	2014	2050
Switzerland	Die Energieperspektiven für die Schweiz bis 2050	Prognos AG	Research institute	Government agency	2012	3	2000	2050
Switzerland	Energiestrategie 2050	Bundesamt für Energie	Government agency		2017	1		2050
Switzerland	Switzerland Energy Transition Scenarios – Development and Application of the Swiss TIMES Energy System Model	Paul Scherrer Institut	Research institute		2014	3	2010	2050
Slovakia	Energy policy of the Slovak Republic	Ministry of Economy of the Slovak Republic	Ministry		2014	3	2010	2035
Slovenia	Energetski koncept Slovenije (Energy concept of Slovenia)	Slovenian Ministry of Infrastructure	Ministry		2018	3	2015	2050
Czech Republic	Státní energetická koncepce České republiky (State energy concept of Czech Republic)	Czech Ministry of Industry and Trade	Ministry		2014	6	2010	2045
Hungary	Zöld Magyarország - Energia Útiterv (Green Hungary - Energy Roadmap)	Wuppertal Institute	Research institute	Environmental organization	2016	4	2010	2040
Hungary	National energy strategy 2030	Hungarian Ministry of National Development	Ministry	-	2012	9	2008	2030

Country-specific scenarios

iii) Key figures – 1

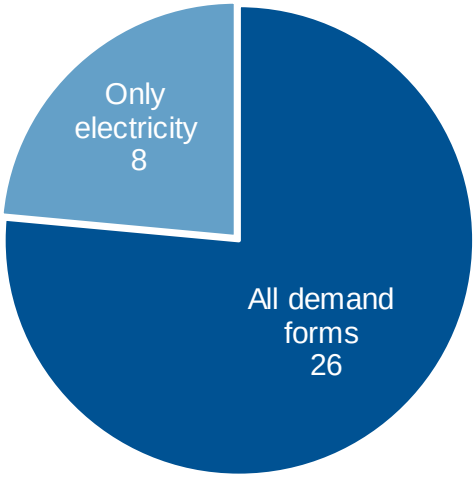


34 *country-specific studies, consisting of* ***126*** *scenarios in total, were identified for* ***15*** *neighbor countries of Germany*

Country-specific scenarios

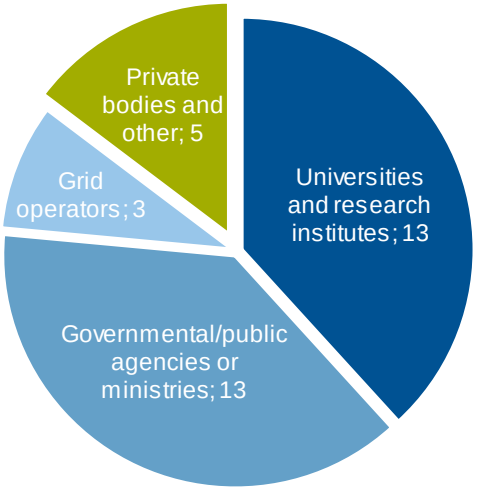
iii) Key figures – 2

Sector coverage



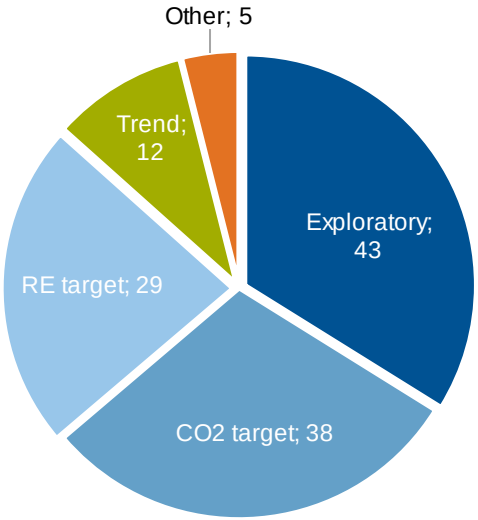
26 *out of the 34 studies span all demand categories (electricity + heating/cooling + mobility), whereas* ***8*** *of them focus on the electricity sector only*

Stakeholders



13 *out of the 34 studies are conducted by universities and research institutes, another* ***13*** *by governmental/public agencies or ministries,* ***3*** *by grid operators and* ***5*** *by private companies and unions*

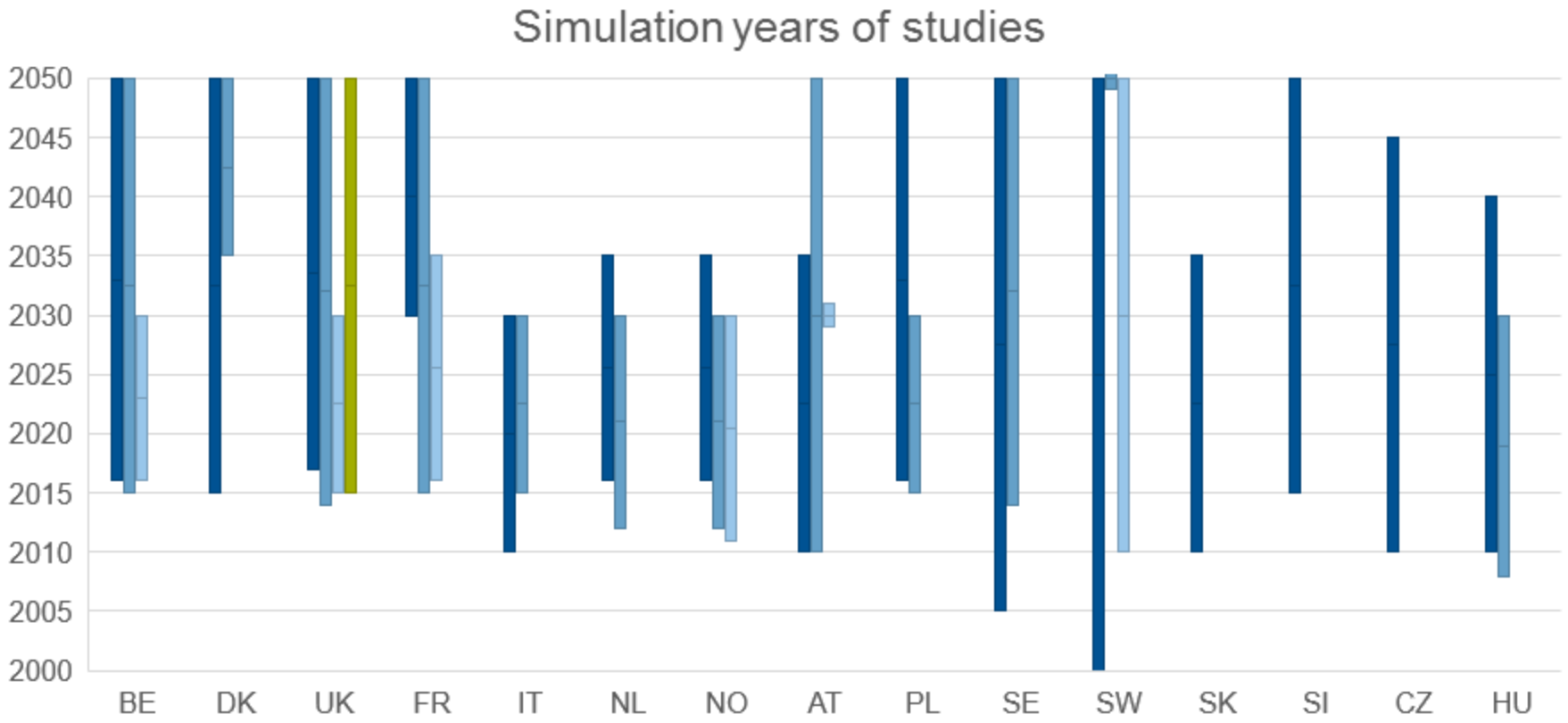
Context of scenarios



Out of ***126*** *scenarios,* ***43*** *are identified to be exploratory,* ***38*** *as target scenarios on* CO_2 *emissions,* ***29*** *as target scenarios on renewable energy shares and* ***12*** *as trend (business-as-usual) scenarios*

2b) Country-specific scenarios

iv) Key figures – 3



***17** out of **34** studies have a period of consideration up to the year 2050*

France – Insights from studies

ADEME [1]

Indicator	■ Targets / ■ Causes	■ Requirements / ■ Outcomes
Energy demand	■ 50% lower final energy demand from 2012–2050	■ Higher efficiency in buildings and lower individual transport
Share of renewable energies	■ 80% (or 90%) renewable electricity by 2050	■ 11% (or 5%) of the electricity still covered by nuclear by 2050
Decarbonization	■ -40% and -75% tot. GHG by 2030 and 2050 (re. 1990)	■ Introduction of novel technology (CCS, H_2…) and changes in lifestyle
Nuclear targets	■ Nuclear electricity down to 50% by 2025	-
Import / export	■ Net import / export balance is zero	-

NegaWatt [2]

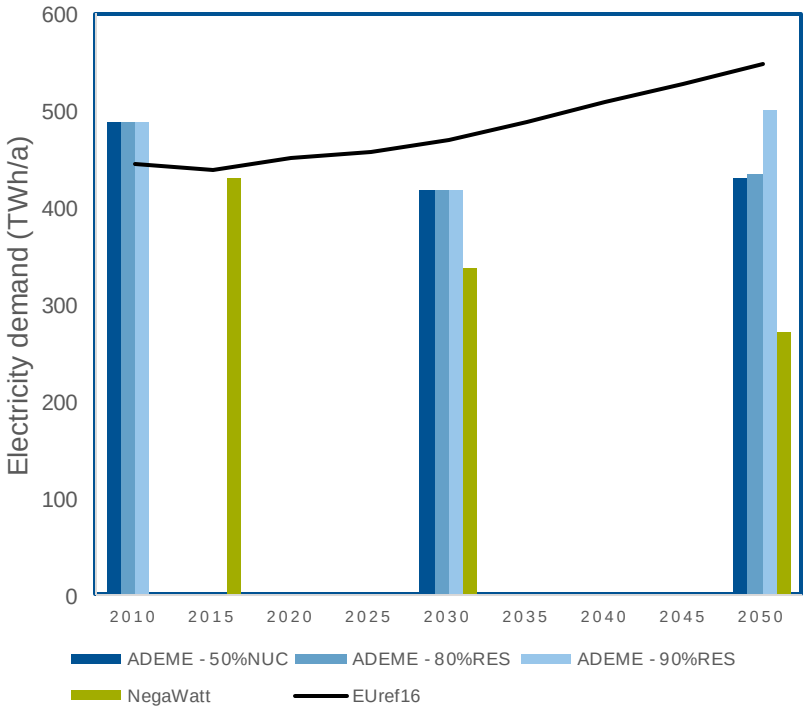
Indicator	■ Targets / ■ Causes	■ Requirements / ■ Outcomes
Energy demand	■ Energy sobriety, efficiency and elimination of waste	■ 50% lower final energy and 63% lower primary energy consumption
Share of renewable energies	■ 100% of energy from renewables by 2050	■ Major drivers: wind in electricity, biomass in overall energy
Decarbonization	■ Zero net (gross - absorption) emissions by 2050	■ Higher CO_2 absorption by agricultural plantations
Nuclear targets	■ Phase-out by 2035	■ Energy independence made possible (currently ~50% dependent)
Import / export	-	-

- The trend is towards reducing (but not phasing out) the nuclear power, whereas energy independence is only possible via complete phase-out
- Halving the total energy demand by 2050 is targeted and can be made possible by demand-side effort

[1] ADEME (2017), Actualisation du scénario énergie-climat ADEME 2035-2050. http://www.ademe.fr/sites/default/files/assets/documents/ademe_visions2035-50_010305.pdf (fr)
[2] Association négaWatt (2017). Scénario négaWatt 2017 – 2050, Dossier de synthèse. https://negawatt.org/IMG/pdf/synthese_scenario-negawatt_2017-2050.pdf (fr)

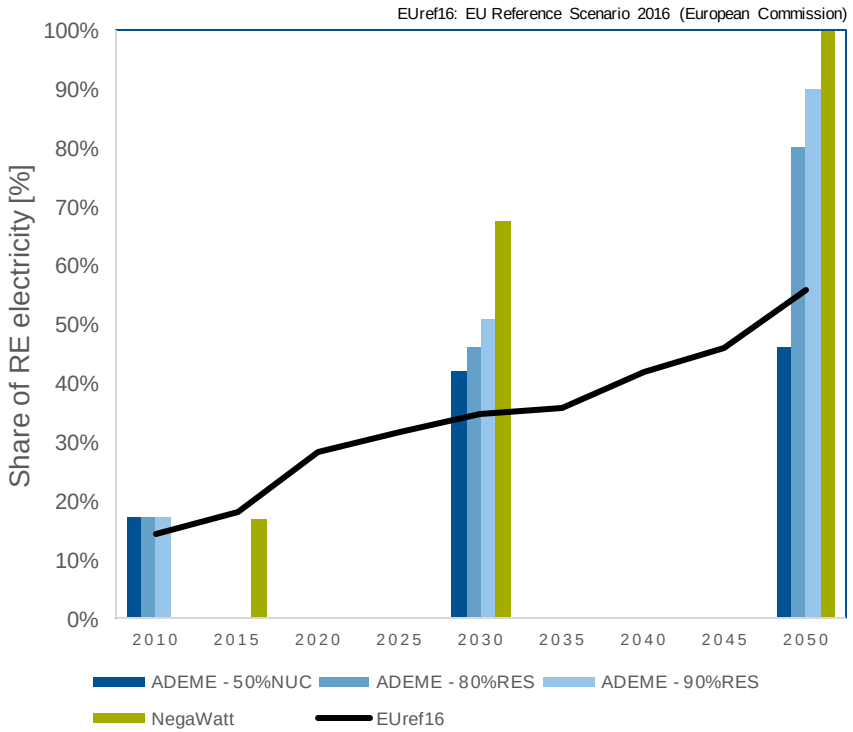
France – Demand & RE share

Electricity demand



- *„EUref16“:* Steady, slight increase in demand
- *„ADEME“* and *„négaWatt“* scenarios*:* Efficiency measures reduce the demand in electricity, except for the 90% RES scenario; where P2H applications eventually shift some heating demand to electricity

Share of renewable electricity



- *„EUref16“:* steady increase; occasional sharp rises due to new wind installations
- *„ADEME“* scenarios: Scenarios targeting up to 90% are achieved. Keeping nuclear at its maximum allowance (50%) leads to ~45% share of renewable electricity by 2050

United Kingdom – Insights from studies

National Grid [3]

Indicator	■ Targets / ■ Causes	■ Requirements / ■ Outcomes
Energy demand	■ Decarbonization of heating and power, more EVs	■ Gas demand ↓, electricity demand ↑
Share of renewable energies	■ Various emission targets / growth scenarios	■ RE share in electricity between 35% and 67% by 2050
Decarbonization	■ -80% total emissions 1990–2050 (2 degrees)	■ 67% RE, %28 nuclear electricity production, electrification of heating
Nuclear targets	■ No plan for a phase-out	■ Nuclear share in electricity between 17% and 28%
Import / export	■ High intermittent generation caused by 2 deg target	■ Interconnector capacity: current *4 = 20 GW required for flexibility

Imperial College London [4]

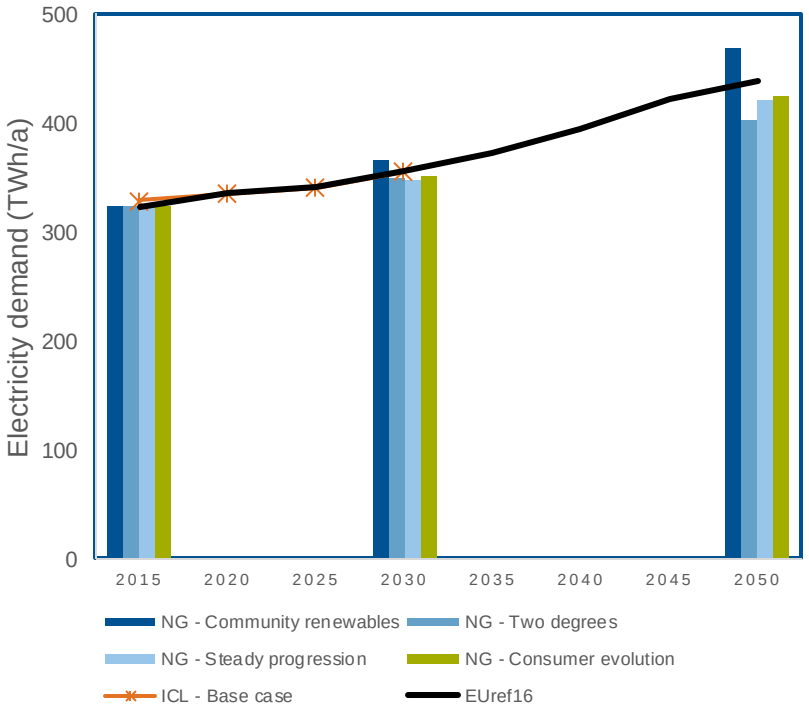
Indicator	■ Targets / ■ Causes	■ Requirements / ■ Outcomes
Energy demand	■ Electrification of domestic heating, more EVs	■ ~10% increase in electricity demand between 2015–2030
Share of renewable energies	■ 20 GW onshore wind, 20GW PV, 3.4 GW biomass by 2030	■ RE share in electricity around 55% by 2030
Decarbonization	■ Carbon intensity target of 100 g/kWh in 2030	■ 22 GW of offshore wind required (base scenario)
Nuclear targets	■ Allowing nuclear expansion from 8.2 to 16.4 GW	■ No improvements over the total system cost of the base scenario
Import / export	■ Net import / export balance is zero	-

- Offshore wind is a key technology for decarbonization, nuclear still prominent
- Necessary flexibility options include storage, frequency regulation for wind, and increased interconnection with mainland Europe

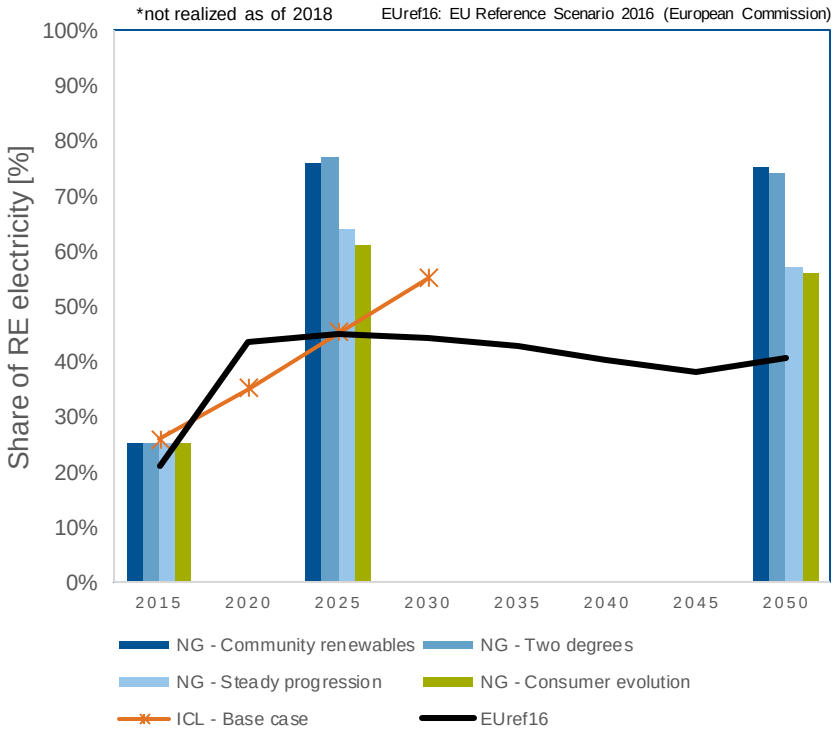
[3] National Grid (2018), Future Energy Scenarios – July 2018. http://fes.nationalgrid.com/media/1363/fes-interactive-version-final.pdf **(only electricity and gas sectors)**
[4] Imperial College London (2016). Whole-system cost of variable renewables in future GB electricity system. https://www.e3g.org/docs/Whole-system_cost_of_variable_renewables_in_future_GB_electricity_system.pdf

United Kingdom – Demand & RE share

Electricity demand



Share of renewable electricity (RE%)



- Electrification in heating and mobility leads to steady increase in demand across every scenario
- Larger GDP growth and electrification of heating in the scenario „*NG – Community renewables*“ (2%/a) result in a higher increase in demand compared to other *NG* scenarios

- „*EUref16*“: 150% increase* in wind installed capacity between 2015 – 2020 leads to a sharp rise in RE%, which later drops due to new nuclear installations starting from 2030
- A wide range of values across the scenarios, up to around 80%

Belgium – Insights from studies

ELIA [5]

Indicator	■ Targets / ■ Causes	■ Requirements / ■ Outcomes
Energy demand	■ Electrification in heating & transport + energy efficiency	■ FEC ↓, electricity consumption ↑
Share of renewable energies	■ High share of RE	■ Strong grid, flexible fleet & demand, and storage required
Decarbonization	■ 80% reduction in GHG emissions (1990-2050)	■ Around 90% carbon-free electricity required
Nuclear targets	■ Nuclear phase-out by 2025	■ New thermal capacity (+3.6 GW) required
Import / export	■ Competitive prices compared to neighbours	■ New interconnectors (+4 GW) and efficient CCGT required

Federal Planning Bureau [6]

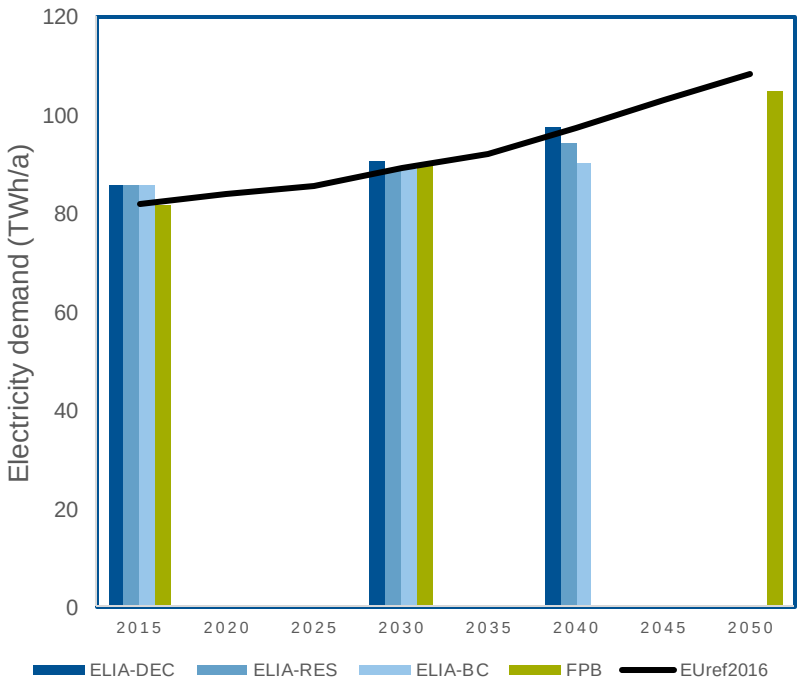
Indicator	■ Targets / ■ Causes	■ Requirements / ■ Outcomes
Energy demand	■ High CO_2-elc. price and efficiency (-), growth (+)	■ Near constant (+0.1%/a) FEC, growing (+0.8%/a) electricity
Share of renewable energies	■ 13% of gross final energy consumption by 2020	■ 12% in 2030, 16% in 2050
Decarbonization	■ Higher RE, CHP & import, shutdown coal plants	■ 10% reduction in total CO_2 (2015–2050)
Nuclear targets	■ Nuclear phase-out by 2025	■ Surge in gas-fired power generation by 2020
Import / export	■ Unavailability of the nuclear fleet + high VRE	■ Rise in net imports between 2030–2050; up to 25 TWh/a

- Across all scenarios: nuclear phase-out set by 2025
- Additional thermal capacity and/or interconnectors necessary for base load
- Wind power is a major renewable electricity contributor

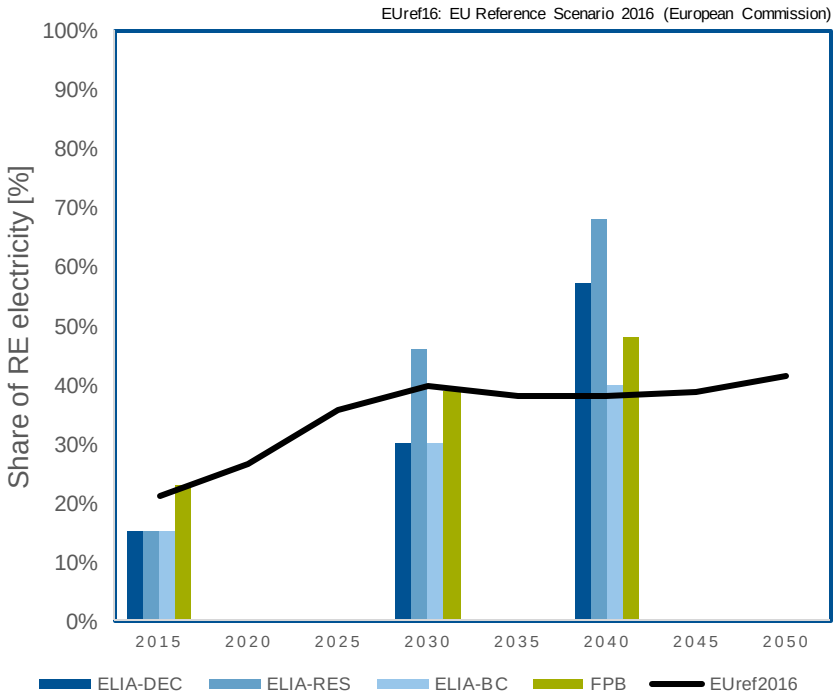
[5] Elia system operator, Electricity scenarios for Belgium towards 2050 (2017). https://www.elia.be/~/media/files/Elia/About-Elia/Studies/20171114_ELIA_4584_AdequacyScenario.pdf
[6] Federal planning bureau, Energy outlook for Belgium towards 2050 (2017). https://www.plan.be/admin/uploaded/201710270928090.For_Energy_2017_11531_F.pdf (fr)

Belgium – Demand & RE share

Electricity demand



Share of renewable electricity (RE%)



- Studies agree on a prediction of consistently increasing electricity demand by 2050
- Electrification of other sectors (e.g. via EV's and heat pumps) outweighs energy efficiency

- Discrepancy in 2015 values, possibly stemming from different definitions for RE
- EUref16 predicts a stagnation of RE% around 40%
- The more ambition RE targets in ELIA scenarios lead to shares up to 70%

Netherlands – Insights from studies

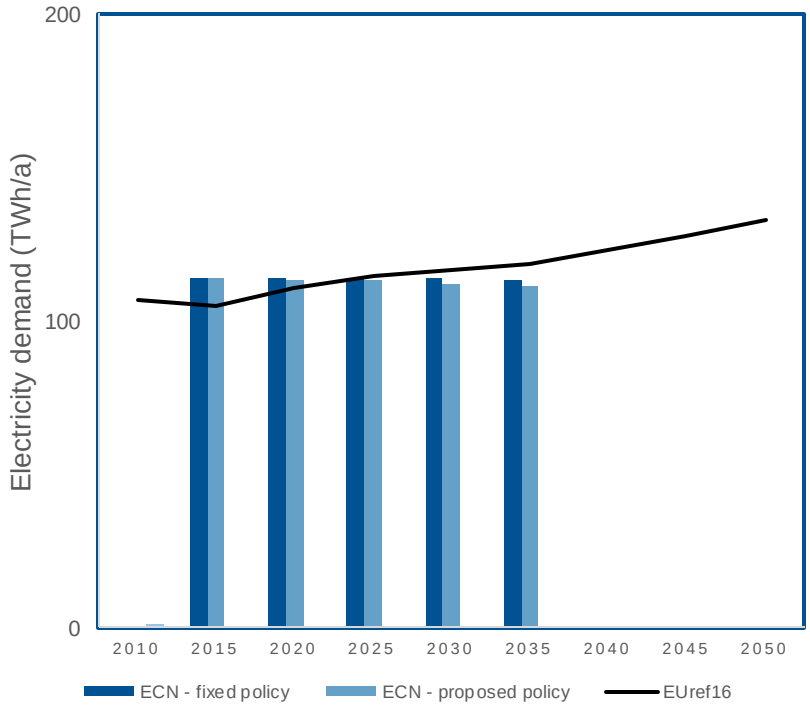
	Indicator	■ Targets / ■ Causes	■ Requirements / ■ Outcomes
ECN [7]	Energy demand	■ Savings especially in residential sector	■ Up to 5% decrease in FE demand between 2015–2035
	Share of renewable energies	■ Support schemes for RE	■ Up to 30% share of RE in FEC by 2035 (major sources: wind and biomass)
	Decarbonization	■ Falling use of gas and coal + rise in offshore wind	■ Total GHG emissions falls below 150 Mton CO_2 eqv. by 2035
	Nuclear targets	■ No new investment in nuclear energy	■ Last nuclear power plant (Borssele) shutting down in 2033
	Import / export	■ Frequent overproduction by offshore wind plants	■ Netherlands becoming a net exporter (up to 30 TWh/a) by 2035

- Support policies are suggested for promoting the expansion of renewable energies
- Offshore wind expected to dominate the electricity generation in future
- Biomass has high contribution to heat sector

[7] The Energy Research Centre of the Netherlands (2017). Nationale Energieverkenning 2017 (National energy outlook 2017). https://www.ecn.nl/publicaties/ECN-O--17-018 (nl)

Netherlands – Demand & RE share

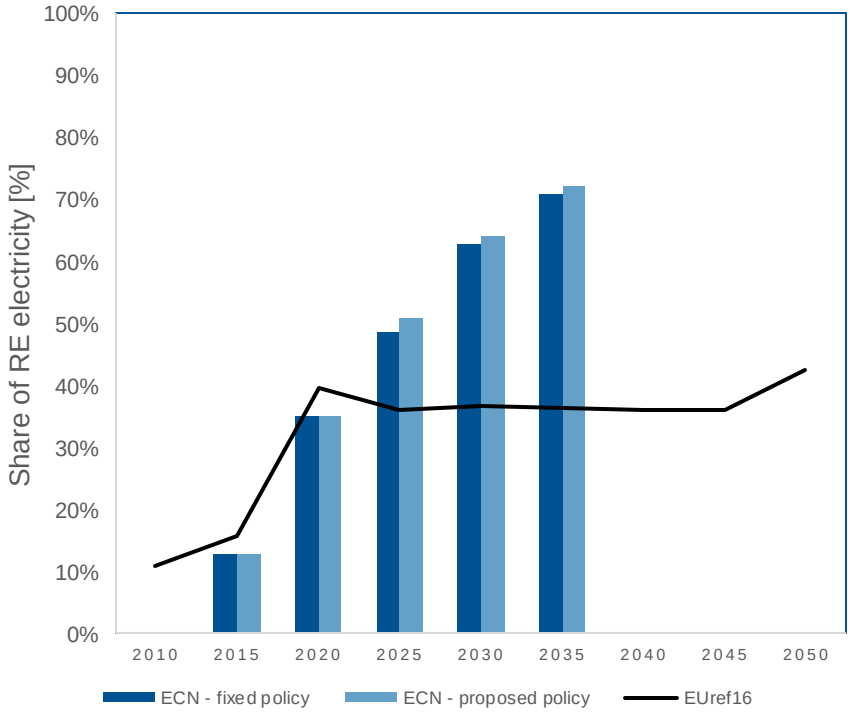
Electricity demand



- *„EUref16“:* Steady increase in electricity demand due to electrification
- *„ECN“* scenarios*:* Despite the rise in EVs and other electrification avenues (e.g. heat pumps in residential and commercial sectors), efficiency measures prevent an overall increase in the electricity demand

Share of renewable electricity

EUref16: EU Reference Scenario 2016 (European Commission)



- *„EUref16“:* sharp increase between 2015 – 2020 through a surge of wind plant installations, stagnation afterwards
- *„ECN“* scenarios: Utilization of solid and gas fired plants are less than *„EUref16“*, resulting in a much higher share of RE in the electricity mix

Denmark – Insights from studies

Aalborg Universitet [8]

Indicator	Targets / Causes	Requirements / Outcomes
Energy demand	Electrification of heating, transport and industry	Electricity demand more than doubles between 2015–2050
Share of renewable energies	100% renewable energy supply by 2050	Flexibility in sectors required through coupling
Decarbonization	100% renewable energy supply by 2050	~80% reduction of CO_2 from energy sector in 2035 and zero in 2050
Nuclear targets	No nuclear energy in Denmark	Dependence on biomass-fired CHP as base-load alternative
Import / export	Low dependence on electricity exchange	Flexibility required via domestic, cross-sector energy exchange

Danish Energy Agency [9]

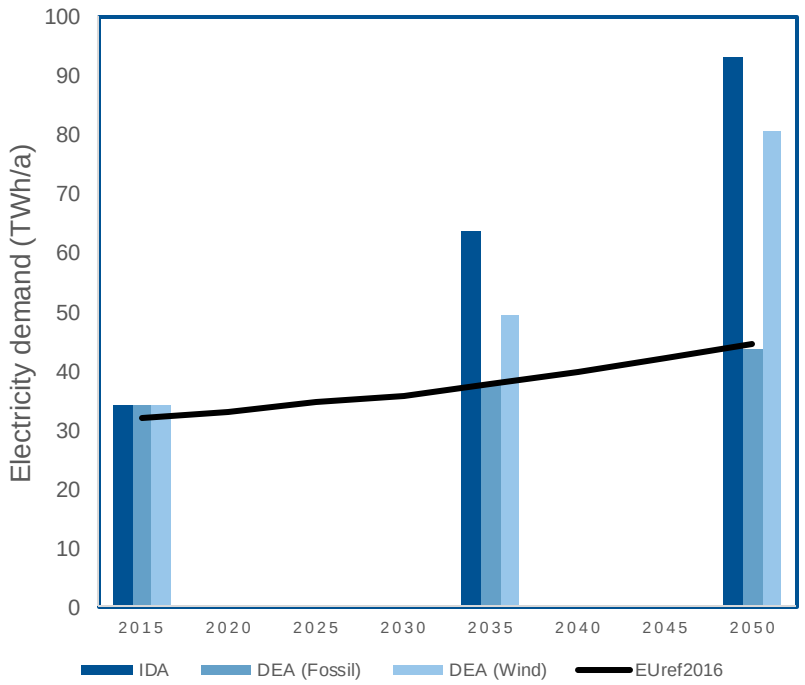
Indicator	Targets / Causes	Requirements / Outcomes
Energy demand	Savings through energy efficiency	Reduction of ‚net' energy consumption to 100 TWh possible in 2050
Share of renewable energies	100% renewable energy supply by 2050 **(DEA-Wind)**	Dominance of wind electricity (50-90% of total eletricity consumption)
Decarbonization	Non-fossil heat/elec. by 2035, energy by 2050 **(DEA-Wind)**	5-25% higher costs compared to a fossil fuel scenario in 2050
Nuclear targets	No nuclear energy in Denmark	Dependence on bioenergy for base-load (domestic capacity 250 PJ)
Import / export	100% self-sufficiency in energy by 2050 **(DEA-Wind)**	Significant use of offshore wind and/or hydrogen required

- Abundance of wind resources enables 100% renewable energy supply by 2050, as well as zero emissions from energy sector
- Expansion of biomass plants is crucial for supplying the base load in the absence of nuclear energy

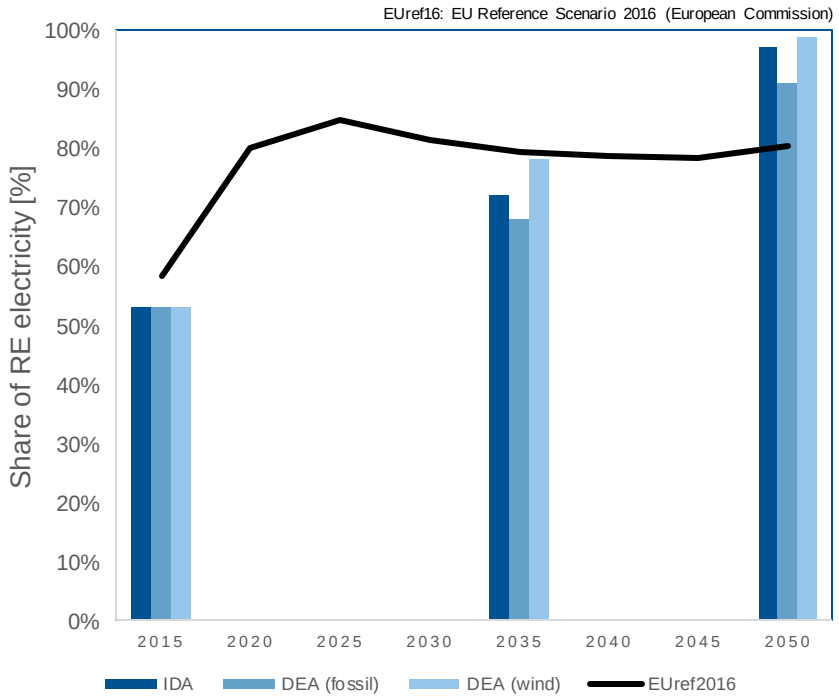
[8] Mathiesen, B. V., Lund, H., Hansen, K., Ridjan, I., Djørup, S. R., Nielsen, S., ... Østergaard, P. A. (2015). IDA's Energy Vision 2050: A Smart Energy System strategy for 100% renewable Denmark. Department of Development and Planning, Aalborg University. http://vbn.aau.dk/files/222230514/Main_Report_IDAs_Energy_Vision_2050.pdf
[9] Danish Energy Agency (2014), Energiscenarier frem mod 2020, 2035 og 2050. https://ens.dk/sites/ens.dk/files/Basisfremskrivning/energiscenarier_-_analyse_2014_web.pdf (da)

Denmark – Demand & RE share

Electricity demand



Share of renewable electricity (RE%)



- Ambitious RE targets in *„IDA“* and *„DEA (wind)“* scenarios correlate to higher demands of electricity through the electrification of heating, transport and industry sectors

- *„EUref16“:* Increase in production in gas-fired plants, starting from 2030, leads to a reduction in RE%
- *„DEA“ and „IDA“ scenarios*: almost 100% renewable electricity production by 2050

Norway – Insights from studies

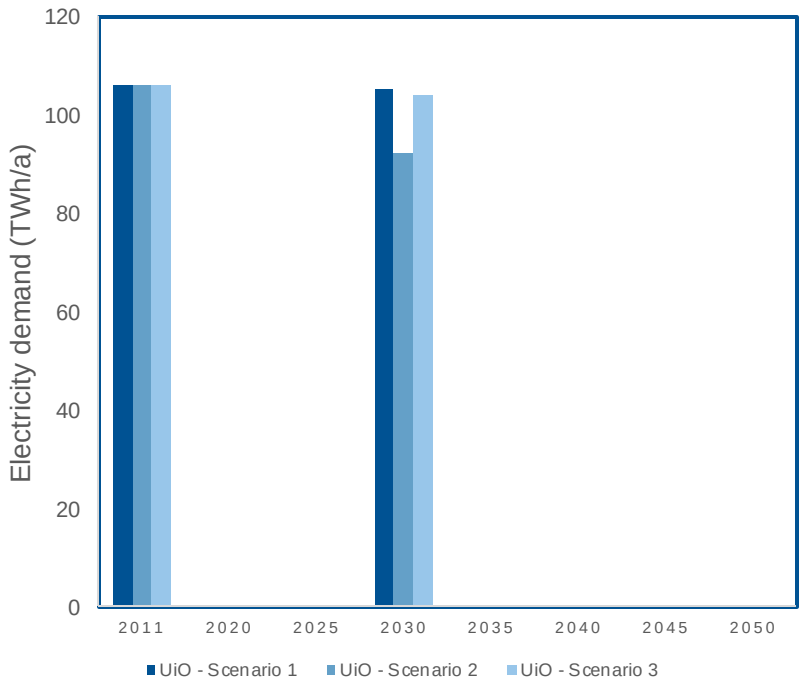
UiO [10]	Indicator	■ Targets / ■ Causes	■ Requirements / ■ Outcomes
	Energy demand	■ Efficiency, electrification mostly in transport	■ No change in electricity demand, ~10% decrease in FEC
	Share of renewable energies	■ High hydropower potential + electrified sectors	■ Up to 80% renewable in FEC possible (2011: 58%)
	Decarbonization	■ Electrified sectors and widespread district heating	■ ~37% reduction in CO_2 emissions estimated (2011 – 2030)
	Nuclear targets	■ No nuclear power in Norway	-
	Import / export	■ Capacity addition in hydropower	■ 50 TWh/year (40% of domestic demand) export in electricity by 2030

- High potential for decarbonization lies on the electrification of the transport sector in Norway (by 2011, 96% of transport is fossil-fueled)
- High export potential emerges by building new hydropower, which must be supplemented by new interconnectors

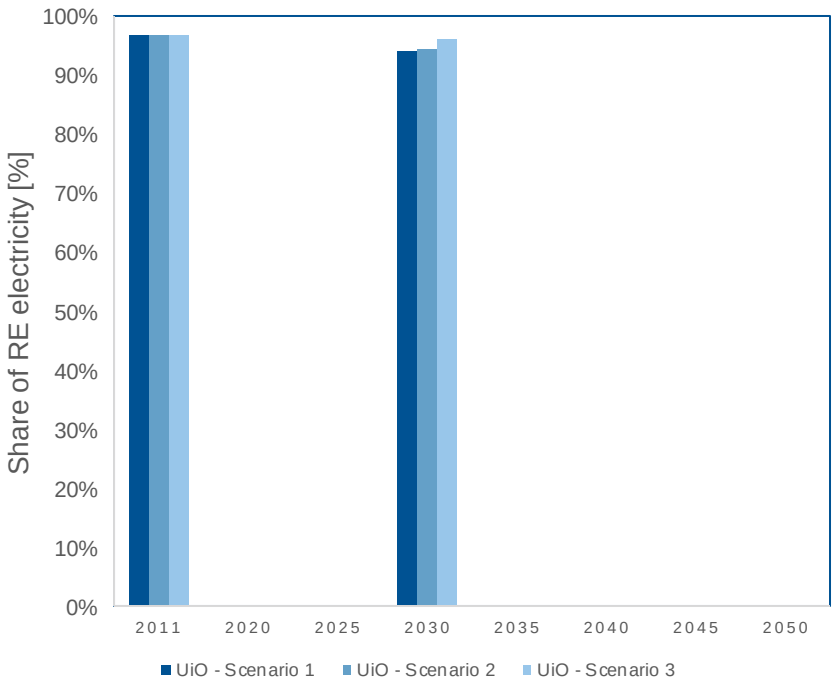
[10] Bendiksen, K, (UiO Energi). Det norske energiesystemet mot 2030. (2014) (*The Norwegian energy system towards 2030*) https://www.duo.uio.no/bitstream/handle/10852/38734/uio_energi_WEB_NY.pdf

Norway – Demand & RE share

Electricity demand



Share of renewable electricity (RE%)



- Efficiency measures are compensated by the electrification of sectors (mainly of transport)
- A stable share of renewable electricity larger than 90% is predicted

Sweden – Insights from studies

SEA [11]	Indicator	■ Targets / ■ Causes	■ Requirements / ■ Outcomes
	Energy demand	■ Various conjunctures and policies regarding energy	■ Level of FEC by 2050 ranges between 243–375 TWh (2014: 375 TWh)
	Share of renewable energies	■ 100% renewable electricity supply **(Legato & Vivace)**	■ Policy instruments: CO_2 tax **(Legato)** or RE certificates **(Vivace)**
	Decarbonization	■ EU GHG targets for 2030 are fulfilled across all scenarios	■ Sweden is expected to set new and more ambitious goals nationally
	Nuclear targets	■ Expansion of new nuclear between 2025–2035 **(Forte)**	■ Active state support specific for nuclear required
	Import / export	■ Vast potential for low emission electricity production	■ Expansion wind & hydro + transmission capacity → high export opportunities

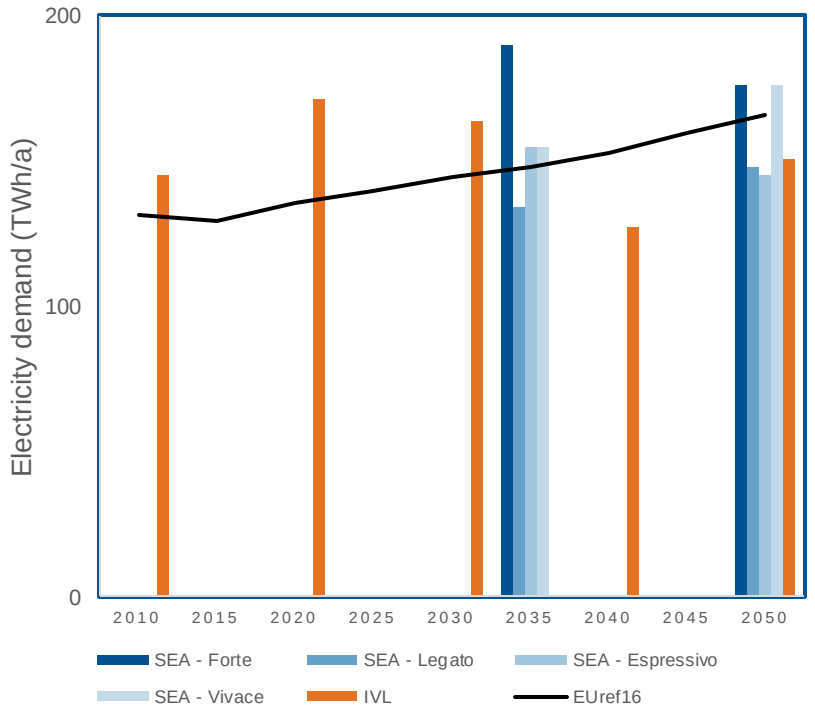
IVL [12]	Indicator	■ Targets / ■ Causes	■ Requirements / ■ Outcomes
	Energy demand	■ Energy efficiency measures across all sectors	■ 30% decrease in FEC and 20% decrease in electricity (2010–2050)
	Share of renewable energies	■ 100% of total energy from renewables by 2050	■ Hydro, wind, PV for electricity; bioenergy for heating and transport
	Decarbonization	■ 100% of total energy from renewables by 2050	■ No energy-related CO_2 by 2050 (only 8 Mton CO_2 from steel industry)
	Nuclear targets	■ Phase-out and decommission by 2040	■ Base-load electricity is then supplied by hydropower
	Import / export	■ High RE capacities coupled with nuclear generation	■ High export potential until nuclear phase-out and by 2050

- High hydropower potential of Sweden may grant it the role of exporter
- Possibility of 100% renewable electricity supply was investigated by both studies

[11] Swedish Energy Agency (2016). Four Futures: The Swedish energy system beyond 2020. https://energimyndigheten.a-w2m.se/FolderContents.mvc/Download?ResourceId=5603
[12] Swedish Environmental Research Institute (2011). Energy Scenario for Sweden 2050: Based on Renewable Energy Technologies and Sources. http://www.wwf.se/source.php/1409709/Energy%20Scenario%20for%20Sweden%202050_bakgrundsrapport%20IVL_sep%202011.pdf

Sweden – Demand & RE share

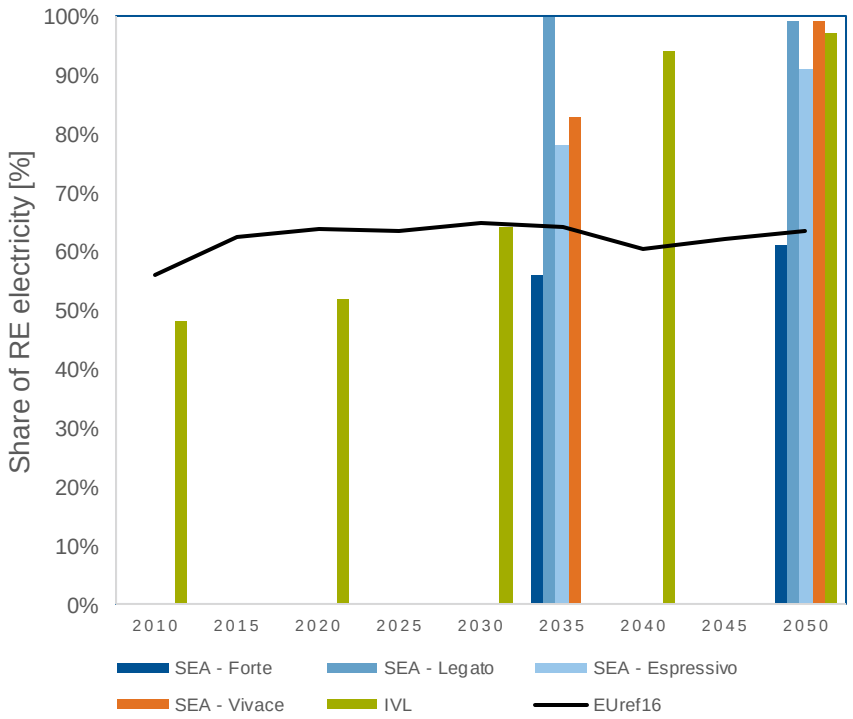
Electricity demand



- *„EUref16“* scenario predicts a steady increase in electricity demand
- *„SEA“* and *„IVL“* studies have a wide range of estimates depending on their scenario assumptions

Share of renewable electricity

EUref16: EU Reference Scenario 2016 (European Commission)



- *„EUref16“* scenario predicts a stable RE% around 60–70% as a nuclear phase-out is not stipulated
- Up to 100% renewable electricity is achieved by the *„SEA“* and *„IVL“* scenarios

Poland – Insights from studies

C: Coal scenario, D+N: Diversified scenario, D-N: Diversified without nuclear, RES: Renewables scenario

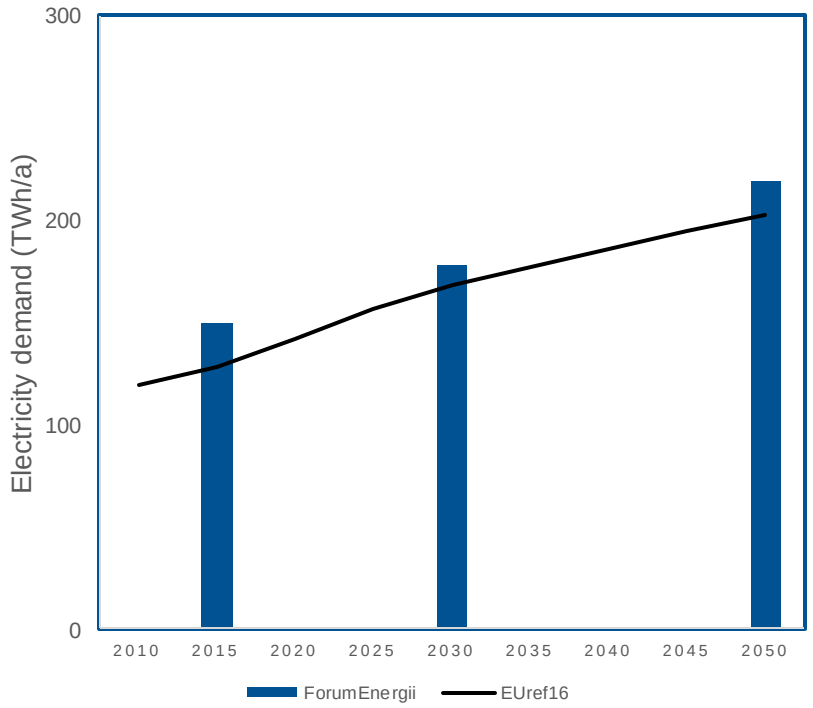
ForumEnergii[13]	Indicator	■ Targets / ■ Causes	■ Requirements / ■ Outcomes
	Energy demand	■ Electrification of transport and heating + efficiency	■ Yearly increase in electricity demand: +1.4%/a
	Share of renewable energies	■ No retrofit or building coal + phase-out in 2050 **(RES)**	■ Large share in RE electricity (around 73%), supported by gas CHP
	Decarbonization	■ High RE scenario with eventual coal phase-out **(RES)**	■ European climate targets are followed, EU ETS levels achieved by 2033
	Nuclear targets	■ Capacity expansion up to 6 GW after 2030 **(D+N)**	■ 10% lower annual system costs by 2050 compared to RES scenario
	Import / export	■ Increase in demand, inadequate fossil resources	■ Notable import dependency (between 19% **(RES)** and 39% **(C)**)

- Contrary to the European Reference Scenario 2016, „ForumEnergii“ predicts considerable utilization of the PV potential in Poland towards 2050 (except in the coal scenario)
- Expansion of wind energy is expected in every scenario because of its competitive LCOE

[13] ForumEnergii (2017). Polish energy sector 2050 – 4 scenarios. http://forum-energii.eu/files/file_add/file_add-99.pdf

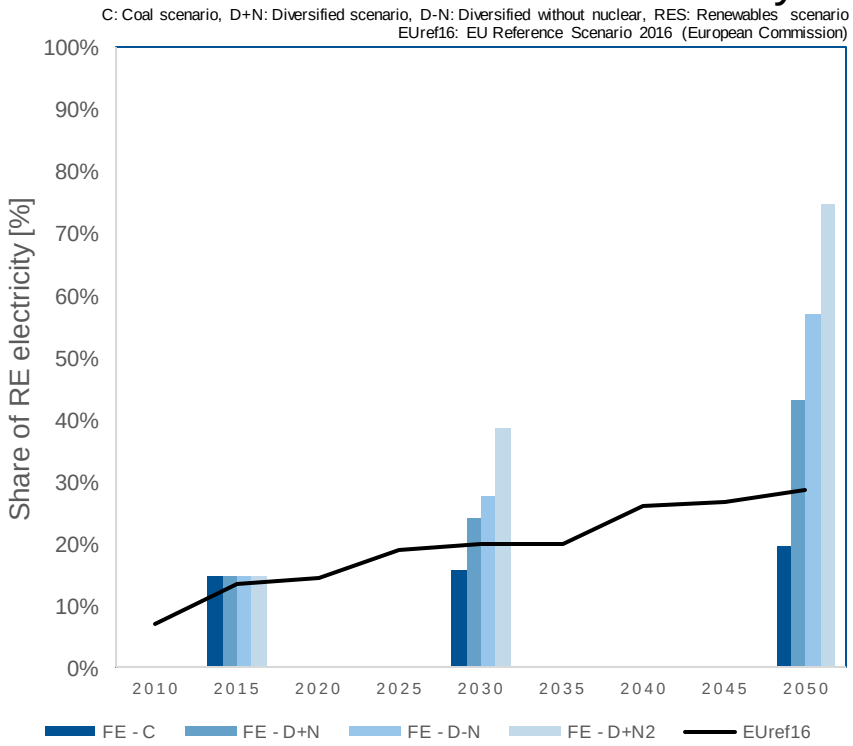
Poland – Demand & RE share

Electricity demand



- Common trend of increasing electricity demand for both scenarios
- Discrepancy in 2015 values

Share of renewable electricity



- *„EUref16“* scenario predicts in general a less ambitious RE% by 2050 compared to the *„ForumEnergii“* scenarios
- *„ForumEnergii“* scenarios illustrate a wide range of outcomes in terms of RE%

Czech Republic – Insights from studies

OPT: Optimized, **GAS:** gas scenario with limited self-sufficiency, **GRE:** green scenario with limited self.sufficiency, **SSF:** safe and self sufficient scenario, **CE:** conventional economic scenario, **DEC:** decarbonization scenario

Ministry of Ind. And Tr. [14, 15]

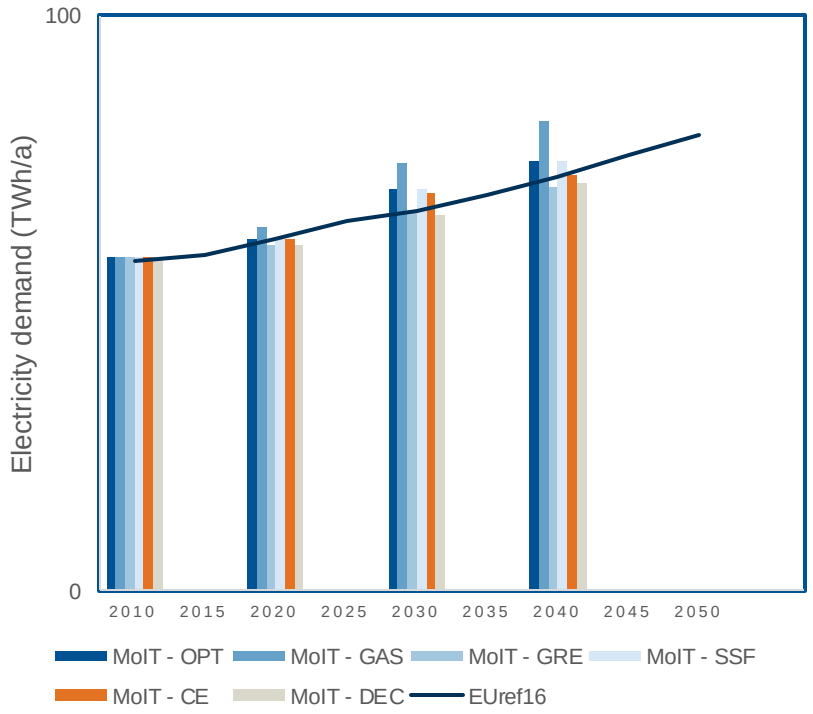
Indicator	■ Targets / ■ Causes	■ Requirements / ■ Outcomes
Energy demand	■ Growth in economic activity (GDP around +2%/a)	■ Very slight increase in FEC (despite saving measures)
Share of renewable energies	■ Limited physical potential for renewable electricity	■ Limited share of RE in the electricity mix
Decarbonization	■ 40%/75% reduction in hard coal/lignite (2010–2040) **(DEC)**	■ Fuel-related CO_2 emissions down to 70 Mt by 2040 (From ~115 Mt in 2010)
Nuclear targets	■ Significant share of nuclear elec. + high public acceptance	■ No phase-out planned; possibly capacity expansion **(OPT)**
Import / export	■ Secure energy supply and commercial advantage of export	■ Maintaining the import/export capacity at 30% of max. load

- Despite low potential for renewable electricity generation, high RE shares in overall energy production are aimed at to be achieved via biomass in heating sector
- Substitution of some fossil-fuel plants with additional nuclear capacity is aimed at for lower emissions

[14] Ministry of Industry and Trade (2014). State Energy Policy of the Czech Republic. https://www.mpo.cz/assets/dokument/52841/60946/636123/priloha001.pdf
[15] Ministry of Industry and Trade (2014). Additional analytical material for the State Energy Policy. https://www.mpo.cz/assets/dokument/52841/60959/636209/priloha004.pdf

Czech Republic – Demand & RE share

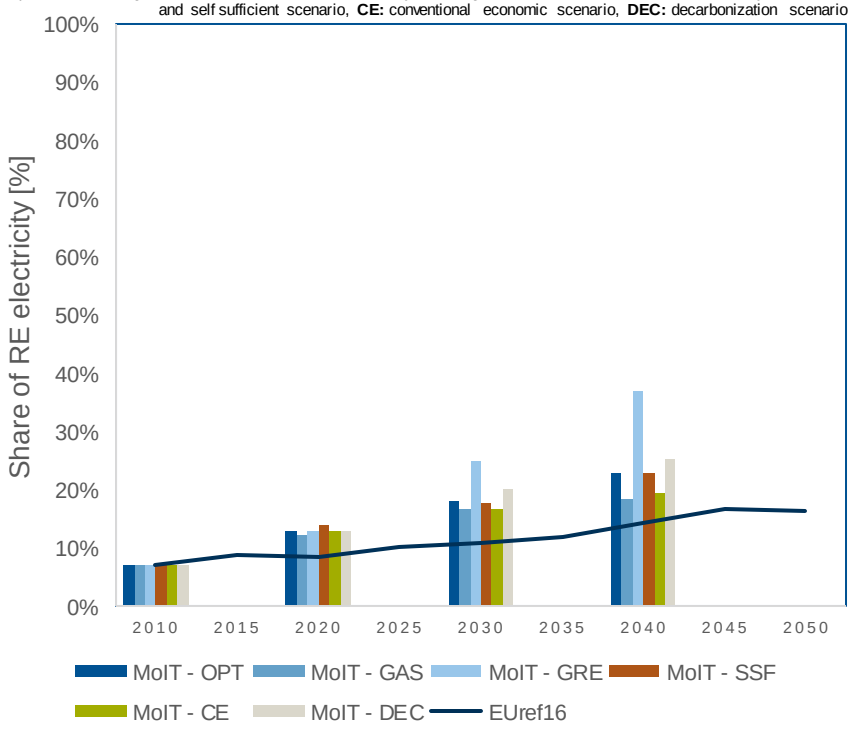
Electricity demand



- Across every scenario, the electricity demand is expected to grow steadily over years

Share of renewable electricity

OPT: Optimized, **GAS:** gas scenario with limited self-sufficiency, **GRE:** green scenario with limited self.sufficiency, **SSF:** safe and self sufficient scenario, **CE:** conventional economic scenario, **DEC:** decarbonization scenario



- Since it envisions less PV and wind expansion, the *„EUref16“* study predicts an overall lower RE% in electricity than the *„MoIT“* scenarios

Slovakia – Insights from studies

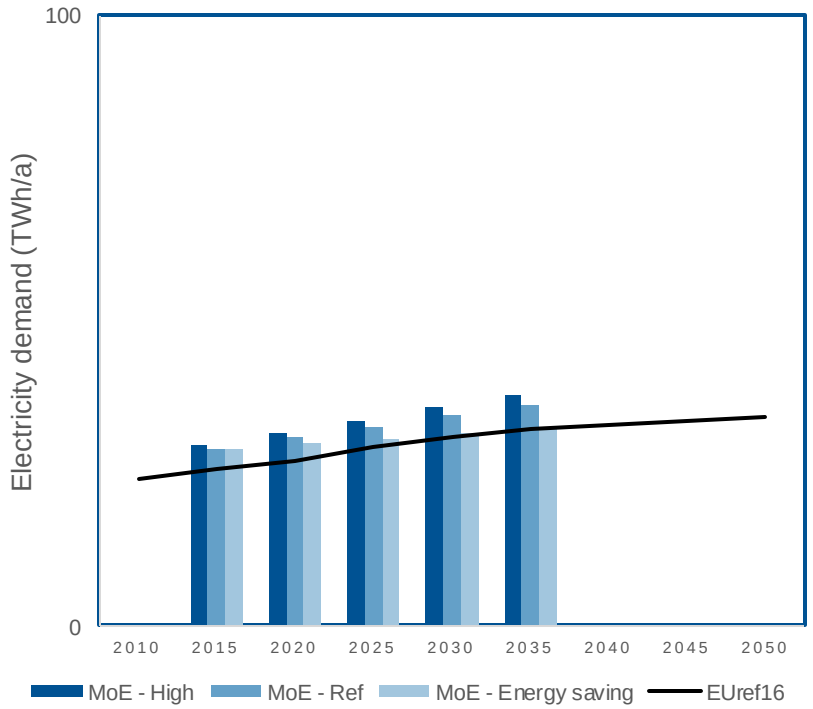
Ministry of Economy [16]	Indicator	■ Targets / ■ Causes	■ Requirements / ■ Outcomes
	Energy demand	■ Further economic growth	■ Increase in FEC in reference scenario despite efficiency measures
	Share of renewable energies	■ Increasing RE share in gross FEC to 14% by 2020	■ Harnessing hydro potential + expansion of wind and bioenergy
	Decarbonization	■ Hydro & nuclear → already low emissions in electricity	■ Higher abatement potential in heating and transport sectors
	Nuclear targets	■ Growing economy + low-carbon policy in electricity	■ Construction of new nuclear in Mochocve (and possibly Bohunice)
	Import / export	■ New NPP + possible extension of Bohunice V2 in 2025	■ Significant surplus in grid -> Slovakia will be an electricity exporter

- High economic growth prevents reducing the energy demand in Slovakia (except in the savings scenario)
- For supplying low-carbon electricity, Slovakia prioritizes the operation (and expansion) of nuclear energy over exploiting renewable energy resources

[16] Ministry of Economy of the Slovak Republic (2014). Energy Policy of the Slovak Republic. https://www.mhsr.sk/uploads/files/47NgRIPQ.pdf

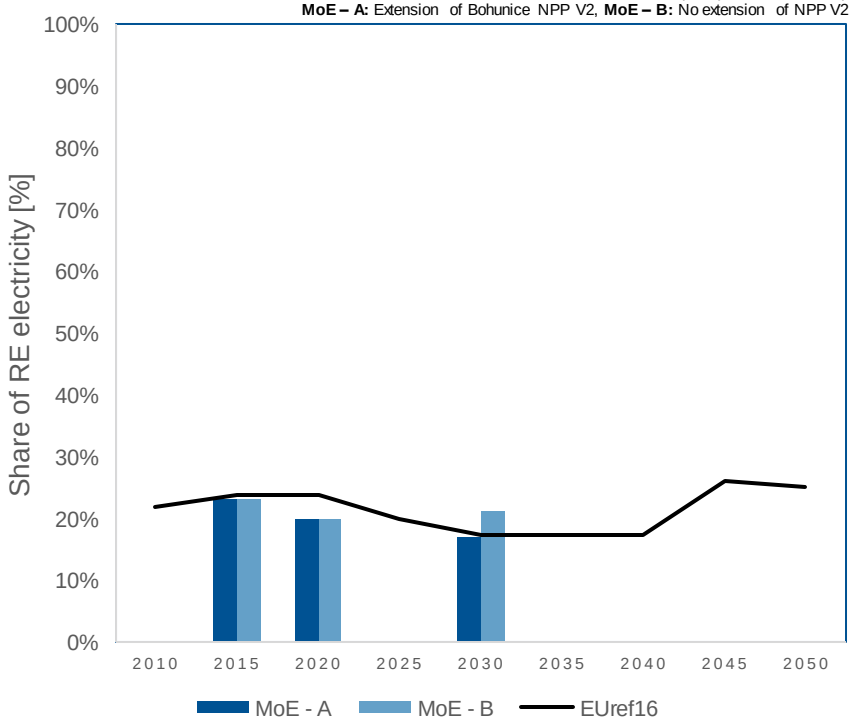
Slovakia – Demand & RE share

Electricity demand



Share of renewable electricity

EUref16: EU Reference Scenario 2016 (European Commission)
MoE – A: Extension of Bohunice NPP V2, **MoE – B:** No extension of NPP V2



- Reflecting the growth in economy, the electricity demand is expected to grow steadily over years
- The nuclear capacity expansion has a negative effect on RE% by 2020 and 2030

Hungary – Insights from studies

Wuppertal [17]

Indicator	■ Targets / ■ Causes	■ Requirements / ■ Outcomes
Energy demand	■ Better insulation, public transportation X GDP growth	■ +10%–(-40%) change in FEC, +40–70% increase in electricity demand 2010–2050
Share of renewable energies	■ Using 10–20% of the technical potential of RE	■ Between 62–78% share of renewable electricity
Decarbonization	■ Efficiency + replacement of aged plants with RE **(GREEN)**	■ Up to 77% reduction of energy-related CO_2 reductions 1990–2050
Nuclear targets	■ Capacity expansion of Paks NPP by 2030 **(NUCLEAR)**	■ Emissions still increase between 2030–2050 (need for extra conv. PP)
Import / export	■ High PV installed capacity **(Scenario GREEN)**	■ Slight export surplus by 2050 (high production from PV in summer)

NG: Nuclear-Green, **ANG:** Antinuclear-Green, **NG+:** Nuclear-Green(+), **NCG:** Nuclear-Coal-Green, **ANG+:** Antinuclear-Green(+)

Ministry of Nat. Dev. [18]

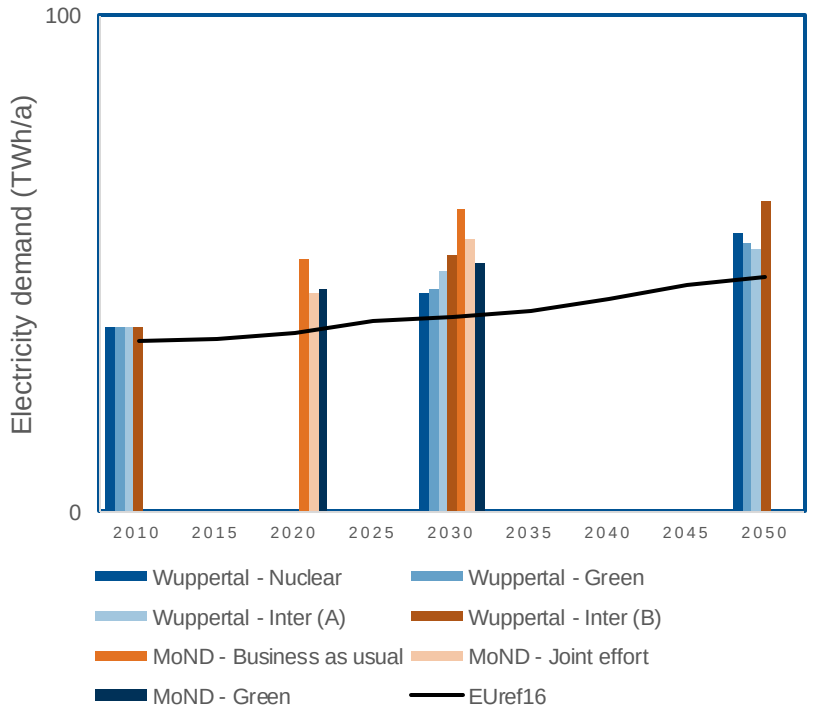
Indicator	■ Targets / ■ Causes	■ Requirements / ■ Outcomes
Energy demand	■ Various levels of political measures	■ +20%–(-30%) change in FEC; up to 50% increase in elec. demand 2008–2030
Share of renewable energies	■ 2020 target: Increase RE share in PEC to 20%	■ Primary measures: CHP plants from biomass/-gas + geothermal heat
Decarbonization	■ Extensive decarbonization in electricity production by 2050	■ Through nuclear and/or gas (with CCS), supported by RE **(N+G)**
Nuclear targets	■ No new NPP, RE targets from NREAP extended **(ANG)**	■ Scenario with the lowest system cost, but has the highest emissions
Import / export	■ Most probable scenario: **(Nuclear-Coal-Green)**	■ Exports up to 13% of the total electricity consumption possible by 2030

- The future course of final energy demand is not certain; depends on policies regarding the growth rate and the extent of efficiency measures
- Hungary is likely to become an electricity exporting country by 2030–2050

[17] Wuppertal Institute (2016). Alternative and Sustainable Energy Scenarios for Hungary. https://www.energiaklub.hu/files/study/ASES-ENG.pdf
[18] Ministry of National Development (2012). National Energy Strategy 2030. http://2010-2014.kormany.hu/download/7/d7/70000/Hungarian%20Energy%20Strategy%202030.pdf

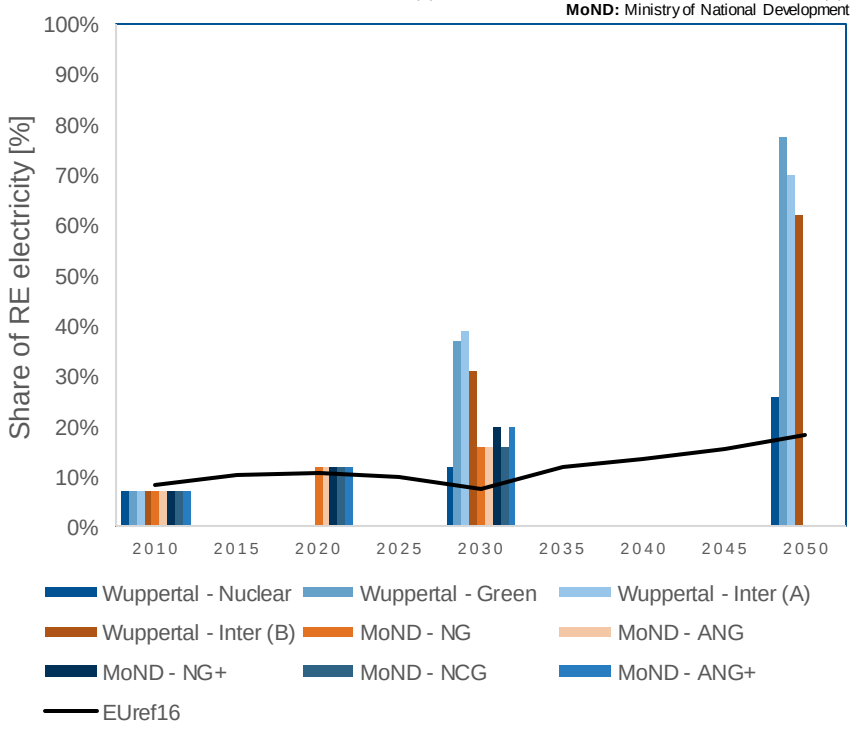
Hungary – Demand & RE share

Electricity demand



Share of renewable electricity

NG: Nuclear-Green, **ANG:** Antinuclear-Green, **NG+:** Nuclear-Green(+), **NCG:** Nuclear-Coal-Green, **ANG+:** Antinuclear-Green(+), **MoND:** Ministry of National Development



- The electricity demand is expected to grow steadily over years across every scenario
- *„EUref16“* scenario predicts a lower rate of increase than the other studies

- *„MoND“ and „EUref16“* scenarios expect a RE% up to 20% by 2030 and 2050 respectively
- Ambitious RE-scenarios of the Wuppertal Institute demonstrate the possibility of 40% and 80% share of renewable electricity by 2030 and 2050 respectively

Austria – Insights from studies

Umweltbundesamt1 [19]

Indicator	■ Targets / ■ Causes	■ Requirements / ■ Outcomes
Energy demand	■ Keeping FEC constant at 300 TWh for 2020 – 2035	■ Additional measures **(WAM)** in efficiency, energy saving in buildings
Share of renewable energies	■ >34% of the total energy production by 2020	■ High utilization of hydropower and biomass
Decarbonization	■ Non-ETS GHG emissions 2015–2035: -16%	■ Up to 30% reduction is possible with additional measures **(WAM)**
Nuclear targets	■ No nuclear energy in Austria	-
Import / export	■ Lower energy demand via additional measures	■ Austria becomes net energy exporter by 2020

Umweltbundesamt2 [20]

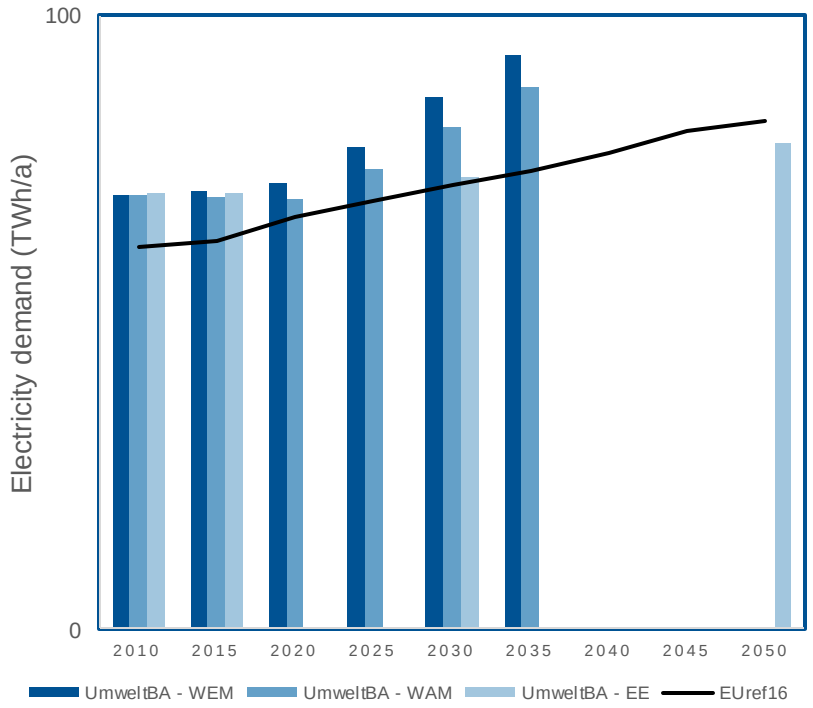
Indicator	■ Targets / ■ Causes	■ Requirements / ■ Outcomes
Energy demand	■ Non-fossil heating in buildings + electrified mobility	■ 45% reduction of FEC (to 177 TWh) between 1990–2050
Share of renewable energies	■ >85% of RE potential harnessed	■ >90% of total energy production is RE by 2050
Decarbonization	■ Intensive substitution of fossil fuels by RE	■ Up to 90% reduction in energy-related -80% of total- GHG emissions
Nuclear targets	■ No nuclear energy in Austria	-
Import / export	■ Frequent overproduction by variable RE	■ Austria exports 20% of its electricity production by 2050

- Hydropower is regarded as the prominent form of electricity production in Austria
- The scenarios cover a wide range of decarbonization pathways and demonstrate the possibility of high utilization of renewable energies (not limited to electricity)

[19] Umweltbundesamt (2015). Energiewirtschaftliche Szenarien im Hinblick auf die Klimaziele 2030 und 2050. http://www.umweltbundesamt.at/fileadmin/site/publikationen/REP0534.pdf (de)
[20] Umweltbundesamt (2016). Szenario erneuerbare Energie 2030 und 2050. http://www.umweltbundesamt.at/fileadmin/site/publikationen/REP0576.pdf (de)

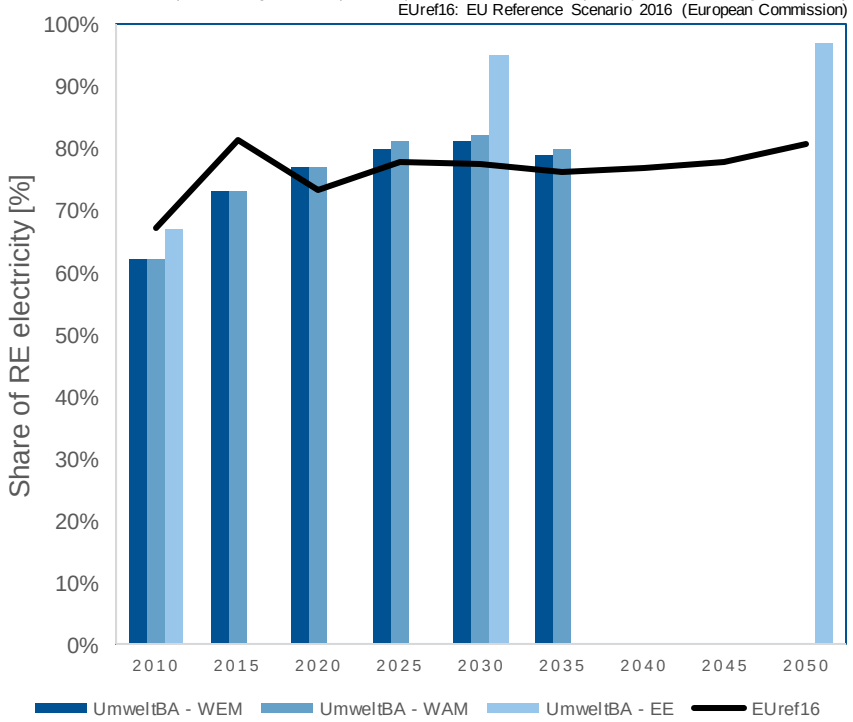
Austria – Demand & RE share

Electricity demand



Share of renewable electricity

WEM: (With existing measures), WAM (With additional measures), EE (Renewable energies scenario)
EUref16: EU Reference Scenario 2016 (European Commission)



- Common trend of increasing electricity demand across all scenarios, with varying rates
- Discrepancy in 2010 – 2015 values

- *„EUref16“* scenario predicts a share of renewable electricity converging around 75%
- An almost completely renewable electricity mix is demonstrated by the scenario *„UmweltBA – EE“*

Slovenia – Insights from studies

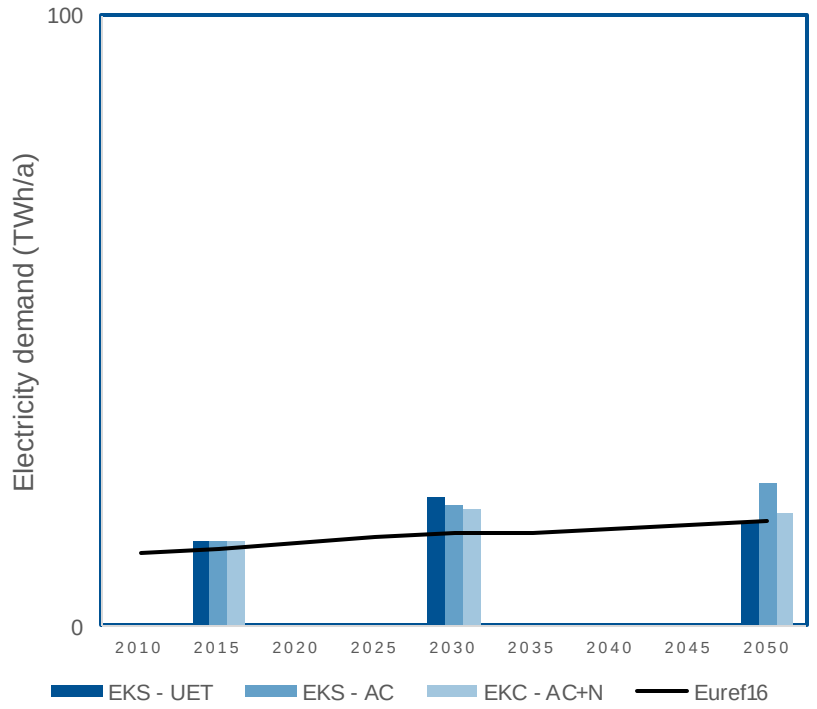
	Indicator	■ Targets / ■ Causes	■ Requirements / ■ Outcomes
EKS [21]	Energy demand	■ Growth, efficiency and electrification (in transport) targeted	■ ±10% change in FEC, +20–65% increase in electricity demand 2015–2050
	Share of renewable energies	■ 52% share of RE in final energy consumption (target)	■ 65% RE heat, 50–100% RE electricity, expansion of electric mobility
	Decarbonization	■ Reduction of GHG emissions by 80% between 1990–2050	■ 52% share of RE in FEC, 38% primary energy savings, 66% EV‘
	Nuclear targets	■ More than one third of electricity generation is nuclear	■ Phase-out is not planned (life-time extension made for Krsko NPP)
	Import / export	-	-

- In Slovenia, expansion of renewable energy is planned across all sectors
- Solar and hydropower are expected to be the major sources for renewable electricity
- Nuclear phase-out is not planned, and capacity expansion is possible (after 2045)

[21] Ministry of Infrastructure (2017). Energy Concept of Slovenia. http://www.mzi.gov.si/fileadmin/mzi.gov.si/pageuploads/Kabinet_ministra/gradivozarazpravoEKS.docx (si)

Slovenia – Demand & RE share

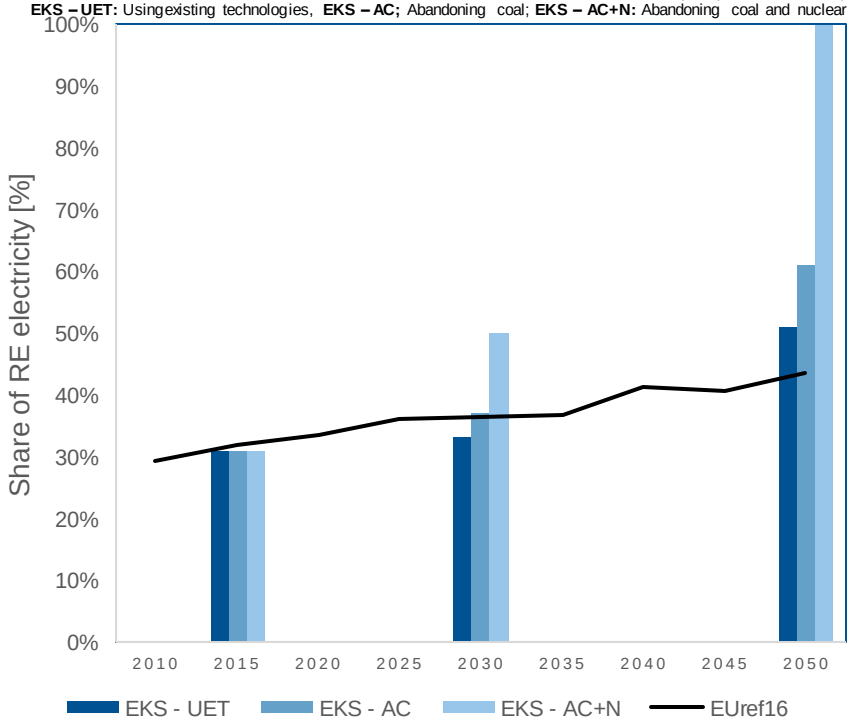
Electricity demand



- Reflecting the growth in economy and the effect of electrification especially in transport, the electricity demand is expected to grow steadily over years

Share of renewable electricity

EUref16: EU Reference Scenario 2016 (European Commission)
EKS – UET: Usingexisting technologies, **EKS – AC;** Abandoning coal; **EKS – AC+N:** Abandoning coal and nuclear



- *„EUref16“* expects a growth in RE% up to 40% by 2050, in general lower than *„EKS“* scenarios
- The *„EKS“* scenarios predict in general higher shares of renewable electricity than *„EUref16“*

Italy – Insights from studies

MSE [22]

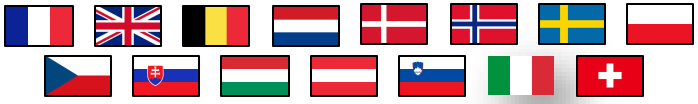
Indicator	■ Targets / ■ Causes	■ Requirements / ■ Outcomes
Energy demand	■ ~10 Mtoe reduction of FEC between 2015–2030	■ Savings potential especially from residential and transport sectors
Share of renewable energies	■ 2030 → 28% of FEC, 55% of electricity	■ PV and wind electricity production doubling between 2015–2030
Decarbonization	■ Coal phase-out by 2025	■ More gas capacity (~2 GW) and connections (eg. Sardegna – Continent)
Nuclear targets	■ No nuclear energy in Italy	-
Import / export	■ Providing flexibility in a high RE system	■ Further strengthening the interconnections with foreign countries

AIEE [23]

Indicator	■ Targets / ■ Causes	■ Requirements / ■ Outcomes
Energy demand	■ Energy efficiency measures across sectors	■ 7–13 Mtoe reduction of FEC between 2015–2030
Share of renewable energies	■ Expansion of PV and wind (80 / 45 TWh by 2030) **(AIEE-UE)**	■ ~70% share of renewable electricity
Decarbonization	■ -40% total GHG emissions between 2015–2030 **(AIEE-UE)**	■ Policy support → 31% of final energy demand by renewable sources
Nuclear targets	■ No nuclear energy in Italy	■ High importance of RE and efficiency for ensuring energy security
Import / export	■ Higher investment in renewable energy plants	■ Less imported electricity by 2030

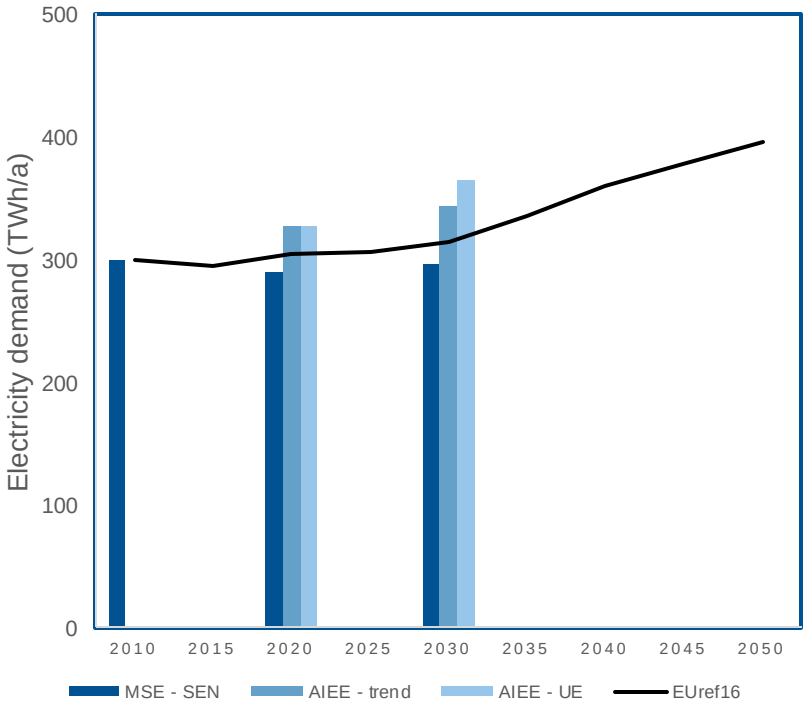
- Savings in residential and transport sectors are main drivers for reduction in energy demand
- PV and wind, along with already installed hydropower, are the key technologies for the renewable electricity production

[22] Ministero dello sviluppo economico (2017). Strategia energetica nazionale (National energy strategy). http://www.sviluppoeconomico.gov.it/images/stories/documenti/testo_della_StrategiaEnergeticaNazionale_2017.pdf (it)
[23] Associazione Italiana Economisti dell'Energia. [per FEDERMANAGER] (2017). Una strategia energetica per l'Italia. http://www.federmanager.it/pubblicazione/2017-strategia-energetica-litalia/(it)



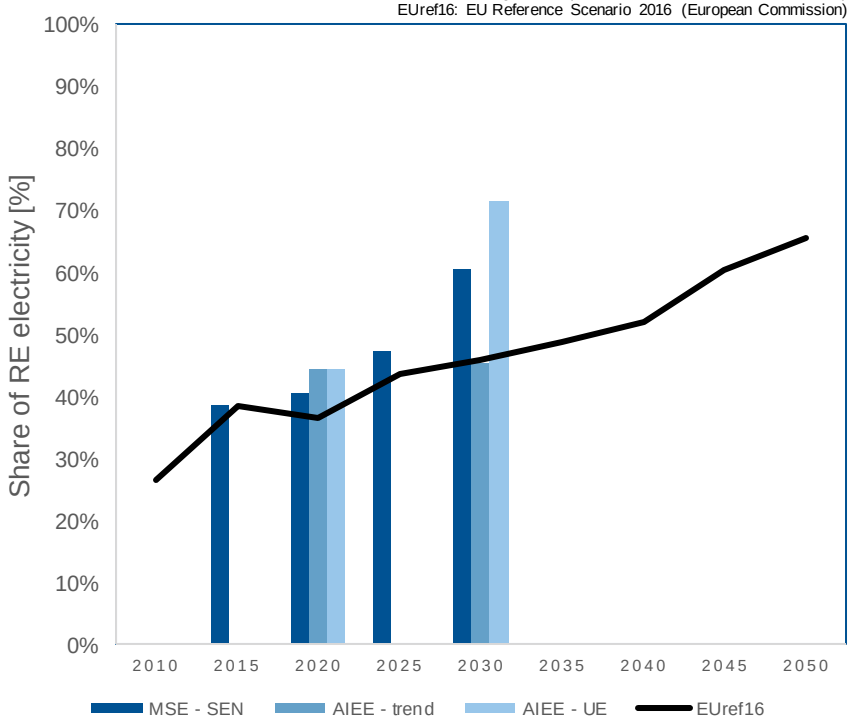
Italy – Demand & RE share

Electricity demand



Share of renewable electricity

AIEE – UE: EU Emission targets met (-40% total GHG between 1990 – 2030)
EUref16: EU Reference Scenario 2016 (European Commission)



- *„EUref16“ and „AIEE“* scenarios*:* Steady increase in demand
- *„MSE - SEN“* scenario*:* The increase by electrification (in residential, transport and industry) compensated by efficiency measures

- *„EUref16“:* steady increase up to 60% by 2050
- *„MSE - SEN“* and *„AIEE“* scenarios: Scenarios diverging considerably from each other by year 2030. Meeting the EU-2030 emission targets requires an expansion of RE considerably higher than the EU reference scenario

Switzerland – Insights from studies

Prognos [24]

Indicator	■ Targets / ■ Causes	■ Requirements / ■ Outcomes
Energy demand	■ Various measures and policies regarding energy	■ 20–45% reduction in FEC, +20%–(-10%) change in electricity demand 2010–2050
Share of renewable energies	■ High hydropower potential and existing capacity	■ RE electricity above 90% possible in 2050 by expanding PV capacity
Decarbonization	■ Energy-related CO_2 emissions reduced by 80% (2010–2050)	■ No change in nuclear plant runtimes + in-depth measures in efficiency & RE
Nuclear targets	■ Decision 2011: plants are not replaced after operating time	■ Nuclear power phases-out by 2034 (end of time Leibstadt plant)
Import / export	■ Phase-out of nuclear + increase in RE	■ Energy dependency reduced up to 30% by 2050 (from 80% in 2010)

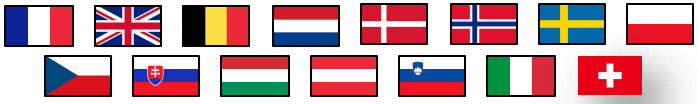
BAU: Business as usual, LC60: 60% reduction of CO2 emissions by 2050, SEC: Secure energy supply

PSI [25]

Indicator	■ Targets / ■ Causes	■ Requirements / ■ Outcomes
Energy demand	■ Electrification of heat/transport and climate/security policies	■ 18–40% reduction in FEC, 2–33% increase in electricity demand 2010–2050
Share of renewable energies	■ RE potential fully harnessed **(LC60)**	■ RE electricity above 65% (mainly hydro and some PV)
Decarbonization	■ Energy-related CO_2 emissions abated by 60% (2010–2050)	■ Business-as-usual is not enough; new measures are needed e.g. further decarbonization of transport, switching to heat pumps, deployment new RE
Nuclear targets	■ Nuclear power phases-out by 2034	■ Existing nuclear plants are gradually replaced by CCGT and CHPs
Import / export	■ No net electricity imports	■ Large scale exploitation of RE + new CC gas generation for supply security

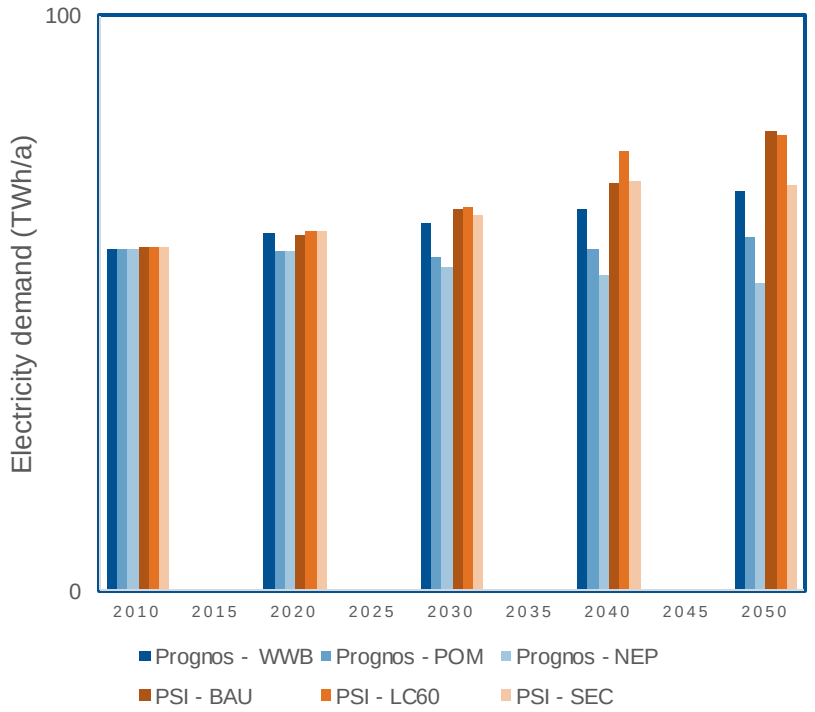
- Hydropower is and will stay as the major electricity source in Switzerland
- Nuclear plants reaching their end of operation creates the need for an alternative technology: building new gas capacity and new RE (such as solar PV) are among the solutions

[24] Prognos AG (and commissioned by Bundesamt für Energie) (2012). Die Energieperspektiven für die Schweiz bis 2050. http://www.bfe.admin.ch/php/modules/publikationen/stream.php?extlang=de&name=de_564869151.pdf (de)
[25] Kannan, R.; Turton, H. (2014) Switzerland Energy Transition Scenarios – Development and Application of the Swiss TIMES Energy System Model (STEM). Paul Scherrer Institut. https://www.psi.ch/eem/PublicationsTabelle/2014-STEM-PSI-Bericht-14-06.pdf



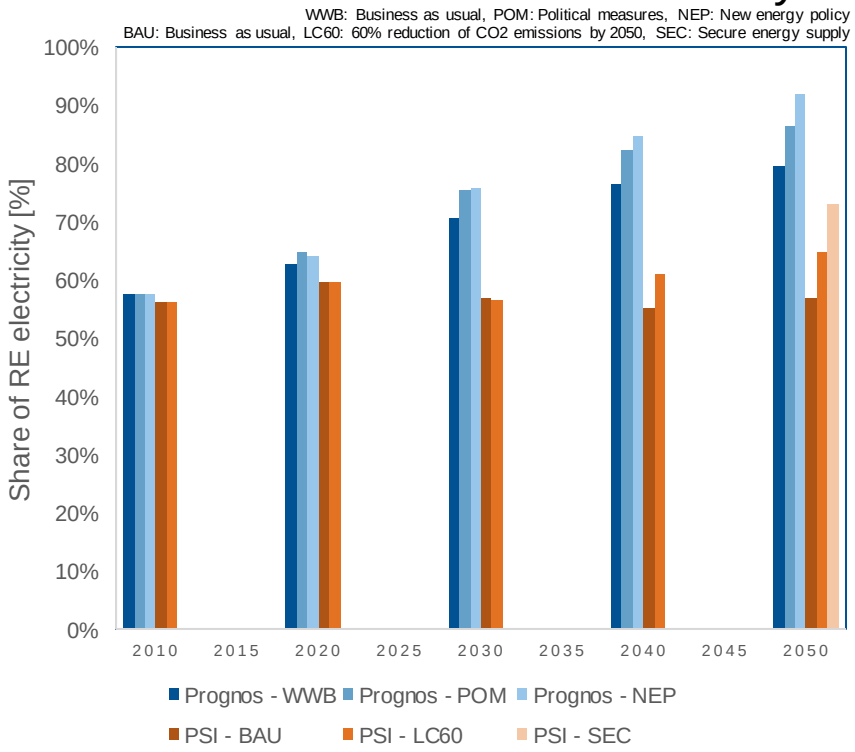
Switzerland – Demand & RE share

Electricity demand



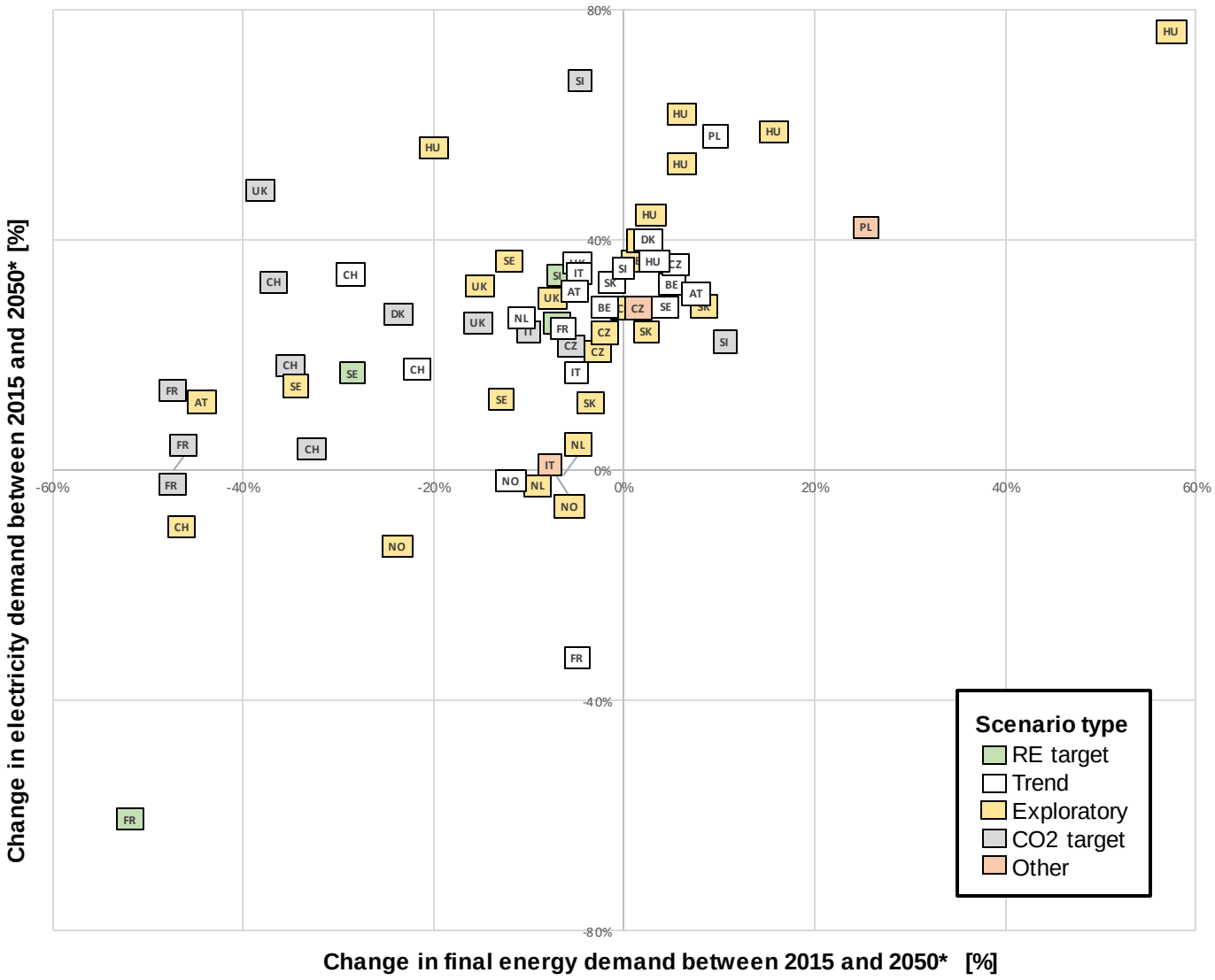
- Depending on their varying assumptions, the scenarios of the *„Prognos“* study predict either an increase or a slight decrease in the electricity demand
- In the *„PSI“* scenarios, the effect of electrification is dominant and the electricity demand has an increasing trend as a result

Share of renewable electricity



- *„Prognos“* study predicts a RE% reaching over 90%
- The reach of RE% in the *„PSI“* study is limited, resulting from the expansion of CCGT and CHP gas plants

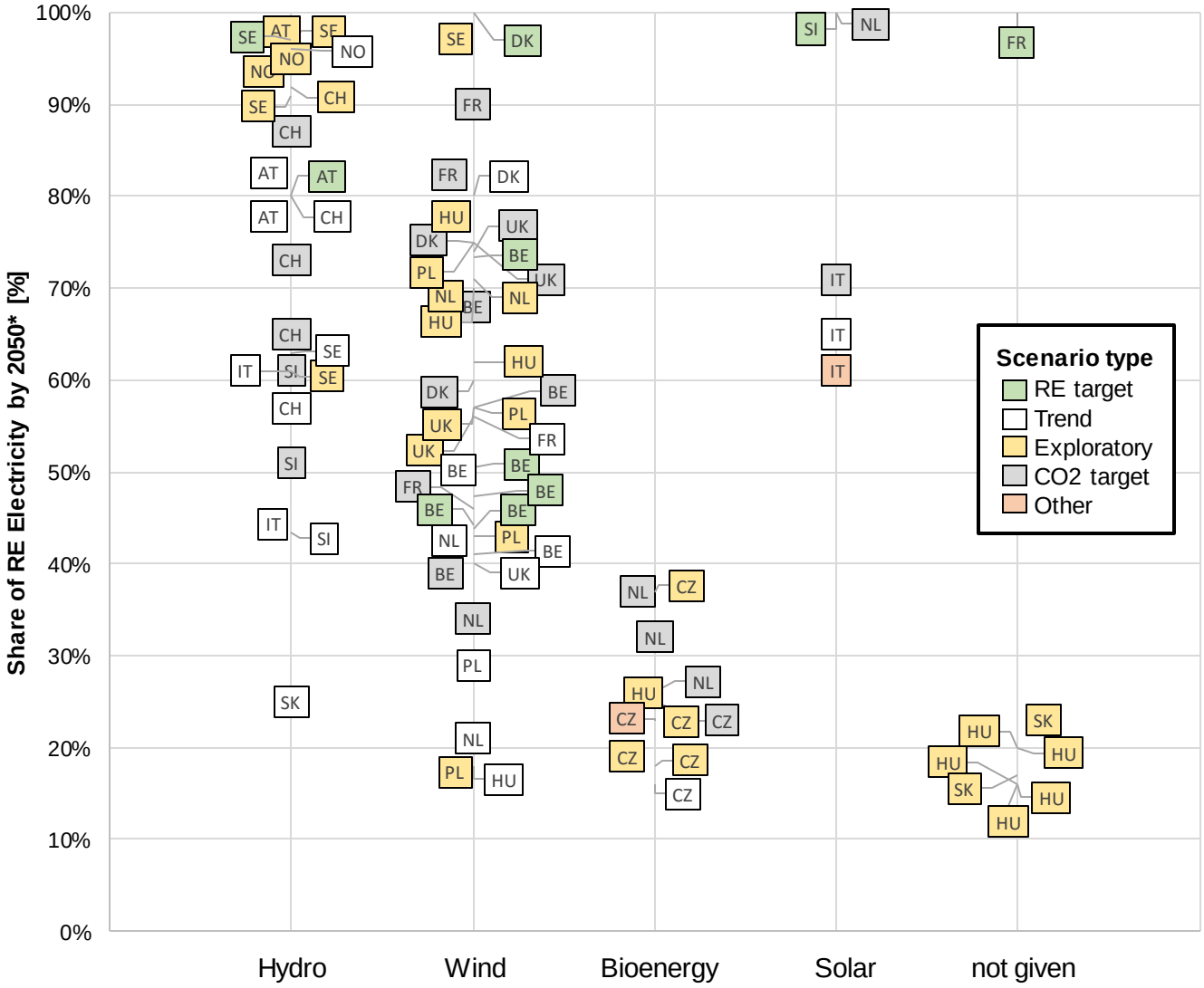
3) Analysis – Electricity vs. final energy demand



- *Common trend:* ***decrease*** *in the final energy consumption whereas the electricity demand* ***increases*** *through growth and* ***electrification*** *of end use sectors (left-upper quadrant)*
- *Trend scenarios (white) predict small changes in both final energy and electricity consumption*
- *CO_2 target scenarios (gray) predict significant reductions in final energy consumption*
- *In particular, electrification in transport sector was mentioned by the studies for* ***14*** *of the 15 countries, and of residential heating for* ***12*** *of the 15 countries*

* For studies not simulating until 2050, the latest simulation year is taken instead

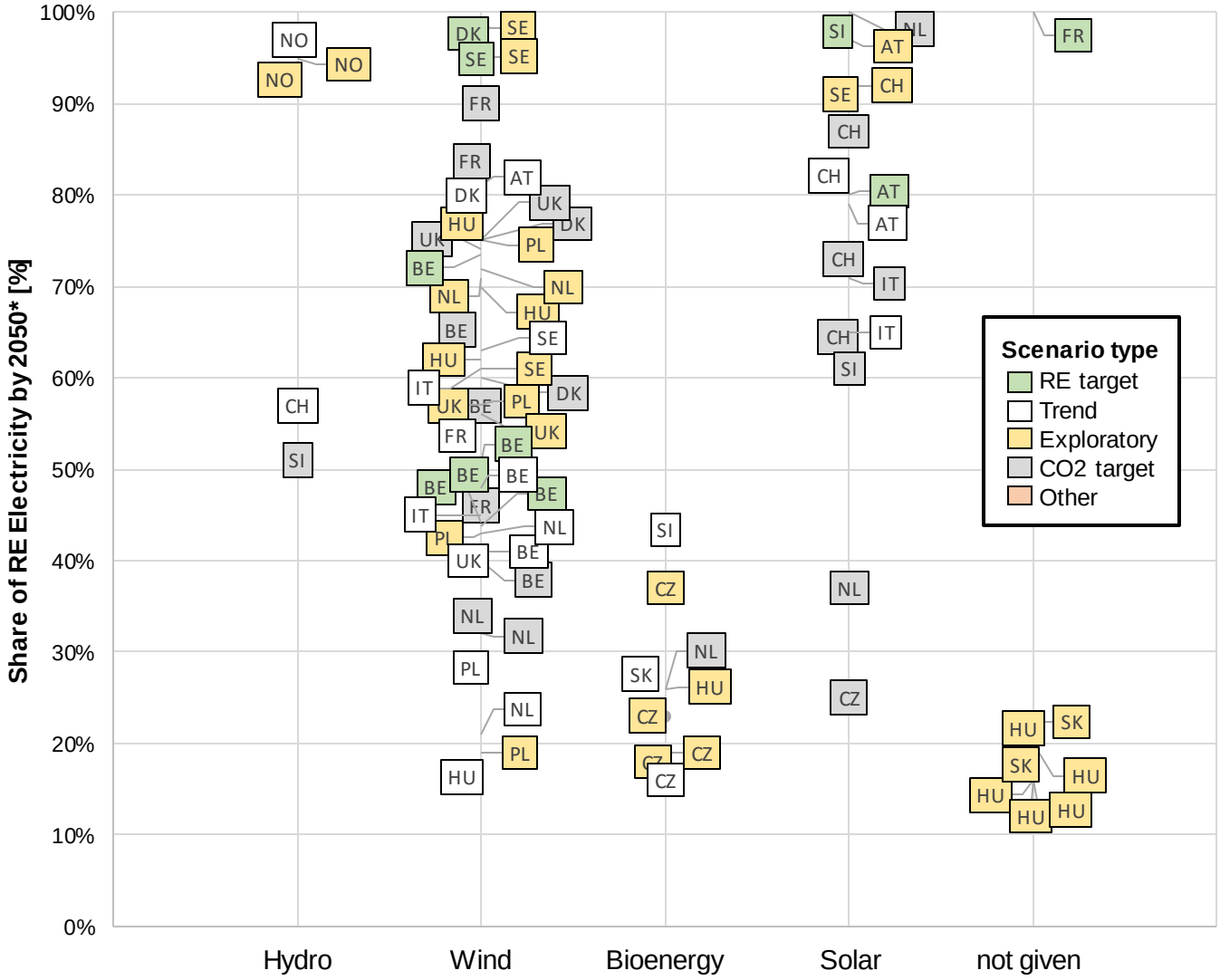
3) Analysis – RE share in electricity – Dominant technologies



- *Hydropower and wind energy are the dominating RE technologies for most of the countries (in terms of total electricity production)*
- *A wide range of RE shares between 10% and 100% of total electricity are predicted across studies*
- *100% RE scenarios mostly consist of exploratory or RE target scenarios*

* For studies not simulating until 2050, the latest simulation year is taken instead

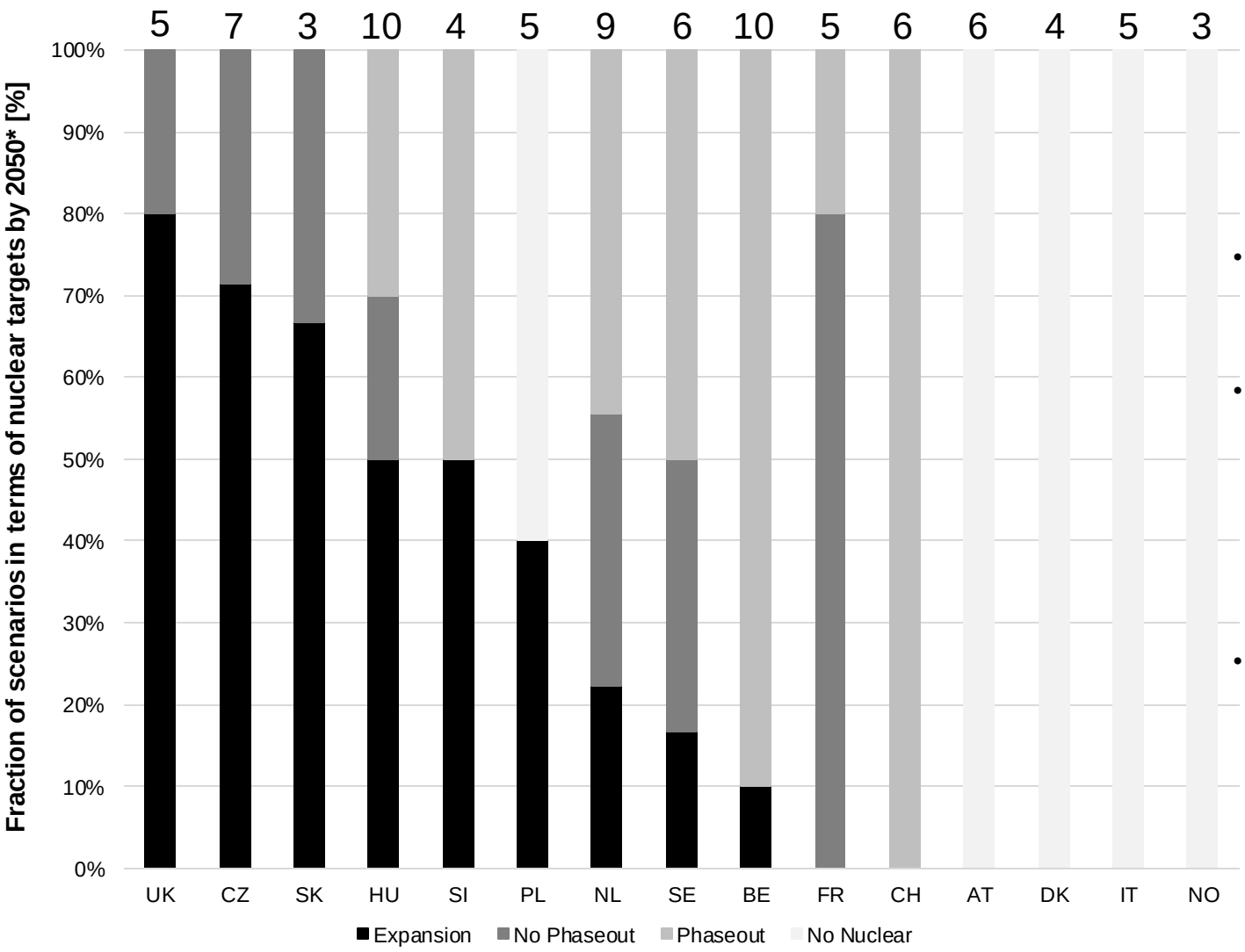
3) Analysis – RE share in electricity – Emerging technologies



- *Expansion of wind energy (and solar to some extent) is highest for large number of countries* ***(53% of all scenarios for wind, 20% for solar)***

* For studies not simulating until 2050, the latest simulation year is taken instead

3) Analysis – Nuclear targets

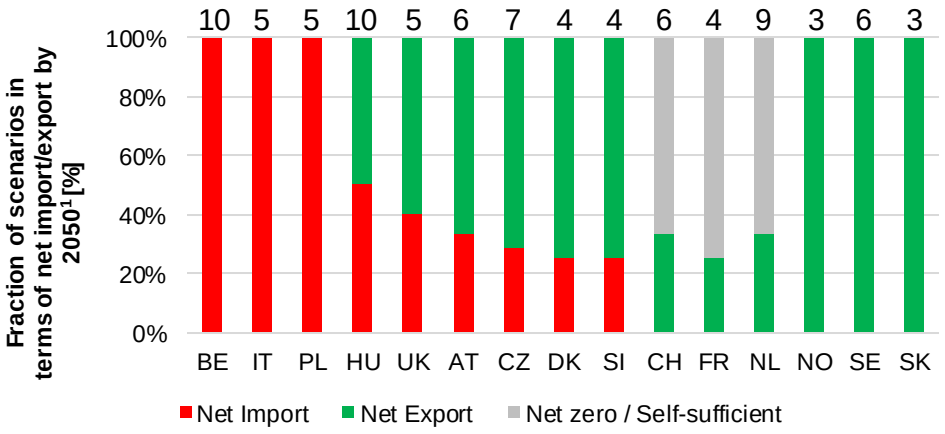


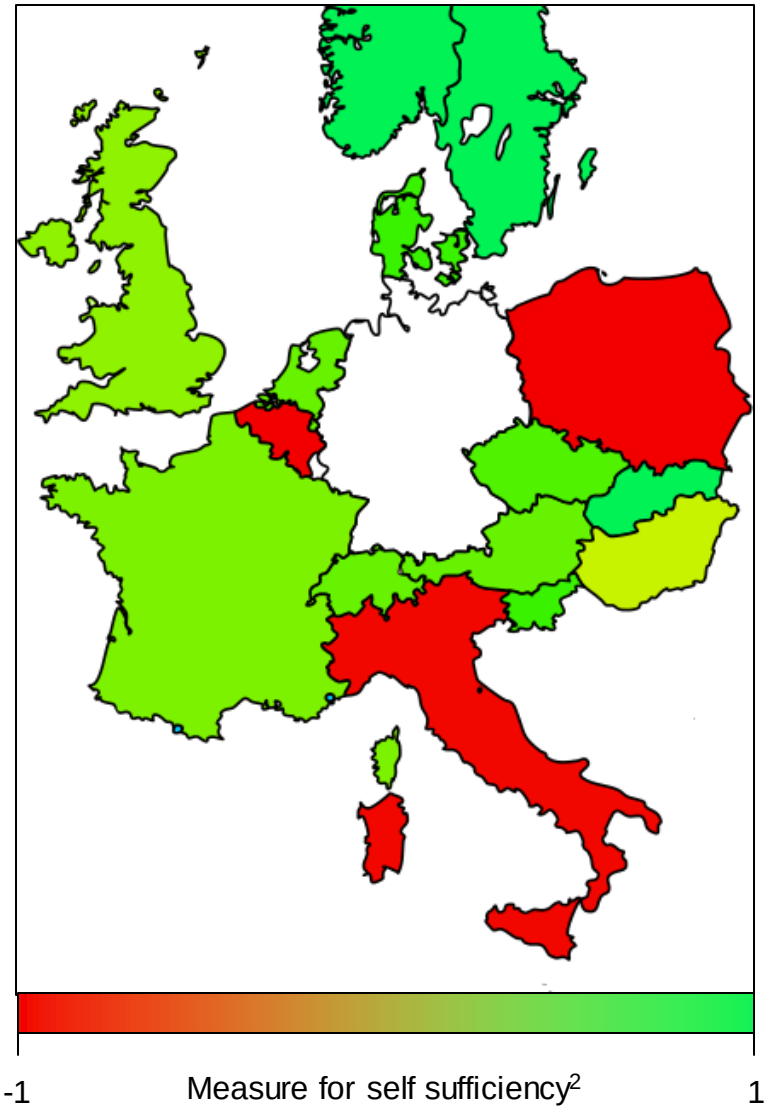
- *Studied countries have a large variety of nuclear energy targets*
- ***4** out of the **15** countries (Austria, Denmark, Italy and Norway) already have no nuclear power, on the other hand Belgium and Switzerland target phase out*
- *Countries such as UK, Czech Republic and Slovakia target nuclear expansion in the majority of their scenarios*

* For studies not simulating until 2050, the latest simulation year is taken instead

3) Analysis – Import/export

- *Belgium, Italy and Poland stand out as the countries where each scenario predicts positive net import of electricity by its end year of simulation*
- *Each scenario for Norway, Sweden and Slovakia predicts generation of surplus electricity to be exported to neighboring countries (Norway and Sweden via hydropower, Slovakia new nuclear)*
- *General trend is towards self-sufficiency (number of net export studies are higher than the number of net import studies)*





[1] For studies not simulating until 2050, the latest simulation year is taken instead

[2] $\frac{\#Scenarios_{net\_export} - \#Scenarios_{net\_import}}{\#Scenarios_{total}}$