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

S.E. Tanzer / 29 February 2024
THIS IS NOT [YET] TRUE:
The EU has set a target for 90%* reduction in greenhouse gas emissions by 2040.

* 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.

* 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
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

- CO₂ and non-CO₂ GHGs
- Reductions and Removals
- Industrial and Land Sector
- Different rates of progress

Image Source: European Commission, 2024

*Excluding non-BECCS industrial removals
**Including bioenergy with carbon capture and storage (BECCS)
## Breaking down “90% net reduction” into other net targets

<table>
<thead>
<tr>
<th>Category</th>
<th>Mt CO$_2$eq</th>
<th>% change 2015-2040</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total net emissions in 2040</td>
<td>356</td>
<td>-90%</td>
</tr>
<tr>
<td>- of which, <strong>Power</strong> and district heating</td>
<td>-10</td>
<td>-101%</td>
</tr>
<tr>
<td>- of which, <strong>Other energy</strong> sectors (inc. DACCS)</td>
<td>11</td>
<td>-95%</td>
</tr>
<tr>
<td>- of which, <strong>Industry</strong></td>
<td>89</td>
<td>-85%</td>
</tr>
<tr>
<td>- of which, <strong>Transport</strong> (domestic, international, bunkers)</td>
<td>267</td>
<td>-76%</td>
</tr>
<tr>
<td>- of which, <strong>Agriculture</strong></td>
<td>271</td>
<td>-30%</td>
</tr>
<tr>
<td>- of which, <strong>LULUCF</strong> (inc. removals in agricultural land)</td>
<td>-317</td>
<td>+2%</td>
</tr>
</tbody>
</table>
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 CO₂ per year
- Limit biomass use to below **9 EJ** per year (all sectors)

N.B. reductions are from a 2015 baseline
Is this a realistic wishlist?
• Residential: heatpumps and cookstoves (n.b. model includes change in heating/cooling demand due to climate change)
• Industry: [e]-hydrogen and electricity
• Transport: electric cars and e-fuels
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.
Electrify everything

- 95 Mtoe of \( \text{H}_2 \) consumption
- of which, 50 for e-fuels

**Figure 23:** Net installed storage and new fuels production capacity, 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

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.
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.
7-fold increase between 2030 and 2040

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

Source: PRIMES
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)

<table>
<thead>
<tr>
<th></th>
<th>2011-2020</th>
<th>2021-2030</th>
<th>2031-2040</th>
<th>2041-2050</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S1</td>
<td>S2</td>
<td>S3</td>
<td>S1</td>
</tr>
<tr>
<td>Total energy system costs</td>
<td>1766</td>
<td>2130</td>
<td>2419</td>
<td>2472</td>
</tr>
<tr>
<td>Billion EUR</td>
<td>11.9%</td>
<td>12.5%</td>
<td>12.4%</td>
<td>12.7%</td>
</tr>
<tr>
<td>% GDP</td>
<td>2.3%</td>
<td>2.5%</td>
<td>1.51%</td>
<td>1.42%</td>
</tr>
<tr>
<td>Fossil fuel imports</td>
<td>336</td>
<td>427</td>
<td>293</td>
<td>277</td>
</tr>
<tr>
<td>Billion EUR</td>
<td>3.3%</td>
<td>4.2%</td>
<td>3.3%</td>
<td>3.0%</td>
</tr>
<tr>
<td>% GDP</td>
<td>2.3%</td>
<td>2.5%</td>
<td>1.51%</td>
<td>1.42%</td>
</tr>
</tbody>
</table>

Source: PRIMES.
And finally, how much does it cost?

Most of the energy system costs are from transport.

Investment now pays off with lower costs later.

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

Source: PRIMES.

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

<table>
<thead>
<tr>
<th></th>
<th>2040</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industry</td>
<td>130-131</td>
<td>131-133</td>
</tr>
<tr>
<td>Services</td>
<td>249</td>
<td>255</td>
</tr>
</tbody>
</table>

*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.
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, H₂ pipelines, CO₂ 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

When a metric becomes a target, it ceases to be a good metric.

Sounds bad. Let’s offer a bonus to anyone who identifies a metric that has become a target.

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

Image Source: European Commission, 2024
Impact Assessment Main Modelling Suite

Economics
- Framework conditions: Population & GDP
- Economic structure: GEM-E3

Energy
- Global system: POLES-JRC
- EU energy system: PRIMES
- EU transport system: PRIMES-TREMOVE

Land use & agriculture
- Global & EU forestry + LU: GLOBIOM
- EU agriculture: CAPRI
- Global, EU: GAINS
- Non-CO₂ GHG Air pollution

Image Source: European Commission, 2024
## Scenario Summary

<table>
<thead>
<tr>
<th>Power system</th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
<th>LIFE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limited remaining CO2 emissions in 2040, share of renewables in total electricity production increases compared to 2030</td>
<td>Close to decarbonised in 2040, larger deployment of renewables</td>
<td>Fully decarbonised in 2040, the system operates mostly with renewables</td>
<td></td>
<td></td>
</tr>
<tr>
<td>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.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| 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 | Electrification of energy consumption, some development of e-fuels by 2040 | More e-fuels by 2040 than in S2 | Circular economy trends limiting raw materials needs | Enhanced circularity entails comparatively lower needs for primary production of materials, and so lower needs for carbon capture |

| Industry | Very limited carbon capture in industrial processes | Deployment of carbon capture | Further deployment of carbon capture |  |

| Buildings | Low average annual renovation rate in 2031-2040 and high in 2041-2050 | Similar average renovation rate in 2031-2040 and high in 2041-2050 | High average annual renovation rate in 2031-2040 and low in 2041-2050 | Lower thermostat settings for heating and cooling temperature deliver additional energy savings |

### 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.
<table>
<thead>
<tr>
<th>Scenario Summary Cont'd</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Transport</strong></td>
</tr>
<tr>
<td>EU Sustainable &amp; Smart Mobility Strategy and Action Plan: milestones achieved (particularly with regard to rail, inland waterways and short-sea shipping)</td>
</tr>
<tr>
<td><strong>Road transport</strong></td>
</tr>
<tr>
<td>CO2 standards for cars and vans: -100% vs 2021 from 2035 onwards</td>
</tr>
<tr>
<td>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</td>
</tr>
<tr>
<td><strong>Maritime transport</strong></td>
</tr>
<tr>
<td>Lower end of the IMO GHG reduction target range (-70% in 2040 vs 2008)</td>
</tr>
<tr>
<td>Mid-point of the IMO target range (-75% in 2040 vs 2008)</td>
</tr>
<tr>
<td><strong>Aviation</strong></td>
</tr>
<tr>
<td>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)</td>
</tr>
<tr>
<td>Slightly 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</td>
</tr>
<tr>
<td><strong>Food system</strong></td>
</tr>
<tr>
<td>Continuation of current trends based on the Agricultural Outlook 2022</td>
</tr>
<tr>
<td>Very limited GHG reductions in agriculture</td>
</tr>
<tr>
<td><strong>LULUCF</strong></td>
</tr>
<tr>
<td>Small increase of forest land and decrease in grassland</td>
</tr>
<tr>
<td>Policy intensity to cover mitigation costs equivalent to meeting the 2030 target</td>
</tr>
<tr>
<td><strong>Non-land-related non-CO2 GHG emissions</strong></td>
</tr>
<tr>
<td>Non-land-related non-CO2 emissions slowly decline, combining current policy framework and transformation of the energy system</td>
</tr>
</tbody>
</table>

Image Source: European Commission, 2024
## Sectoral net GHG emissions

<table>
<thead>
<tr>
<th></th>
<th>2015</th>
<th>2040</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reduction vs 1990 - %</strong></td>
<td>-24%</td>
<td>-78%</td>
<td>-88%</td>
</tr>
<tr>
<td><strong>Net GHG Emissions (target scope)</strong></td>
<td>3592</td>
<td>1051</td>
<td>578</td>
</tr>
<tr>
<td>Power and district heating</td>
<td>1031</td>
<td>120</td>
<td>8</td>
</tr>
<tr>
<td>Other energy sectors</td>
<td>237</td>
<td>71</td>
<td>45</td>
</tr>
<tr>
<td>Industry</td>
<td>605</td>
<td>267</td>
<td>181</td>
</tr>
<tr>
<td>Residential &amp; services</td>
<td>519</td>
<td>119</td>
<td>92</td>
</tr>
<tr>
<td>Other non-energy sectors</td>
<td>130</td>
<td>33</td>
<td>26</td>
</tr>
<tr>
<td>Domestic transport</td>
<td>780</td>
<td>190</td>
<td>143</td>
</tr>
<tr>
<td>Agriculture</td>
<td>385</td>
<td>351</td>
<td>302</td>
</tr>
<tr>
<td>Waste management</td>
<td>120</td>
<td>65</td>
<td>52</td>
</tr>
<tr>
<td>LULUCF net removals</td>
<td>-322</td>
<td>-218</td>
<td>-316</td>
</tr>
<tr>
<td>International transport</td>
<td>107</td>
<td>52</td>
<td>46</td>
</tr>
</tbody>
</table>

**International Transport (memo items)**

<table>
<thead>
<tr>
<th></th>
<th>2015</th>
<th>2040</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>233</td>
<td>124</td>
<td>113</td>
<td>106</td>
</tr>
<tr>
<td>27</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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.
## Summary of key energy indicators, 1/2

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

Image Source: European Commission, 2024
## Summary of key energy indicators, 2/2

<table>
<thead>
<tr>
<th>Energy indicators – Power generation</th>
<th>2030</th>
<th>2040</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gross electricity generation (TWh)</strong></td>
<td>3362</td>
<td>4563</td>
<td>4899</td>
</tr>
<tr>
<td><strong>Net installed power capacity (GW)</strong></td>
<td>1617</td>
<td>2181</td>
<td>2377</td>
</tr>
<tr>
<td>- Fossil fuels</td>
<td>238</td>
<td>172</td>
<td>164</td>
</tr>
<tr>
<td>- Nuclear</td>
<td>94</td>
<td>71</td>
<td>71</td>
</tr>
<tr>
<td>- Renewables</td>
<td>1285</td>
<td>1939</td>
<td>2142</td>
</tr>
<tr>
<td><strong>Storage and flexibility options (GW)</strong></td>
<td>172</td>
<td>213</td>
<td>254</td>
</tr>
</tbody>
</table>

### Final Energy

<table>
<thead>
<tr>
<th></th>
<th>2030</th>
<th>2040</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Final Energy Consumption (Mtoe)</strong></td>
<td>764</td>
<td>622</td>
<td>614</td>
</tr>
<tr>
<td><strong>Electricity share in FEC</strong></td>
<td>33%</td>
<td>48%</td>
<td>50%</td>
</tr>
<tr>
<td><strong>e-Fuels share in FEC</strong></td>
<td>0%</td>
<td>1%</td>
<td>3%</td>
</tr>
</tbody>
</table>

*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.
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

<table>
<thead>
<tr>
<th></th>
<th>2040</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Carbon Captured – MtCO2/year</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S1</td>
<td>86</td>
<td></td>
</tr>
<tr>
<td>S2</td>
<td>222</td>
<td></td>
</tr>
<tr>
<td>S3</td>
<td>344</td>
<td></td>
</tr>
<tr>
<td>S3*</td>
<td>452</td>
<td></td>
</tr>
<tr>
<td><strong>By Source</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Industrial Processes</td>
<td>37</td>
<td>123</td>
</tr>
<tr>
<td>Power (fossil fuels)</td>
<td>26</td>
<td>41</td>
</tr>
<tr>
<td>Power (biomass) and DACC**</td>
<td>16</td>
<td>54</td>
</tr>
<tr>
<td>Biogenic (upgrade of biogas into biomethane)</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td><strong>By Application (use and storage)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E-fuels</td>
<td>43</td>
<td>75</td>
</tr>
<tr>
<td>Synthetic materials</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Underground storage</td>
<td>42</td>
<td>147</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th></th>
<th>2040</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S1</td>
<td>S2</td>
<td>S3</td>
<td>S3**</td>
</tr>
<tr>
<td><strong>Gross GHG emissions (MtCO2-eq)</strong></td>
<td>1273</td>
<td>943</td>
<td>748</td>
<td>411</td>
</tr>
<tr>
<td><strong>Total Removals (MtCO2-eq)</strong></td>
<td>-222</td>
<td>-365</td>
<td>-391</td>
<td>-447</td>
</tr>
<tr>
<td>Industrial Removals (MtCO2)</td>
<td>-4</td>
<td>-49</td>
<td>-75</td>
<td>-114</td>
</tr>
<tr>
<td>LULUCF net removals (MtCO2-eq)</td>
<td>-218</td>
<td>-316</td>
<td>-317</td>
<td>-333</td>
</tr>
</tbody>
</table>

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
## Energy System Investment

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

<table>
<thead>
<tr>
<th></th>
<th>S1 2031-2040</th>
<th>S1 2041-2050</th>
<th>S2 2031-2040</th>
<th>S2 2041-2050</th>
<th>S3 2031-2040</th>
<th>S3 2041-2050</th>
<th>ΔLIFE 2031-2040</th>
<th>ΔLIFE 2041-2050</th>
<th>ΔLIFE 2031-2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply</td>
<td>236</td>
<td>377</td>
<td>306</td>
<td>289</td>
<td>328</td>
<td>308</td>
<td>341</td>
<td>281</td>
<td>311</td>
</tr>
<tr>
<td>Power grid</td>
<td>79</td>
<td>88</td>
<td>84</td>
<td>88</td>
<td>81</td>
<td>85</td>
<td>96</td>
<td>75</td>
<td>85</td>
</tr>
<tr>
<td>Power plants</td>
<td>97</td>
<td>187</td>
<td>142</td>
<td>128</td>
<td>157</td>
<td>142</td>
<td>151</td>
<td>133</td>
<td>142</td>
</tr>
<tr>
<td>Other</td>
<td>59</td>
<td>102</td>
<td>81</td>
<td>72</td>
<td>90</td>
<td>81</td>
<td>94</td>
<td>73</td>
<td>83</td>
</tr>
<tr>
<td>Demand excl. transport</td>
<td>332</td>
<td>377</td>
<td>354</td>
<td>355</td>
<td>357</td>
<td>356</td>
<td>372</td>
<td>338</td>
<td>355</td>
</tr>
<tr>
<td>Industry</td>
<td>38</td>
<td>31</td>
<td>35</td>
<td>46</td>
<td>24</td>
<td>35</td>
<td>48</td>
<td>22</td>
<td>35</td>
</tr>
<tr>
<td>Residential</td>
<td>225</td>
<td>250</td>
<td>237</td>
<td>237</td>
<td>242</td>
<td>239</td>
<td>248</td>
<td>230</td>
<td>239</td>
</tr>
<tr>
<td>Services</td>
<td>49</td>
<td>78</td>
<td>63</td>
<td>53</td>
<td>73</td>
<td>63</td>
<td>57</td>
<td>67</td>
<td>62</td>
</tr>
<tr>
<td>Agriculture</td>
<td>19</td>
<td>19</td>
<td>19</td>
<td>19</td>
<td>19</td>
<td>19</td>
<td>20</td>
<td>18</td>
<td>19</td>
</tr>
<tr>
<td>Transport</td>
<td>866</td>
<td>875</td>
<td>870</td>
<td>861</td>
<td>885</td>
<td>873</td>
<td>856</td>
<td>882</td>
<td>869</td>
</tr>
<tr>
<td>Total</td>
<td>1433</td>
<td>1629</td>
<td>1531</td>
<td>1505</td>
<td>1570</td>
<td>1537</td>
<td>1570</td>
<td>1501</td>
<td>1535</td>
</tr>
<tr>
<td>Total excl. transport</td>
<td>567</td>
<td>754</td>
<td>661</td>
<td>644</td>
<td>685</td>
<td>664</td>
<td>713</td>
<td>619</td>
<td>666</td>
</tr>
<tr>
<td>Memo: Real GDP (period average)</td>
<td>19444</td>
<td>22369</td>
<td>20906</td>
<td>19444</td>
<td>22369</td>
<td>20906</td>
<td>19444</td>
<td>22369</td>
<td>20906</td>
</tr>
</tbody>
</table>

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

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

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 (\(^{280}\))
Carbon Capture Deployment

Figure 8: Total (left) and additional (right) carbon captured yearly in selected years
Figure 31: Consumption of hydrogen by sector, 2040-2050

Source: PRIMES.
Figure 32: Final Energy Consumption by fuel, 2015-2050

- Synthetic fuels
- Coal
- Hydrogen
- District Heating
- Renewables
- Electricity
- Gas
- Oil

Legend: S1, S2, S3, LIFE

Year: 2015, 2019, 2030, 2040, 2050

Mtoe (Million tons of oil equivalent)

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
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