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The 2040 EU climate target (and its implications for the power sector)

S.E. Tanzer / 29 February 2024

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THIS IS NOT [YET] TRUE:

The EU has set a target for 90%* reduction in greenhouse gas emissions by 2040.

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* Compared to the 1990 baseline

WHAT IS TRUE:

The European Commission has issued a communication that recommends a target for 90%* reduction in net greenhouse gas emissions by 2040.

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* Compared to the 1990 baseline

So, what then am I talking about today?

- The 605-page Commission **impact assessment** accompanying the proposed target
- Based on scenario modelling
  - using PRIMES for the energy system model
  - Model suite details available in MIDAS
  - also includes scenario of lifestyle change demand reduction


EUROPEAN
COMMISSION

Strasbourg, 6.2.2024
SWD(2024) 63 final

PART 1/5

COMMISSION STAFF WORKING DOCUMENT

IMPACT ASSESSMENT REPORT

Part 1

Accompanying the document

COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS

Securing our future

Europe's 2040 climate target and path to climate neutrality by 2050 building a sustainable, just and prosperous society

{COM(2024) 63 final} - {SEC(2024) 64 final} - {SWD(2024) 64 final}

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Is this target [sufficiently] ambitious?

Ambition in Context

Linear trajectory from 2030 to 2050 targets: **78%** by 2040

“Unchanged policy framework” trajectory: **88%** by 2040

Scenarios considered by the EC:

S1: **78%** by 2040

S2: **88%** by 2040

S3: **92%** by 2040

Firstly, a net metric obscures a multitude of things….

Stacking together

- CO_2 and non-CO_2 GHGs
- Reductions and Removals
- Industrial and Land Sector
- Different rates of progress

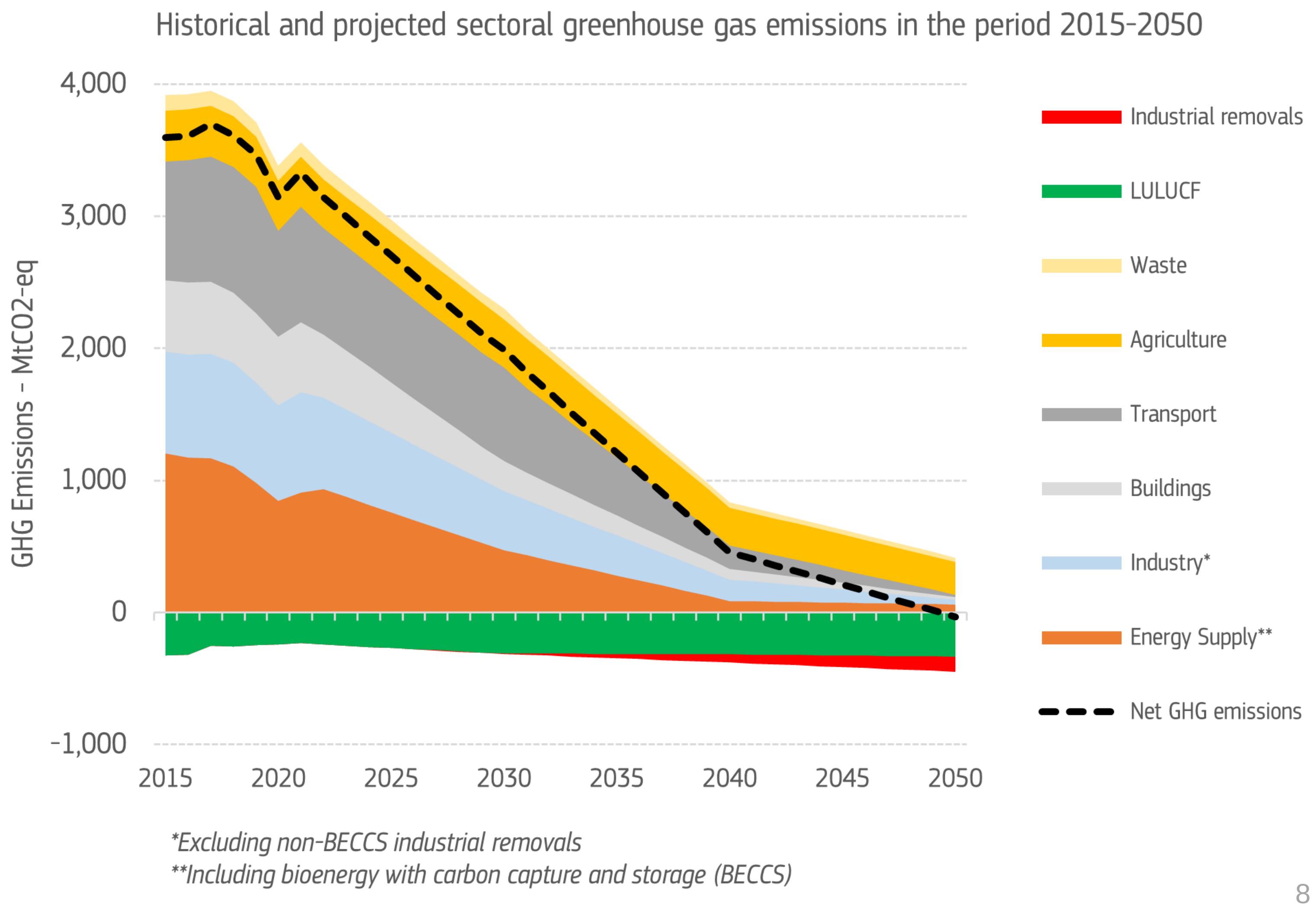

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Image Source: European Commission, 2024

Breaking down "90% net reduction" into other net targets

	Mt CO_2eq	% change 2015-2040
Total net emissions in 2040	**356**	-90%
of which, **Power** and district heating	**-10**	-101%
of which, **Other energy** sectors (inc. DACCS)	**11**	-95%
of which, **Industry**	**89**	-85%
of which, **Transport** (domestic, international, bunkers)	**267**	-76%
of which, **Agriculture**	**271**	-30%
of which, **LULUCF** (inc. removals in agricultural land)	**-317**	+2%

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The Commission’s 2040 Power Sector Wishlist

- ❑ Achieve **GHG-neutrality** before 2040
- ❑ **90% decrease** in fossil fuel use
- ❑ Nearly **double** generation capacity to ca. **5200 TWh**
- ❑ **Triple** installed capacity to ca. **2500 GW**
- ❑ **Double** annual wind and PV deployment rate
- ❑ Support a **25% increase** in final energy consumption (to ca. 3330 TWh)
- ❑ Capture **65 Mt** of CO_2 per year
- ❑ Limit biomass use to below **9 EJ** per year (all sectors)

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N.B. reductions are from a 2015 baseline

Is this a realistic wishlist?

Electrify everything

- Residental: heatpumps and cookstoves
  (n.b. model includes change in heating/cooling demand due to climate change)
- Industry: [e]-hydrogen and electricy
- Transport: electric cars and e-fuels

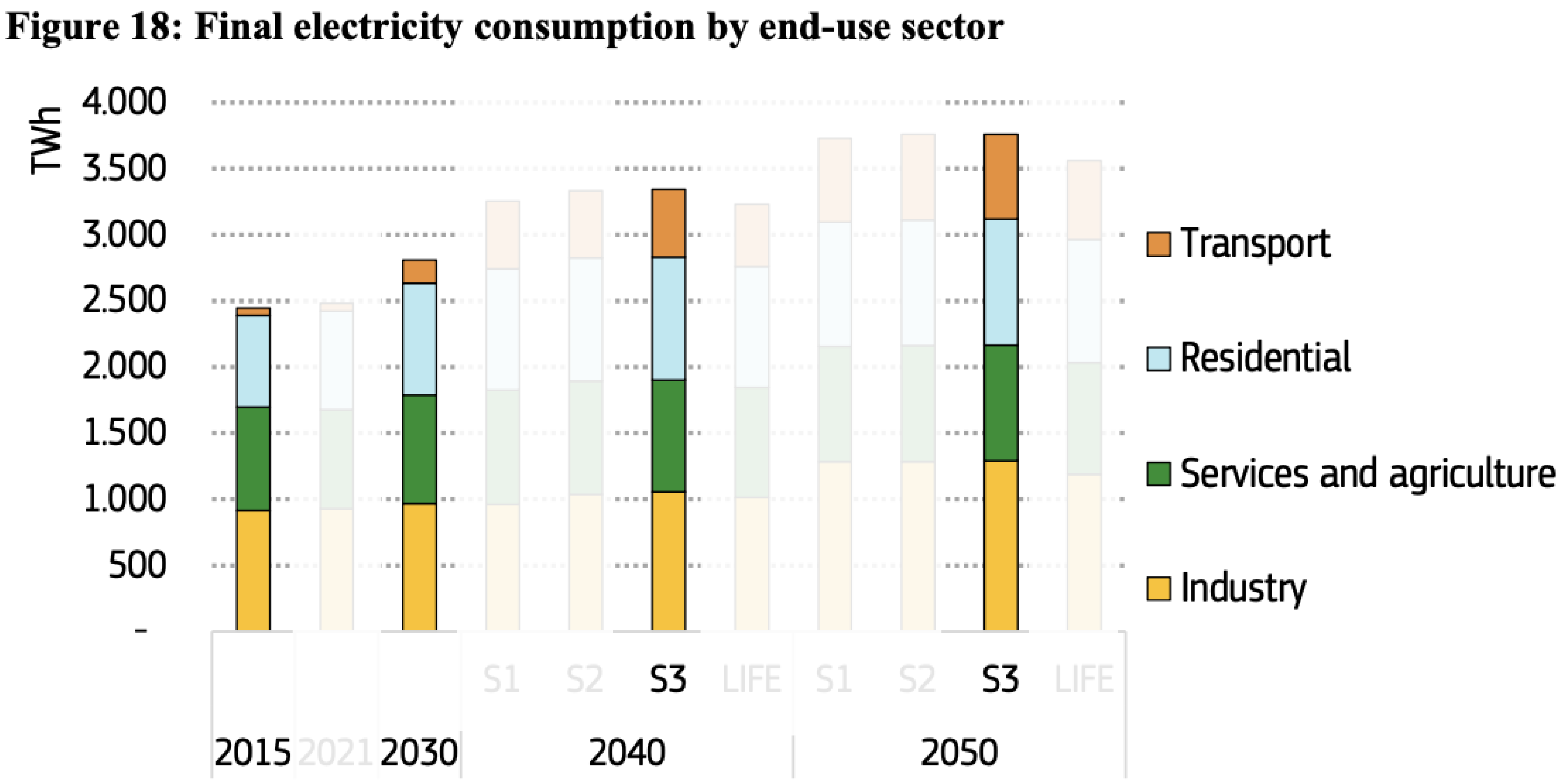
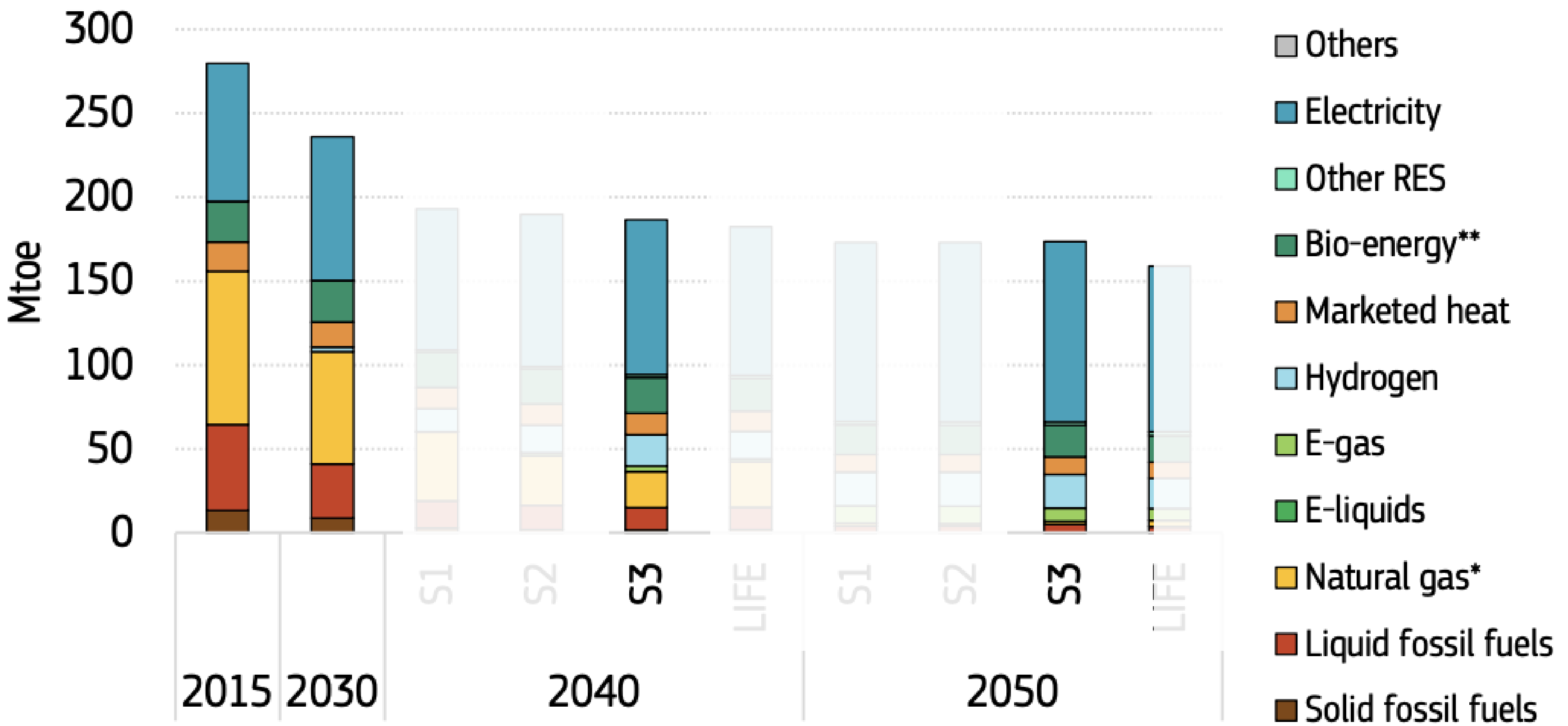


Image Source: European Commission, 2024

Energy Consumption in Industry by Fuel



Note: The energy consumption includes the final energy consumption plus the consumption in refineries.
**Natural gas including manufactured gas (coke-oven gas, blast furnace gas & gasworks gas), but not e-gas.*
***Bioenergy including bio-solids, biofuels, biogas (including waste gas and biomethane) and solid waste.*

Source: PRIMES.

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Image Source: European Commission, 2024

Electrify everything

- 95 Mtoe of H_2 consumption
- of which, 50 for e-fuels

Figure 23: Net installed storage and new fuels production capacity, 2015-2050

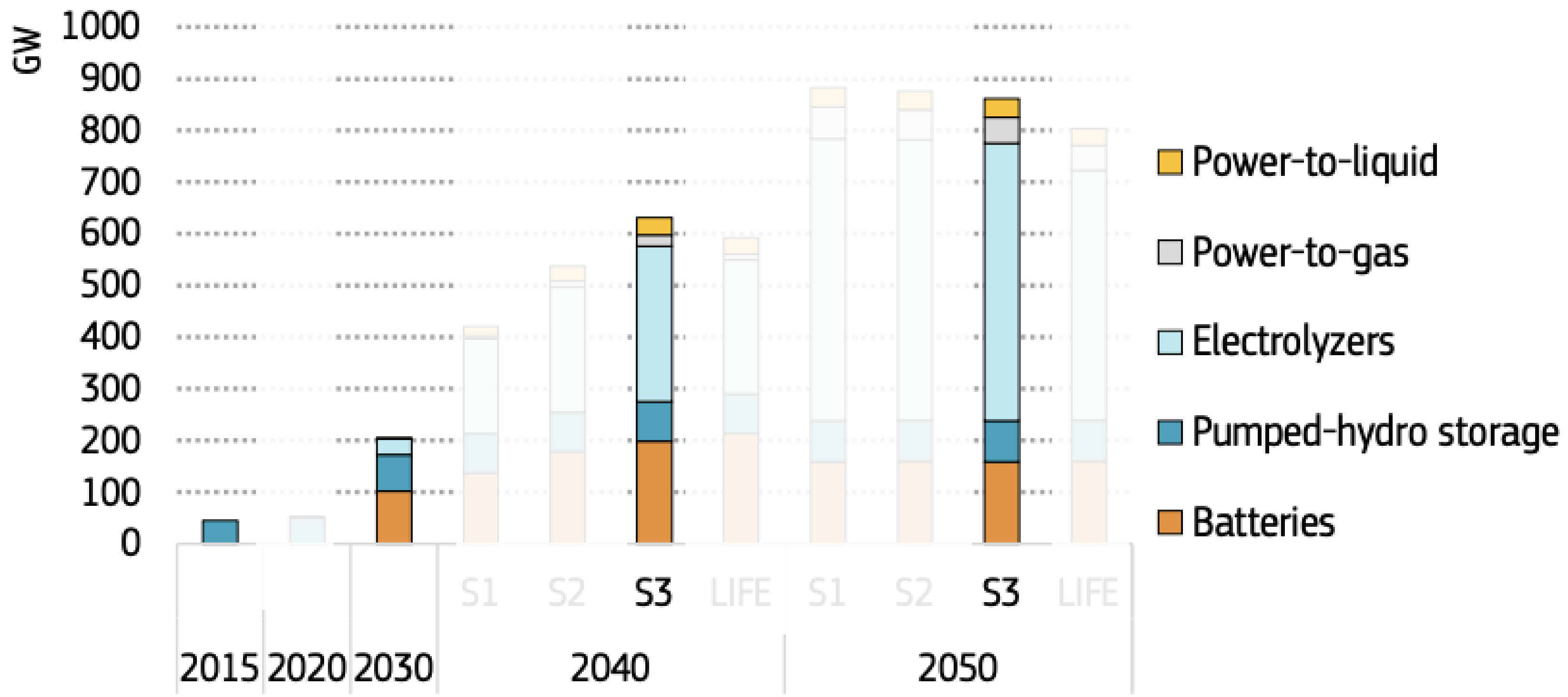

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Image Source: European Commission, 2024

Generation and Installed Capacity by Carrier

Figure 19: Electricity generation by energy carrier, 2015-2050

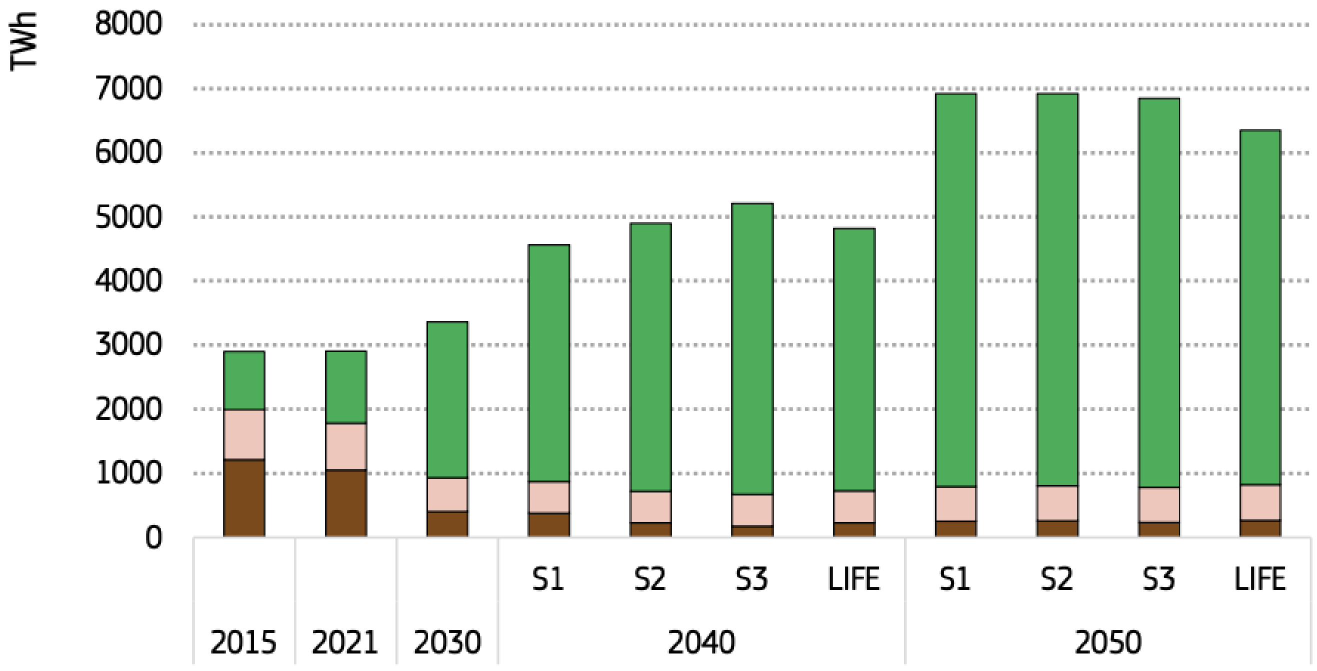


Figure 21: Net installed capacity by energy carrier, 2015-2050

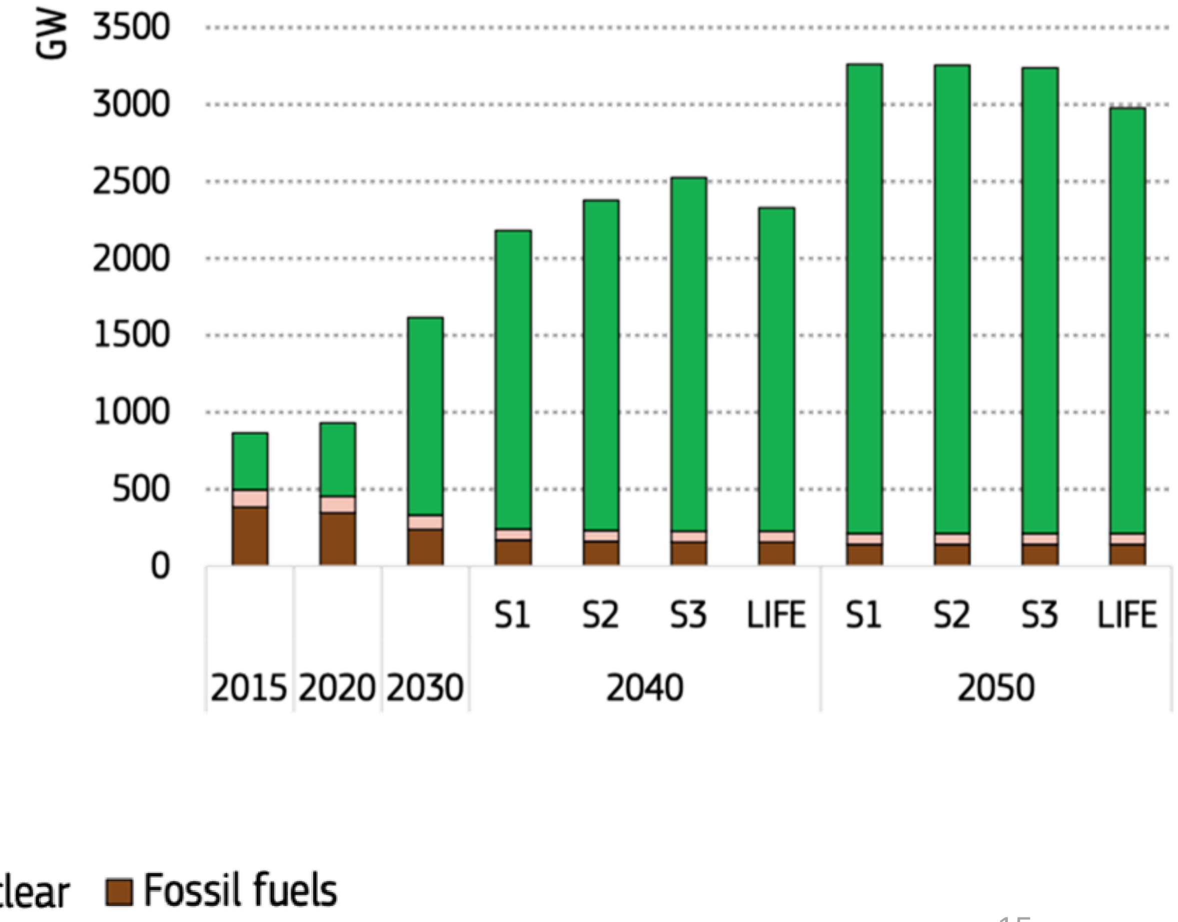
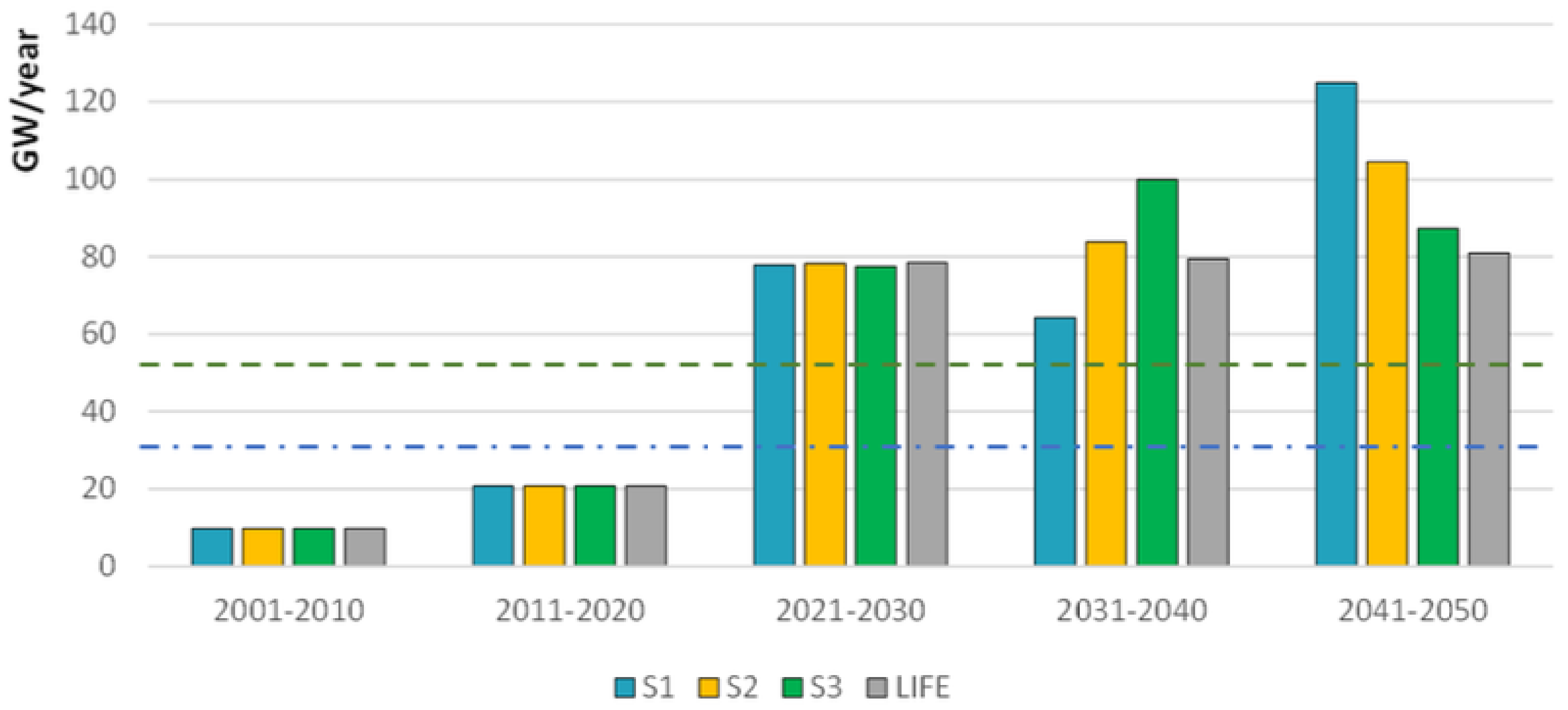


Image Source: European Commission, 2024

And go really fast

Figure 27: Average annual deployment of wind and PV



Note: Blue line: average 2016-2020; Green line: max historical deployment (occurred in 2022).

Source: PRIMES

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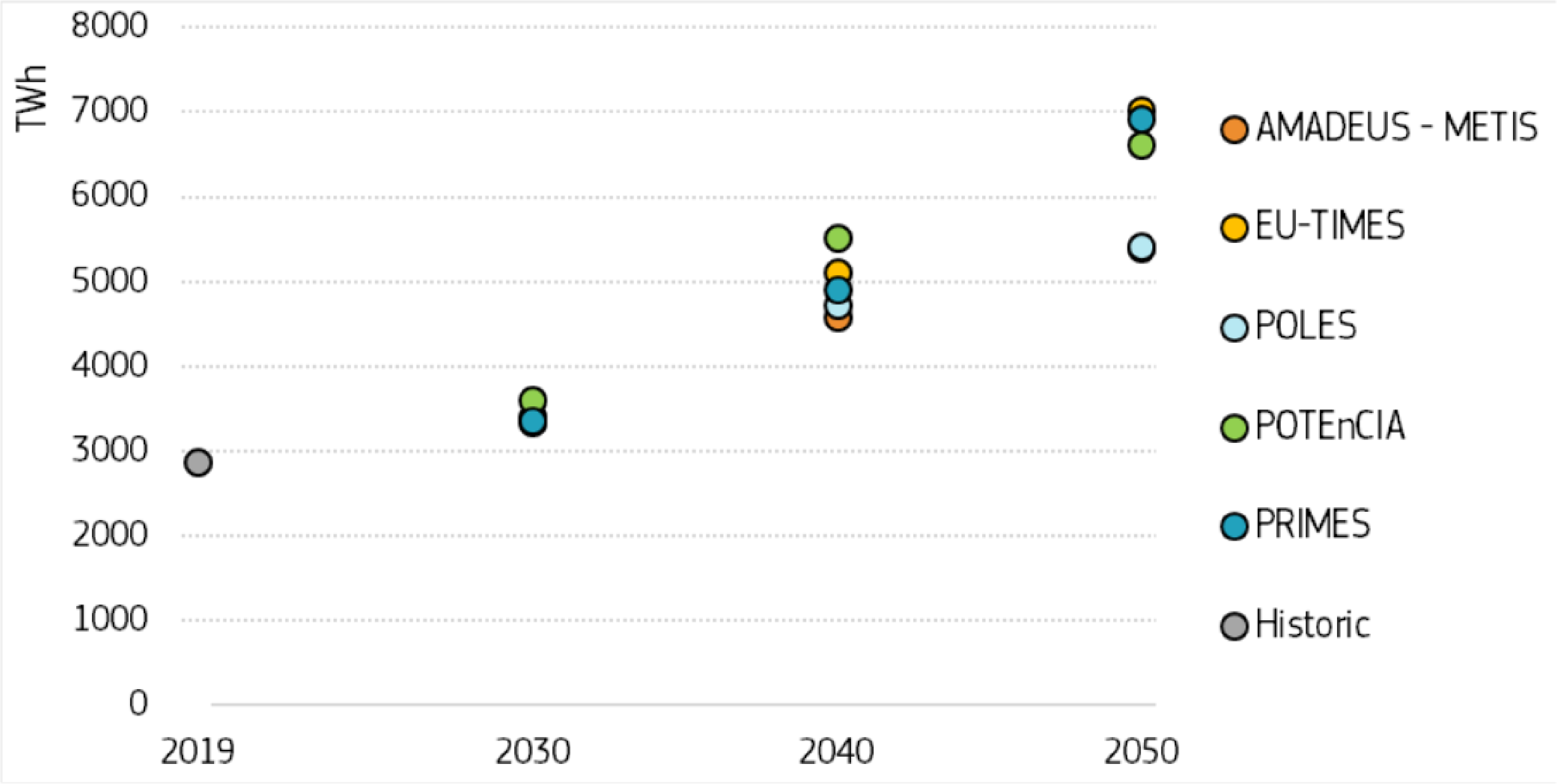
Image Source: European Commission, 2024

Different models, different visions

Stacking together

- EU-TIMES: lower electrification, more RFNBOs
- POTEnCIA: More heat pumps, less RFNBOs
- AMADEUS/POLES: Less DAC, fewer e-fuels

Figure 26: Gross electricity generation in different energy models, 2019-2050



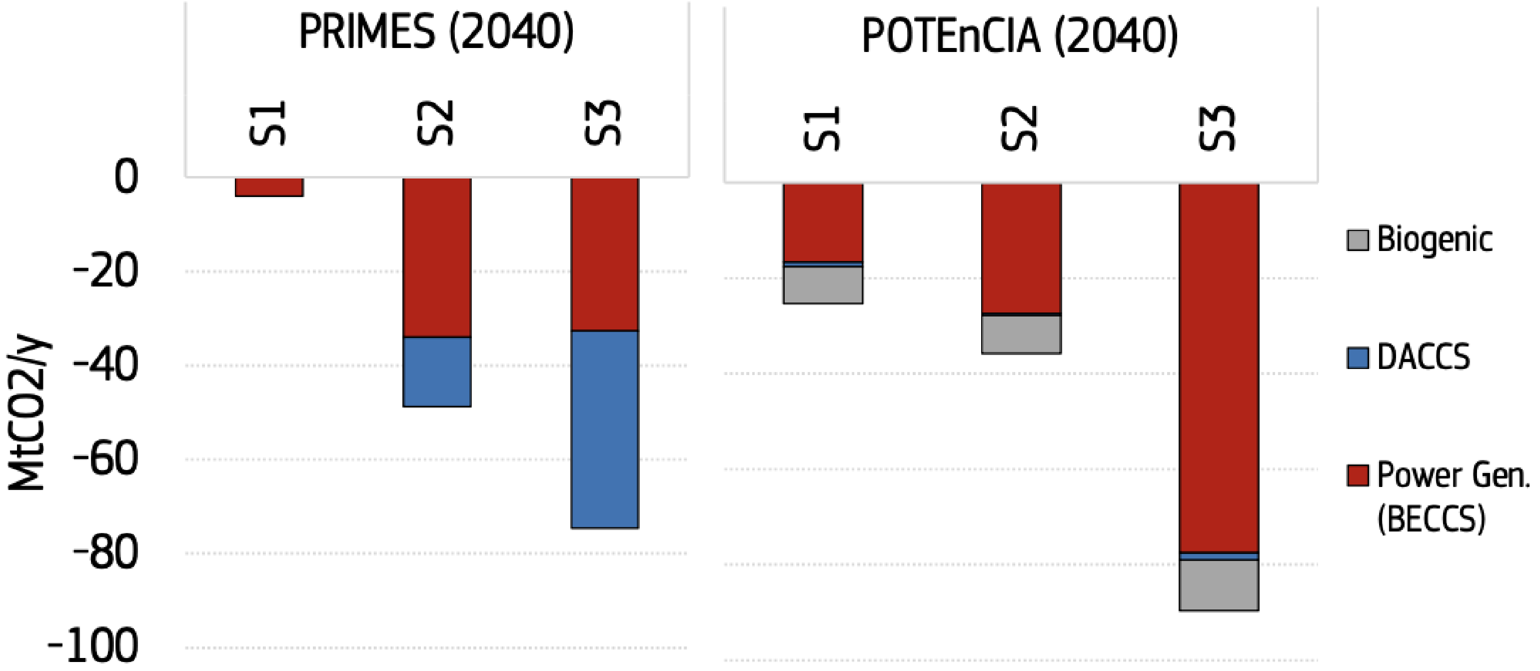
Sources: AMADEUS-METIS, EU-TIMES, POLES, POTEnCIA, PRIMES.

Image Source: European Commission, 2024

Different models, different visions

- Use of removals varies both in magnitude and portfolio
- Very high uncertainty of how CDR (and costs) will develop

Figure 3: Industrial carbon removals in PRIMES and POTEnCIA in 2040



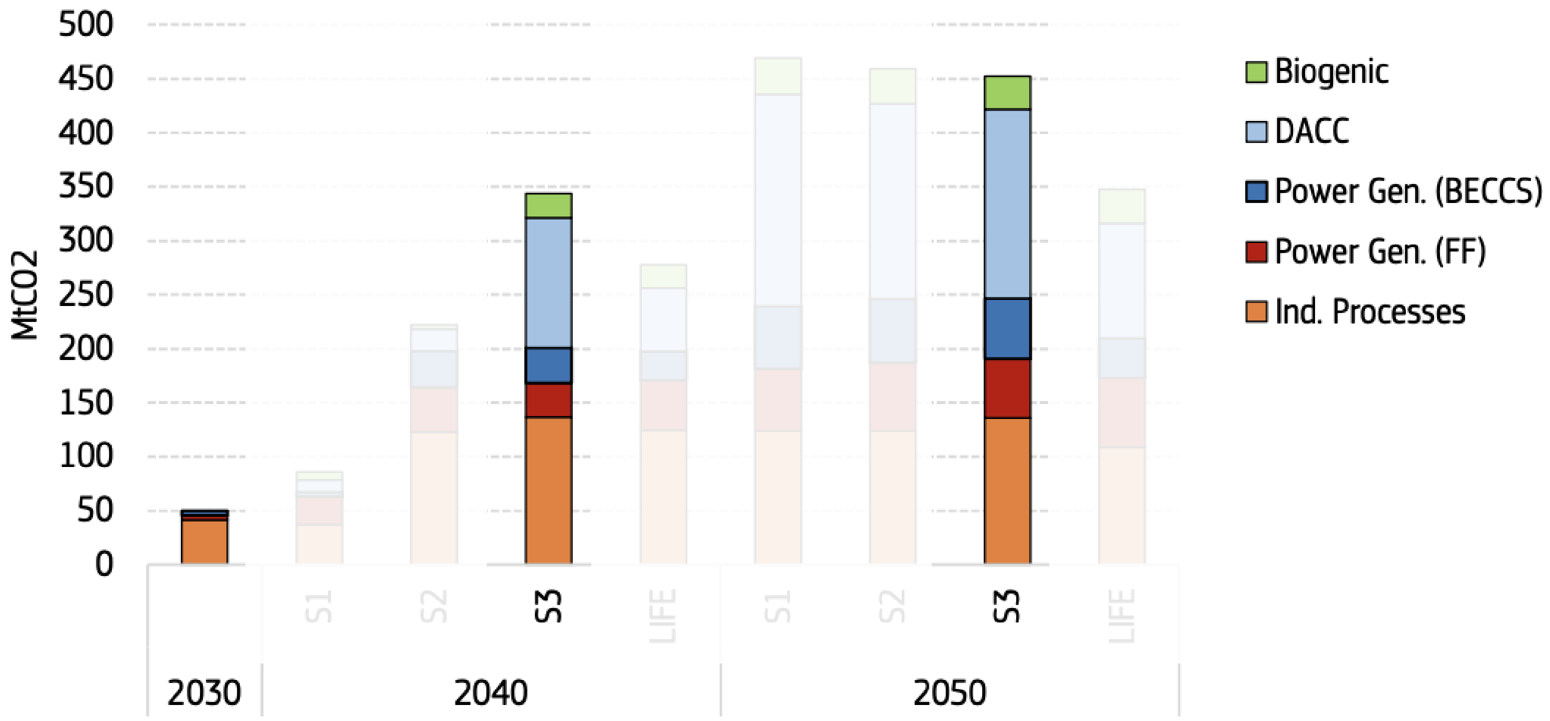
Source: PRIMES, POTEnCIA.

Image Source: European Commission, 2024

But same ambitious deployment rates

- 7-fold increase between 2030 and 2040

Figure 9: Carbon captured by source



Note: Biogenic carbon indicates the carbon resulting from the upgrade of biogas to biomethane.

Source: PRIMES

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Image Source: European Commission, 2024

Whither goes that captured carbon?

Removals:

- 33 Mt/year BECCS (4 in 2030)
- 42 Mt/year DACCS

Fossil CCS

- 169 Mt/year, 32 from power

CCU

- Only DAC and Bio

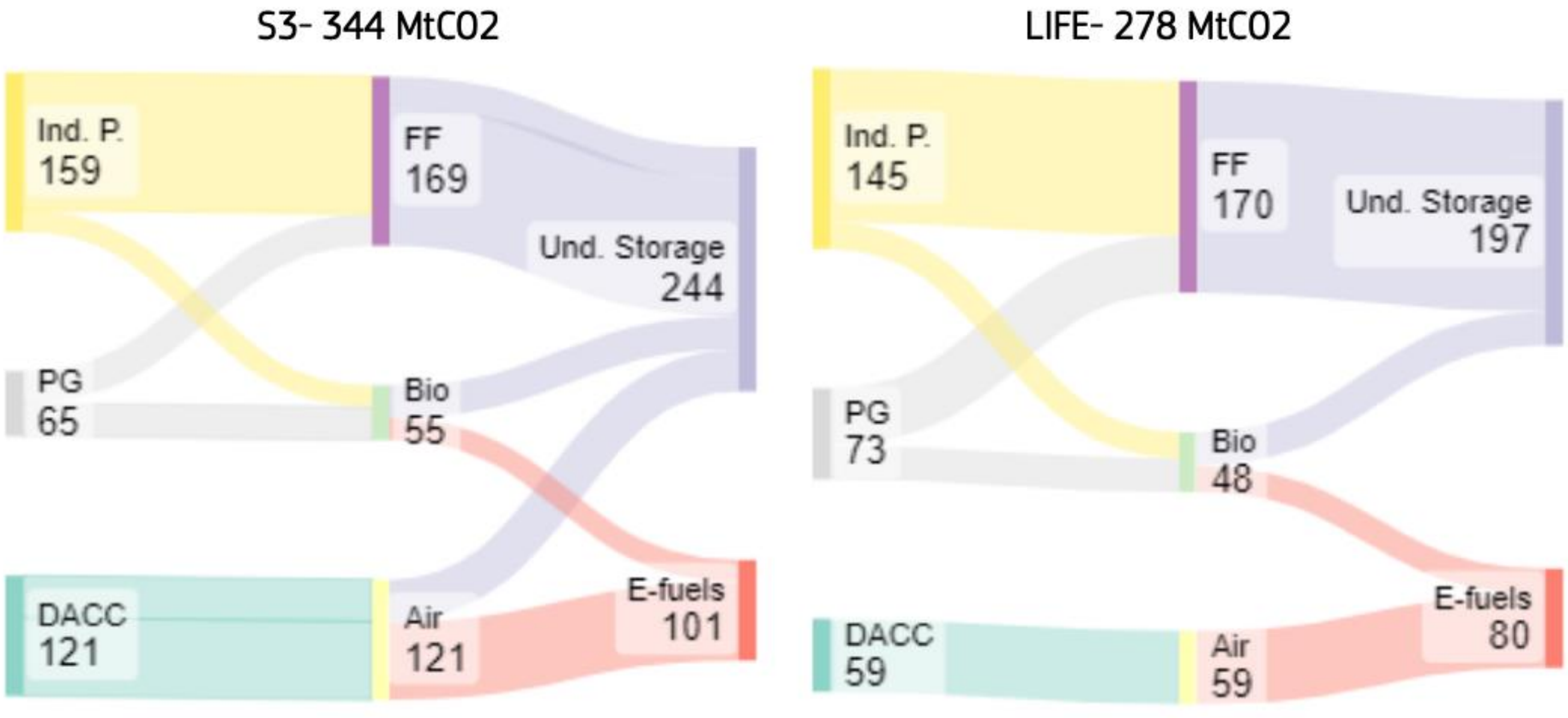

Image Source: European Commission, 2024

What about the grid?

And finally, how much does it cost?

Level of investment as %GDP remains stable

Costs shift away from fuel to capital investments

Table 19: Average annual economy-wide energy system costs (billion EUR)

	2011-2020	2021-2030	2031-2040			2041-2050		
			S1	S2	S3	S1	S2	S3
Total energy system costs								
Billion EUR	1766	2130	2419	2472	2508	2508	2527	2530
% GDP	11.9%	12.5%	12.4%	12.7%	12.9%	11.2%	11.3%	11.3%
Fossil fuel imports								
Billion EUR	336	427	293	277	265	150	142	133
% GDP	2.3%	2.5%	1.51%	1.42%	1.36%	0.67%	0.63%	0.59%

Source: PRIMES.

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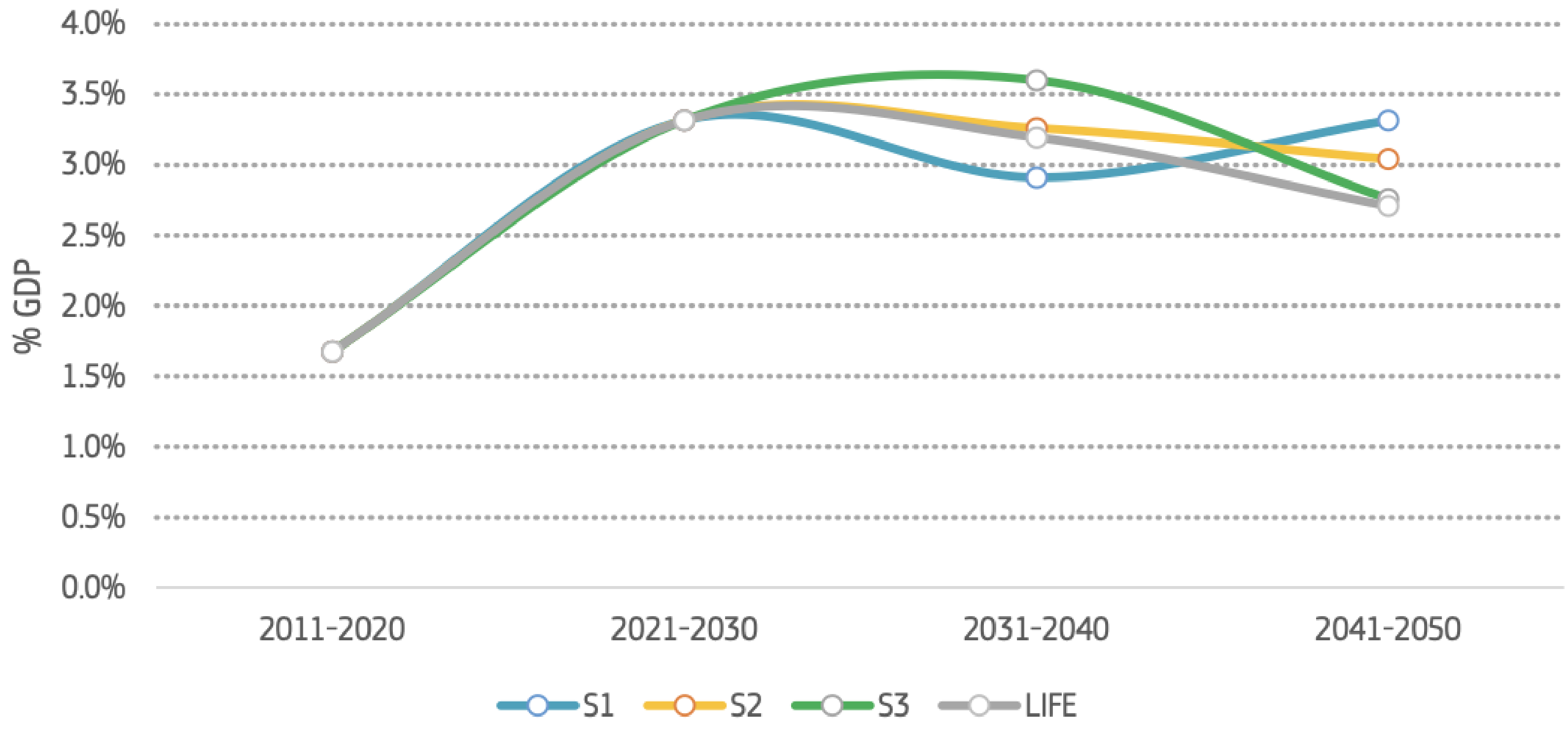
Image Source: European Commission, 2024

And finally, how much does it cost?

Most of the energy system costs is from transport

Investment now pays off with lower costs later

Figure 103: Average annual energy system investment needs, excluding transport



Source: PRIMES.

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Image Source: European Commission, 2024

And finally, how much does it cost?

Compare with today's wholesale price spread:

68–126

EUR/MWh

Data source: Ember 2024

Table 22: Average final price of electricity for businesses

EUR23/MWh	2040	2050
Industry	130-131	131-133
Services	249	255

Note: The electricity prices shown here reflect the evolution of the average electricity production costs to supply these sectors (i.e., considering their load profile) as well as the taxes applied to the sectors.

Source: PRIMES.

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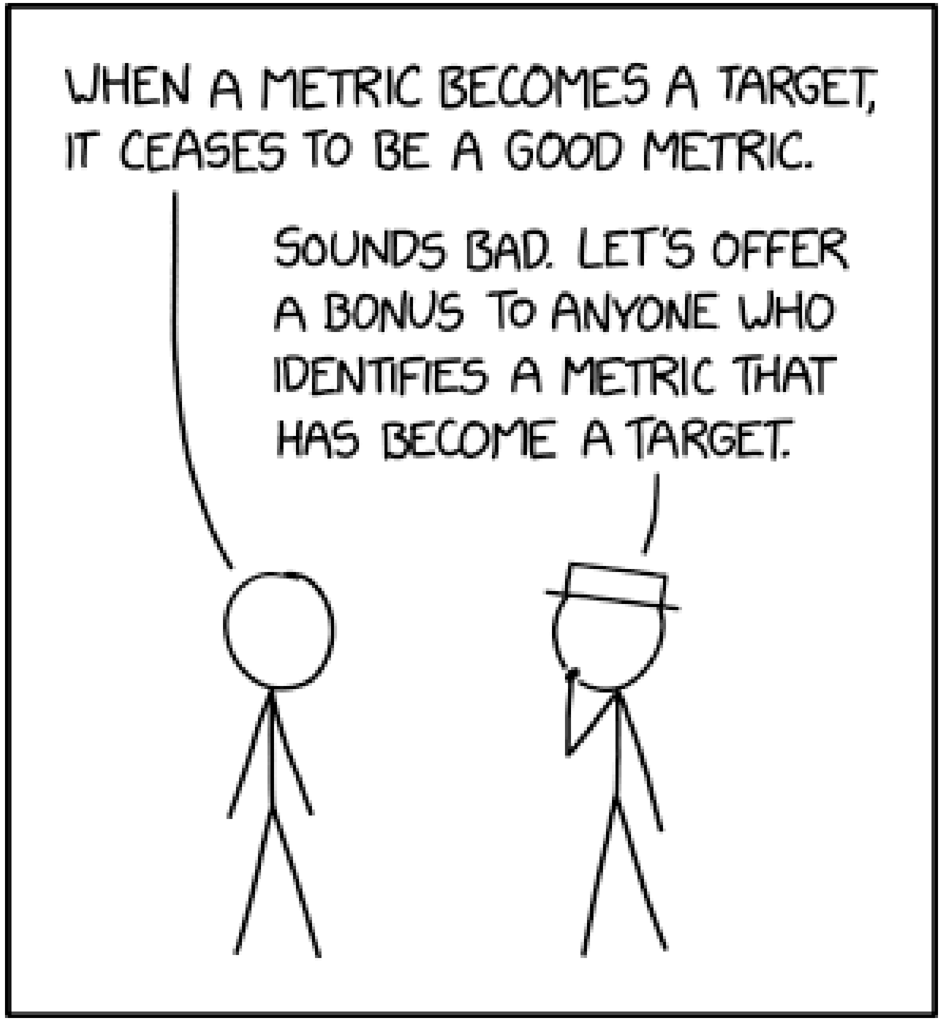
Image Source: European Commission, 2024

Some final thoughts

- Ambition is no substitute for action
- Stacking of reductions, industrial removals, and land-based removals is highly problematic
- System costs are similar overall, but higher near-term costs for higher ambition. Also lowers risks from delayed action.
- Discussion of connection infrastructure is noticeably lacking
  - e.g., for grids, H_2 pipelines, CO_2 pipelines
- Also, land use
- Encourages digitalisation without explicitly considering its energy costs
- LIFE scenario is good inclusion, but more attention needed for demand reduction via behaviour change (e.g., no decrease in transport assumed)

Goodhart's Law



Alt text: [later]: I'm pleased to report we're now identifying and replacing hundreds of outdated metrics an hour

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Image Source: XKCD, 2024

Thank you for your attention

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Intervention Logic

Core Problem

The absence of an EU-wide, economy-wide ambition level for 2040, in terms of net greenhouse gas emission reduction, as an interim target to climate neutrality in 2050

General Objective

Define a 2040 GHG target that will keep the EU on a pathway towards climate neutrality in 2050, and which will serve as a basis to develop the forthcoming post-2030 energy and climate policy framework and enabling policies

Specific Objectives

1. Ensure that climate neutrality is delivered
2. Minimise the EU's GHG budget
3. Ensure that the transition is just
4. Ensure that the long-term competitiveness of the EU economy is maintained
5. Provide predictability for the deployment of best-available, cost-effective and scalable technologies
6. Ensure the security of energy supply of the European Union
7. Ensure environmental effectiveness

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Image Source: European Commission, 2024

Impact Assessment Main Modelling Suite

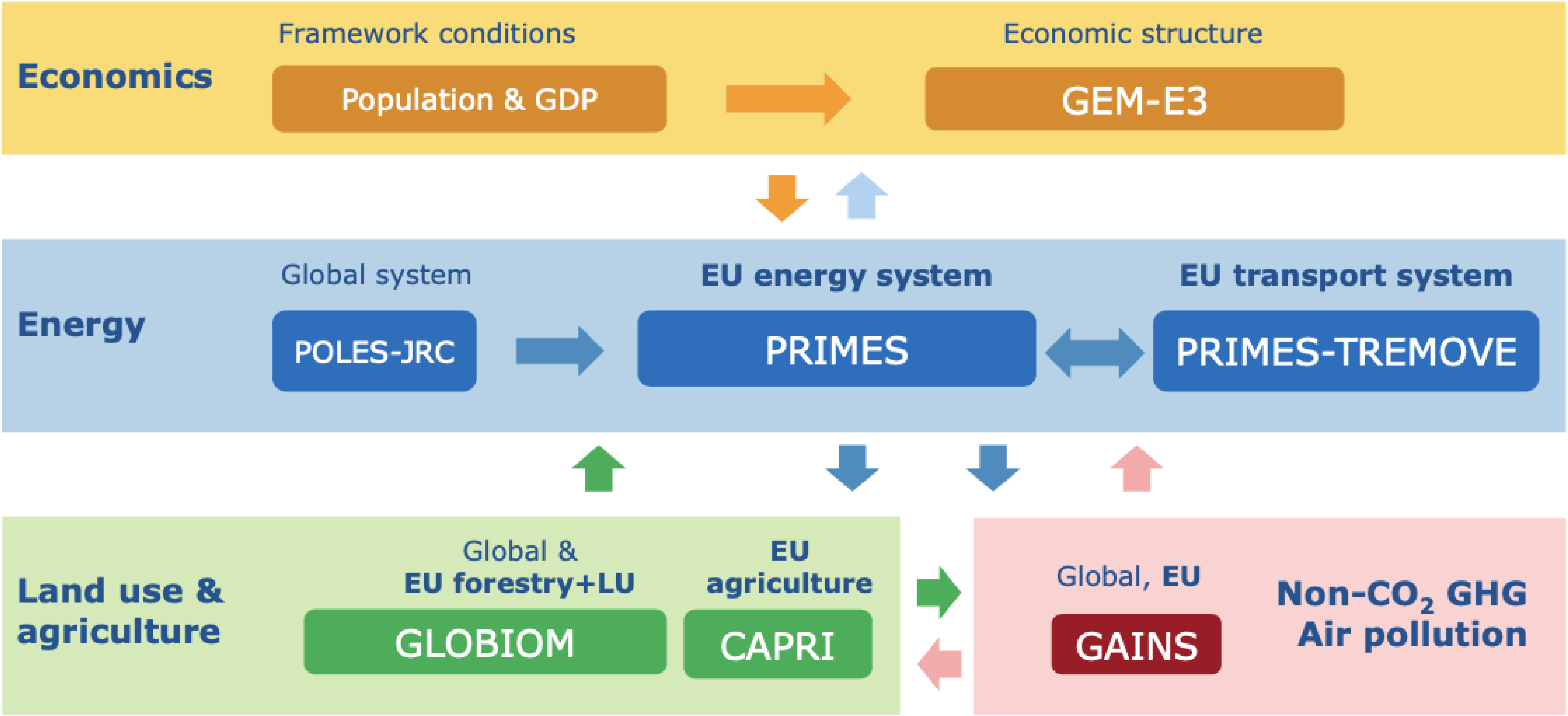

Image Source: European Commission, 2024

Scenario Summary

	S1	S2	S3	LIFE
Power system	Limited remaining CO2 emissions in 2040, share of renewables in total electricity production increases compared to 2030	Close to decarbonised in 2040, larger deployment of renewables	Fully decarbonised in 2040, the system operates mostly with renewables	
	The deployment of renewables is facilitated by system optimisation (interconnections, storage and demand-side response). Nuclear according to MS policies until March 2023; plays a comparable role in all scenarios.			
Bioenergy	Moderate increase by 2040 compared to current, stabilises over 2041-2050	Larger increase by 2040 compared to current, and slightly declines after 2040		
H2 & e-fuels	Some increase in 2040 above 2030 levels	Stronger increase than in S1, notably in the transport sector	Stronger increase than in S2 in all sectors	
Carbon capture	Limited uptake in 2031-2040 and large deployment in 2041-2050	Deployment in 2031-2040, in particular in industrial processes, maintained in 2041-2050	Further deployment in 2031-2040 to cover remaining energy and industrial process emissions	
Carbon removals	Very limited uptake of BECCS by 2040	Some deployment of BECCS and DACCS by 2040	Higher deployment by 2040 of both BECCS and DACCS	
Circularity				Circular economy trends limiting raw materials needs
Industry	Electrification of energy consumption, some development of e-fuels by 2040		More e-fuels by 2040 than in S2	Enhanced circularity entails comparatively lower needs for primary production of materials, and so lower needs for carbon capture
	Very limited carbon capture in industrial processes	Deployment of carbon capture	Further deployment of carbon capture	
Buildings	Further electrification through sustained deployment of heat pumps			Lower thermostat settings for heating and cooling temperature deliver additional energy savings
	Low average annual renovation rate in 2031-2040 and high in 2041-2050	Similar average renovation rate in 2031-2040 and 2041-2050	High average annual renovation rate in 2031-2040 and low in 2041-2050	

Technological feasibility

All the target options remain within the technology feasibility indicators thresholds used by the ESABCC: primary energy biomass of 20 EJ/year in 2050, a maximum amount of carbon capture of 500 Mt CO2/year, hydrogen production capacity of 150 GW in 2030 and a 20% decline of final energy demand between 2020 and 2030. They also remain lower than the technological deployment challenges identified by the ESABCC for wind and solar installed capacities in 2030, (respectively 900 and 623 GW) ([92]), which considered the implication of conservative potential estimates.

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Image Source: European Commission, 2024

Scenario Summary Cont’d

	S1	S2	S3	LIFE
Transport	EU Sustainable & Smart Mobility Strategy and Action Plan: milestones achieved (particularly with regard to rail, inland waterways and short-sea shipping)			
Road transport	CO2 standards for cars and vans: -100% vs 2021 from 2035 onwards	CO2 standards for cars and vans as in S1 + Higher car occupancy & some shift from car to active modes (walking, cycling) and public transport, driven by a shift towards shared and collaborative mobility services and multimodal travel		As in S3 plus stronger shift towards shared and collaborative mobility services and multimodal travel, including sustainable urban transport; ‘smart’ charging
	CO2 standards for HDVs: -90% vs 2019 from 2040 (-100% for buses), more efficient operation of freight vehicles and delivery of goods by optimising multi-modal delivery solutions, higher use of intermodal freight transport		CO2 standards for HDVs: -100% vs 2019 from 2040, more efficient operation of freight vehicles and delivery of goods by optimising multi-modal delivery solutions, higher use of intermodal freight transport	
Maritime transport	FuelEU Maritime GHG intensity targets: -31% in 2040 and -80% in 2050 (vs 2020)			
	Lower end of the IMO GHG reduction target range (-70% in 2040 vs 2008)	Mid-point of the IMO target range (-75% in 2040 vs 2008)	Higher end of the IMO target range (-80% in 2040 vs 2008)	
Aviation	ReFuelEU Aviation SAF mandates (34% in 2040 and 70% in 2050; including a sub-mandate for synthetic aviation fuels and H2: 10% in 2040 and 35% in 2050)	Slightly more ambitious fuel mandates than in S1 (SAF: 36% in 2040 and 72.5% in 2050; synthetic aviation fuels and H2: 12% in 2040 and 37.5% in 2050), incentives for the deployment of zero-emissions aircraft	Slighty more ambitious fuel mandates than in S2 (SAF: 38% in 2040 and 75% in 2050; synthetic aviation fuels: 14% in 2040 and 40% in 2050), incentives for the deployment of zero-emissions aircraft	As in S3 plus fewer business trips and long trips compared to scenarios, modal shift to rail (particularly for short trips)
Food system	Continuation of current trends based on the Agricultural Outlook 2022			Change towards more sustainable food diets, reduction of food waste objectives leading to additional reduction of agriculture GHG
	Very limited GHG reductions in agriculture	GHG in agriculture decrease further thanks to larger deployment of technological options	GHG in agriculture decrease further thanks to full deployment of technological options	
LULUCF	Small increase of forest land and decrease in grassland	Policy intensity to cover mitigation costs equivalent to meeting the 2030 target		
		Higher land-use change with bigger increase of forest land, additional wetland and cropland while stronger decrease of grassland		More available land for carbon farming and high-diversity elements such as set aside and fallow land with natural vegetation through land-use change in grassland and cropland
Non-land-related non-CO2 GHG emissions	Non-land-related non-CO2 emissions slowly decline, combining current policy framework and transformation of the energy system	Non-land-related non-CO2 emissions decline further thanks to additional mitigation		

Image Source: European Commission, 2024

Sectoral net GHG emissions

	2015	2040			2050
		S1	S2	S3	S3**
Reduction vs 1990 - %	**-24%**	**-78%**	**-88%**	**-92%**	**-101%**
Net GHG Emissions (target scope)*	**3592**	**1051**	**578**	**356**	**-38**
Power and district heating[A]	1031	120	8	-10	-39
Other energy sectors[B]	237	71	45	11	-19
Industry[C]	605	267	181	89	16
Residential & services[D]	519	119	92	75	19
Other non-energy sectors[E]	130	33	26	25	22
Domestic transport	780	190	143	120	7
Agriculture[F]	385	351	302	271	249
Waste management	120	65	52	52	28
LULUCF net removals	-322	-218	-316	-317	-333
International transport (target scope[G])	107	52	46	41	11
International Transport (memo items)					
	233	124	113	106	27

*Note: *Calibration residuals to GHG inventory 2023 are allocated to relevant sectors. A: Includes removals from BECCS. B: Includes removals from DACCS. C: includes CO2 from fossil fuel combustion in industry and CO2 from industrial processes. D: Includes fossil fuel combustion CO2 emissions in agriculture. E: CO2 fugitive emissions and non-CO2 emissions from direct use or specific products. F: GHG inventory "category 3". G: international intra-EU aviation, international intra-EU maritime (MRV) and 50% of international extra-EU maritime (MRV).*
***S1 and S2 values for 2050 are similar to S3 and represented in more details in Annex 8.*

Source: PRIMES, GAINS, GLOBIOM.

Image Source: European Commission, 2024

Summary of key energy indicators, 1/2

	2030	2040			2050
		S1	S2	S3	S3**
Policy relevant indicators					
Energy-related CO2 reductions vs 2005	-58%	-83%	-90%	-94%	-103%
RES share in Gross FEC	42.4%	65%	72%	75%	89%
FEC reduction vs 2015 ([55])	-19%	-34%	-34%	-36%	-40%
Energy indicators – Supply					
Gross Available Energy (Mtoe)	1160	1022	1021.	1018	1032
- Fossil fuels	663	375	311	275	150
- of which for non-energy use	*96*	*96*	*96*	*96*	*80*
- of which captured	*1.8*	*11.5*	*13.2*	*13.3*	*24*
- Nuclear	139	129	129	129	142
- Renewables	328	482	544	613	691
Net imports (Mtoe)	572	347	298	267	153
Import dependency (%)	50%	34%	29%	26%	15%
Hydrogen production (Mtoe)([56])	9	60	76	100	185
e-Fuels production (Mtoe)	2	15	27	37	60

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Image Source: European Commission, 2024

Summary of key energy indicators, 2/2

	2030	2040			2050
		S1	S2	S3	S3**
Energy indicators – Power generation					
Gross electricity generation (TWh)	3362	4563	4899	5212	6922
Net installed power capacity (GW)	1617	2181	2377	2525	3256
- Fossil fuels	238	172	164	156	142
- Nuclear	94	71	71	71	71
- Renewables	1285	1939	2142	2298	3027
Storage and flexibility options (GW)	172	213	254	275	238
Final Energy					
Final Energy Consumption (Mtoe)	764	622	614	604	555
Electricity share in FEC	33%	48%	50%	51%	62%
e-Fuels share in FEC	0%	1%	3%	5%	7%

*Note: GAE does not include ambient heat from heat pumps. E-Fuels include power-to-liquid and power-to-gas fuels but not hydrogen. Storage technologies include only battery and pumped-hydro storage, whose decline between 2040 and 2050 is due to the projected increased use of power-to-X technologies. The analysis is based on the 2019 NECPs and national legislation as of March 2023. **S1 and S2 values for 2050 are similar to S3 and represented in more details in Annex 8.*

Source: PRIMES.

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Image Source: European Commission, 2024

Generation and Installed Capacity by Carrier

Figure 19: Electricity generation by energy carrier, 2015-2050

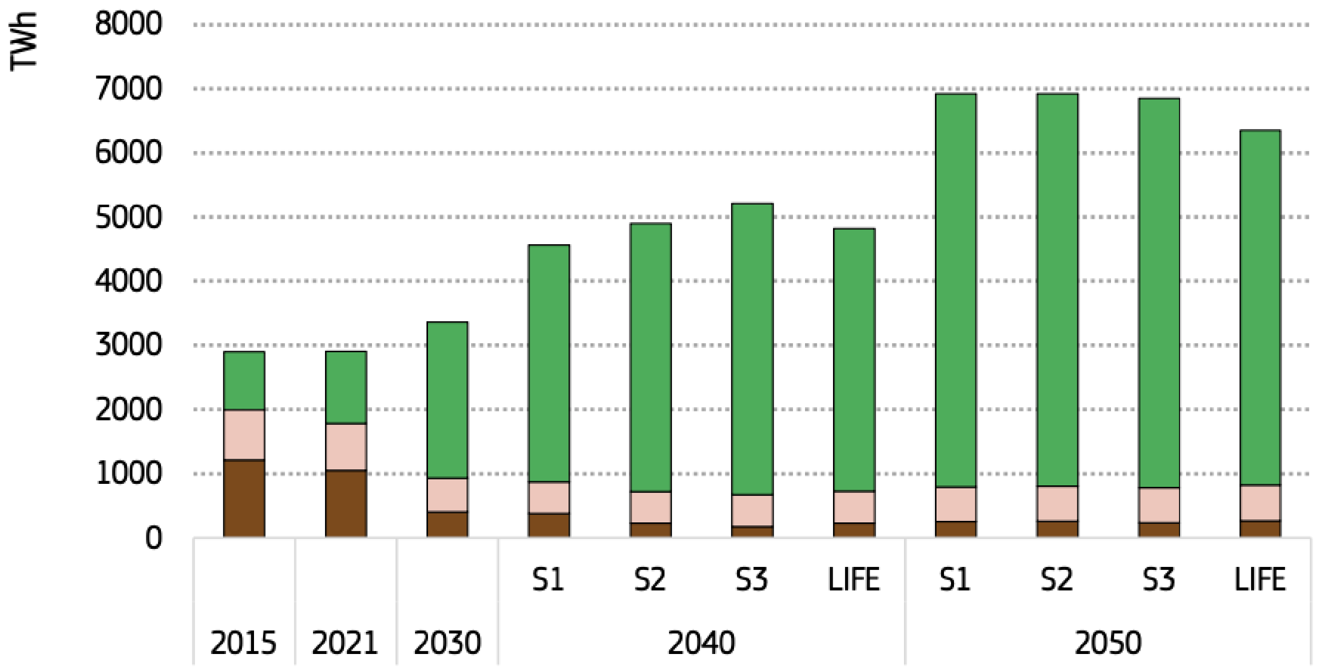

Figure 21: Net installed capacity by energy carrier, 2015-2050

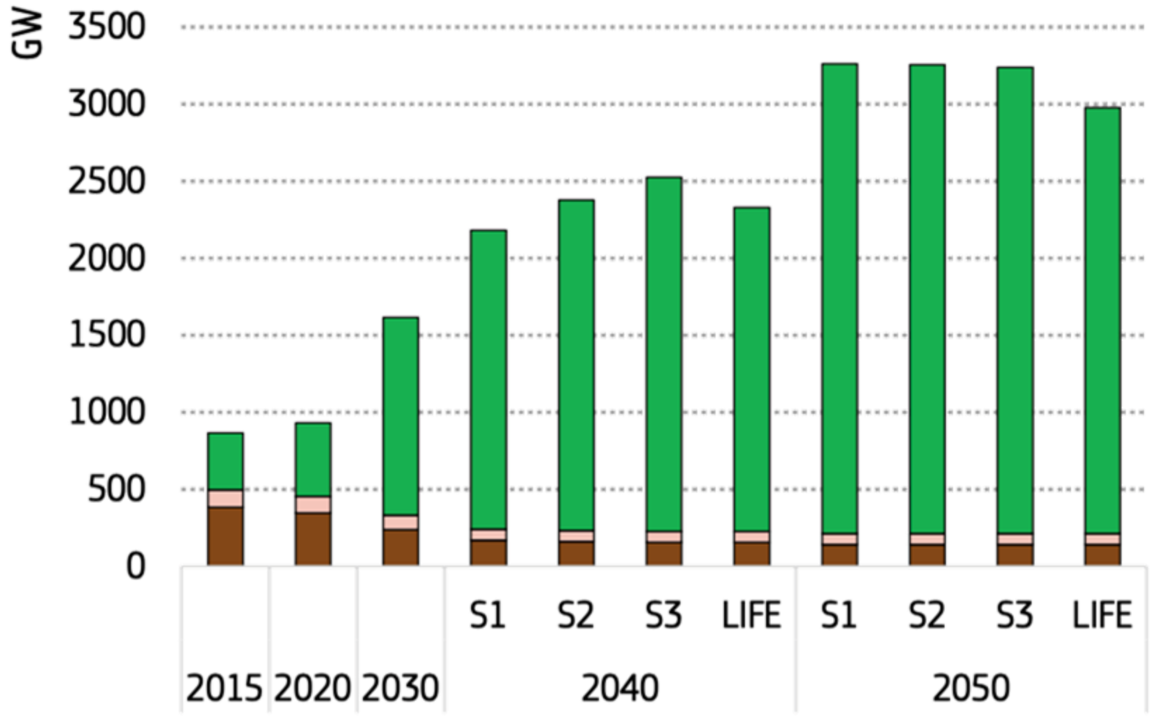

Image Source: European Commission, 2024

Industrial Carbon Capture and Removals

Table 6: Industrial carbon capture and use

	2040			2050
Carbon Captured – MtCO2/year	**S1**	**S2**	**S3**	**S3***
By Source	**86**	**222**	**344**	**452**
Industrial Processes	37	123	137	136
Power (fossil fuels)	26	41	32	55
Power (biomass) and DACC**	16	54	153	232
Biogenic (upgrade of biogas into biomethane)	7	4	22	30
By Application (use and storage)	**86**	**222**	**344**	**452**
E-fuels	43	75	101	147
Synthetic materials	0	0	0	59
Underground storage	42	147	243	247

Note: *S1 and S2 values for 2050 are similar to S3 and represented in more details in Annex 8. **Includes carbon for storage (DACCS) and use.

Source: PRIMES.

Table 7: Industrial removals and net LULUCF removals

	2040			2050
	S1	**S2**	**S3**	**S3****
Gross GHG emissions (MtCO2-eq)	**1273**	**943**	**748**	**411**
Total Removals (MtCO2-eq)	**-222**	**-365**	**-391**	**-447**
Industrial Removals (MtCO2)	-4	-49	-75	-114
LULUCF net removals (MtCO2-eq)	-218	-316	-317	-333

*Note: **S1 and S2 values for 2050 are similar to S3 and represented in more details in Annex 8.*

Source: PRIMES, GAINS, GLOBIOM.

Image Source: European Commission, 2024

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Energy System Investment

Table 16: Average annual energy system investment needs (billion EUR 2023).

	S1			S2			S3			ΔLIFE		
	2031-2040	2041-2050	2031-2050	2031-2040	2041-2050	2031-2050	2031-2040	2041-2050	2031-2050	2031-2040	2041-2050	2031-2050
Supply	236	377	306	289	328	308	341	281	311	-59	-14	-36
Power grid	79	88	84	88	81	85	96	75	85	-15	-2	-9
Power plants	97	187	142	128	157	142	151	133	142	-28	-6	-17
Other	59	102	81	72	90	81	94	73	83	-16	-6	-11
Demand excl. transport	332	377	354	355	357	356	372	338	355	-23	1	-11
Industry	38	31	35	46	24	35	48	22	35	-7	-3	-5
Residential	225	250	237	237	242	239	248	230	239	-12	4	-4
Services	49	78	63	53	73	63	57	67	62	-4	1	-2
Agriculture	19	19	19	19	19	19	20	18	19	0	0	0
Transport	866	875	870	861	885	873	856	882	869	-80	-85	-82
Total	1433	1629	1531	1505	1570	1537	1570	1501	1535	-162	-97	-129
Total excl. transport	567	754	661	644	685	664	713	619	666	-82	-12	-47
Memo:												
Real GDP (period average)	19444	22369	20906	19444	22369	20906	19444	22369	20906	19444	22369	20906

Note: "ΔLIFE" compares the cost of the LIFE scenario to the S3 scenario, which both meet the same overall net GHG reductions by 2040.

Source: PRIMES.

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Table 33: Manufacturing capacity and investment needs per technology (2031-2040)

Technology	Max annual technology deployment in 2030-2040	Installed EU manufacturing capacity in 2030	Market share of EU production	EU manufacturing capacity in 2040	New manufacturing capacity needed post-2030	Factory CAPEX (M€22/unit/year)	Manufacturing capacity investment needs (bn EUR)
Wind	62	33	85%	53	20	260	5.2
Solar PV	55	23	45%	25	2	340	0.7
Heat Pump	53	31	60%	32	1	333	0.5
Battery cell	729	549	90%	656	107	144	15.4
Electrolysers	49	25	100%	49	24	60	1.4
Total							**23.3**

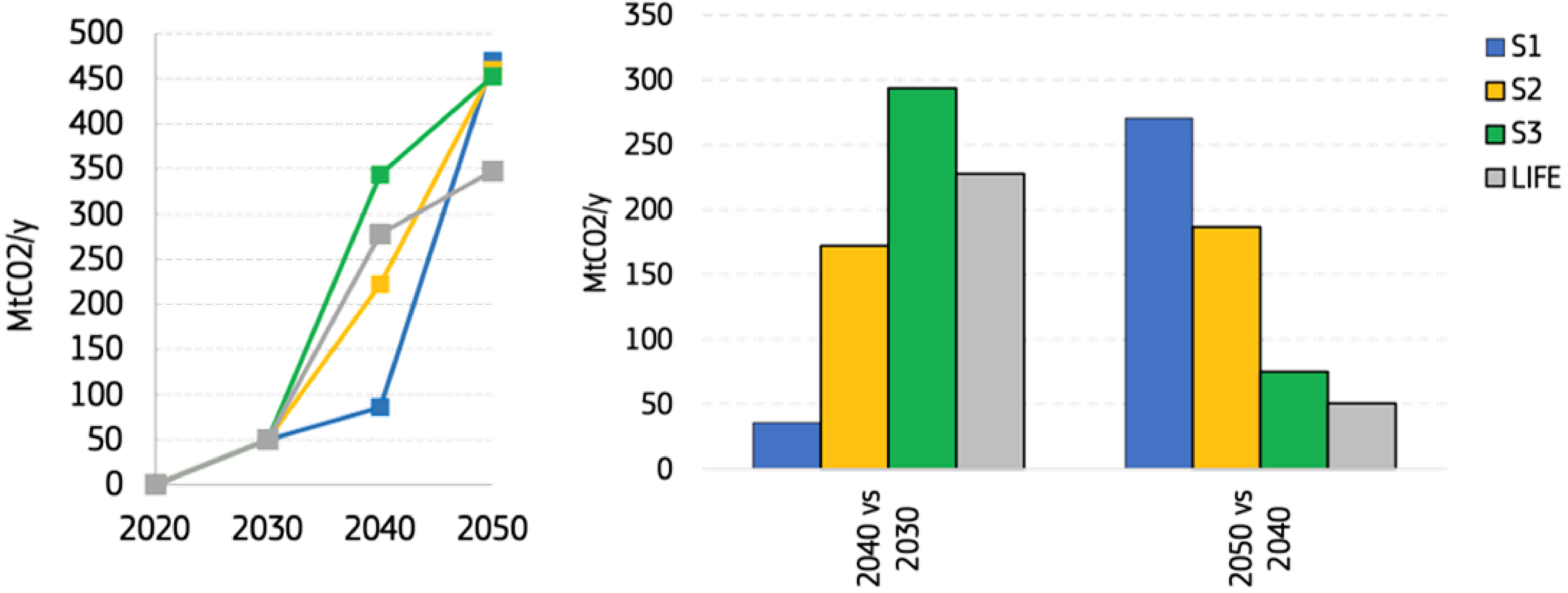
Note: manufacturing capacity needed and investment needs per technology. Capacity is expressed in GWh/year for batteries and GW/year for the other technologies (GW of electricity for electrolysers, GWAC for solar PV)

Source: Commission own calculations based on PRIMES ([280])

Image Source: European Commission, 2024

Carbon Capture Deployment

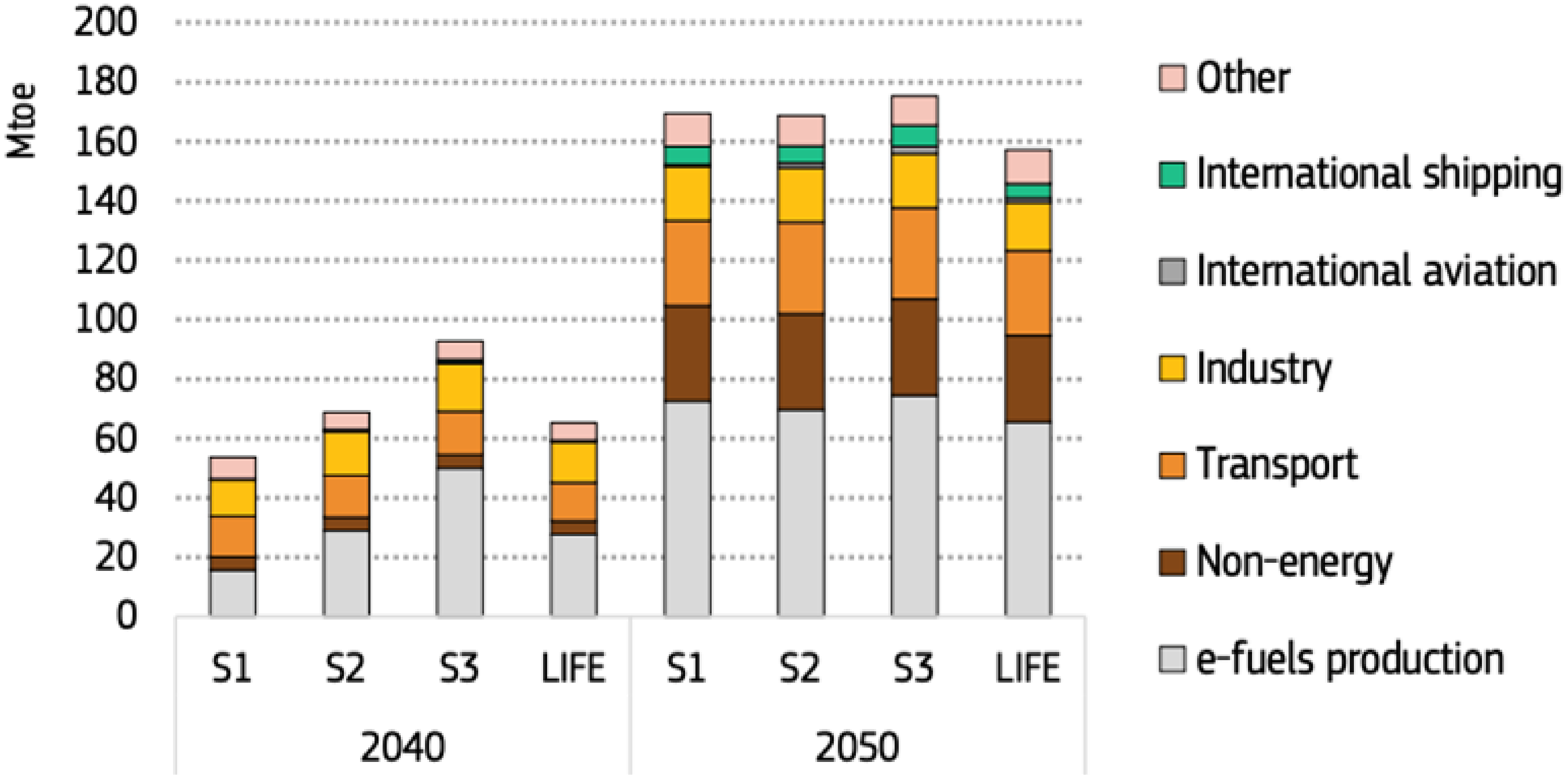
Figure 8: Total (left) and additional (right) carbon captured yearly in selected years



Source: PRIMES.

Image Source: European Commission, 2024

Figure 31: Consumption of hydrogen by sector, 2040-2050



Source: PRIMES.

Image Source: European Commission, 2024

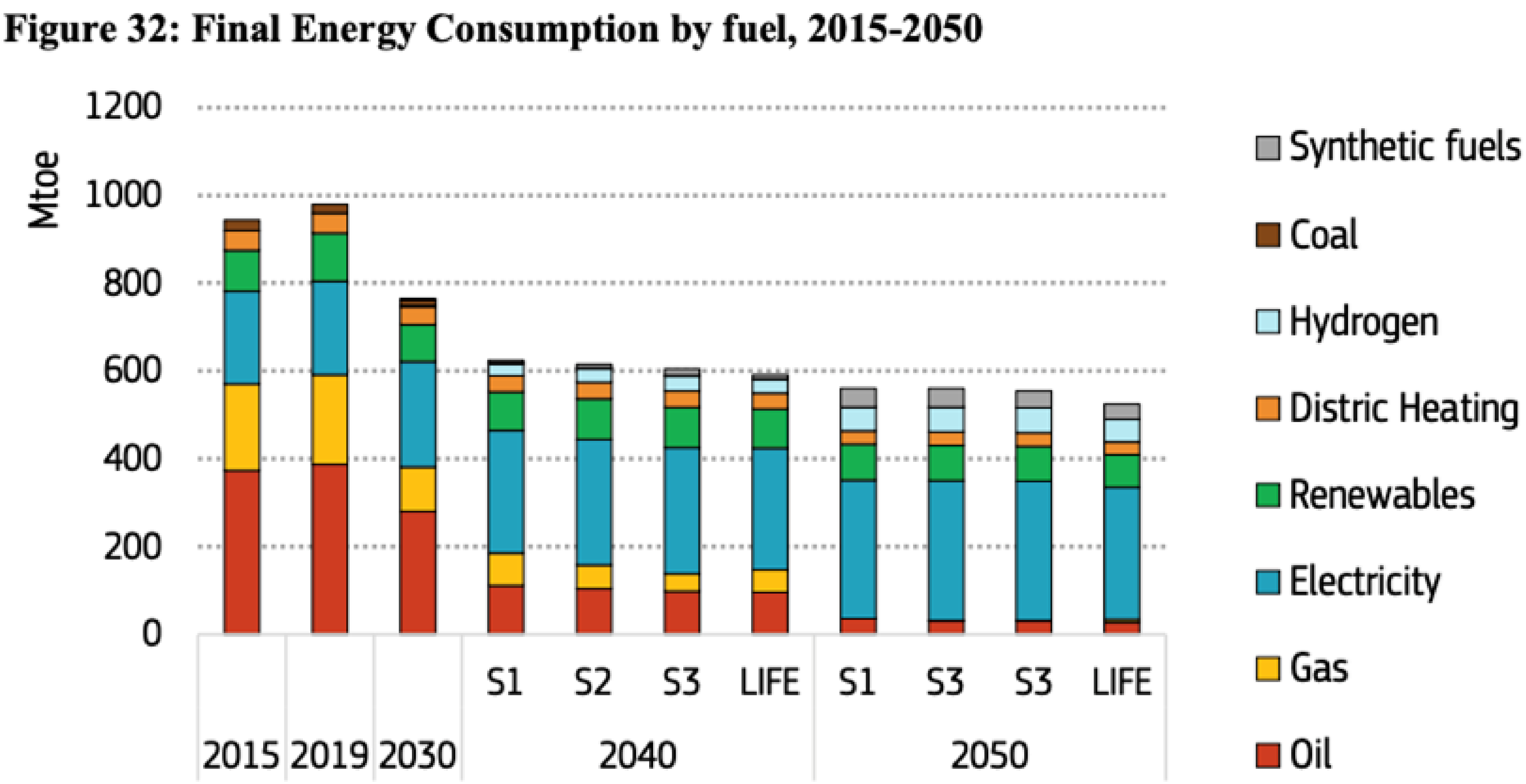
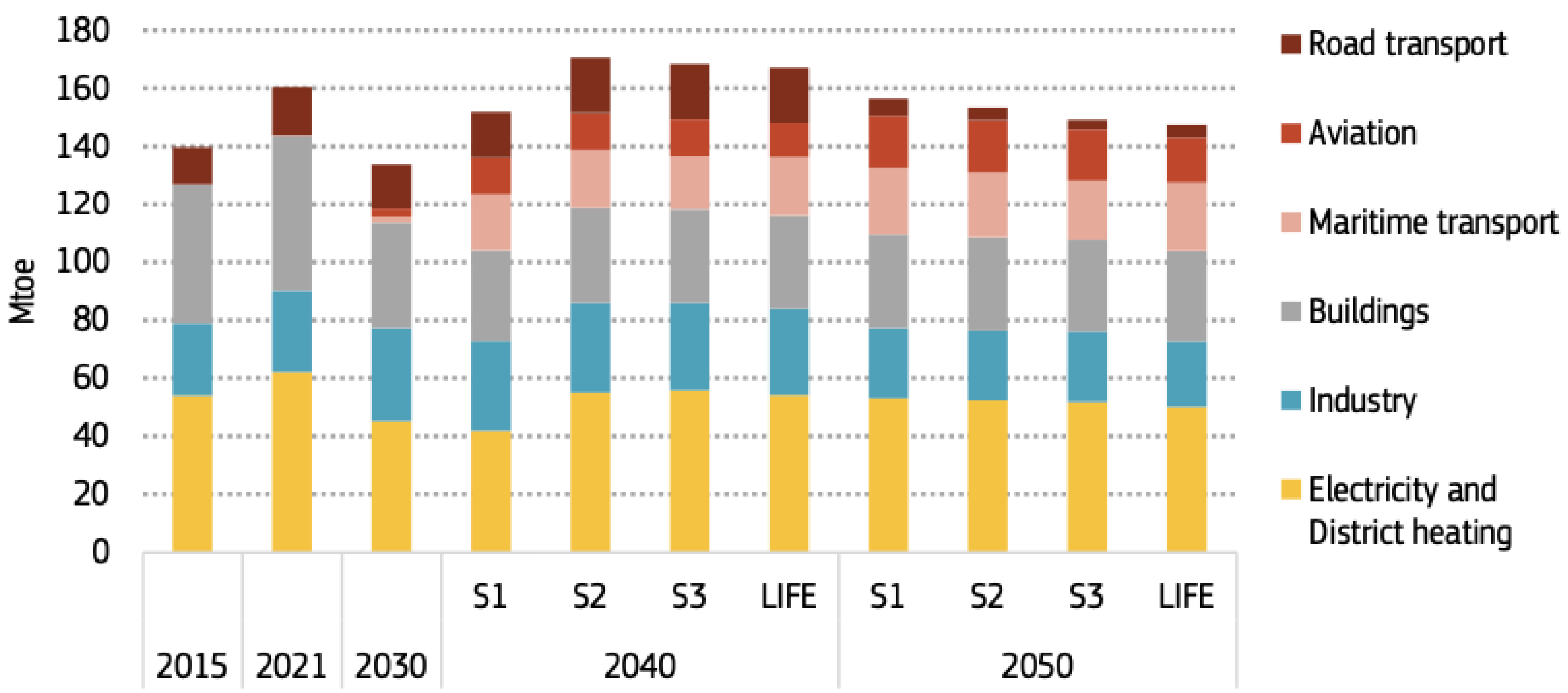


Image Source: European Commission, 2024

Figure 87: Final bioenergy demand by sector and scenario



Note: Graph includes consumption of waste for energy purposes. 'Industry' includes energy sector. 'Buildings' cover household buildings, services, and agriculture.

Source: 2015 and 2021 from Eurostat, projections from PRIMES

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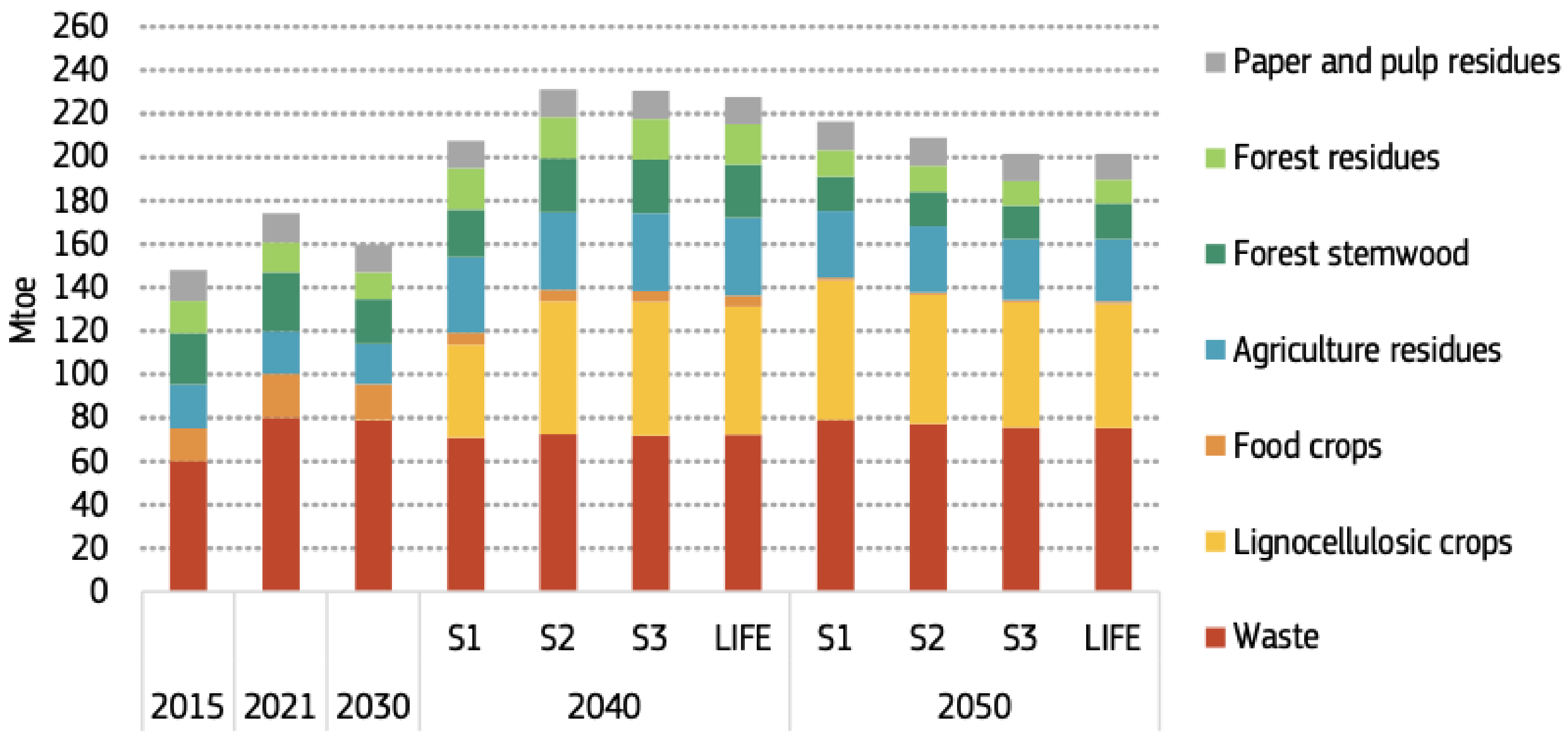
Image Source: European Commission, 2024

Figure 88: Domestic supply of feedstock for bioenergy and waste



Note: 'Lignocellulosic crops' includes short rotation coppice and lignocellulosic grass. Manure is included in 'Waste'.

Source: PRIMES, GLOBIOM

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Image Source: European Commission, 2024