Schwartz and Co
Strategy Consulting

THE GOVERNMENT
OF THE GRAND DUCHY OF LUXEMBOURG

Roadmap for the Decarbonisation of the Luxembourg Manufacturing Industry

Meeting with stakeholders, 14th January 2026

V1.2

Context and objectives

This roadmap presents the assessment of the decarbonisation potential of the Luxembourg Manufacturing Industry by 2030, 2040 and 2050

Context

- In 2018, the **Luxembourg manufacturing industry was responsible for around 17 % of Luxembourg total GHG emissions** and almost 80 % of the total GHG emissions of the Luxembourg manufacturing industry were caused by installations subject to the EU-ETS. **Luxembourg aims at long term climate neutrality by 2050 at the latest**
- In 2025, Luxembourg Ministry of the Economy, and Ministry of Environment, Climate and Biodiversity have entrusted Schwartz and Co with developing the roadmap for the decarbonisation of the Luxembourg manufacturing industry

Objectives

- The present roadmap presents :
  - The **identification and estimation of the Luxembourg Manufacturing Industry decarbonisation potential and the related energy consumption evolution** in 2030, 2040 and 2050, as quantifiable today
  - The **identification and estimation of the decarbonisation potential by industry sector and by decarbonisation lever** in 2030, 2040 and 2050
  - The **required annual volumes of low-carbon energy vectors and of captured carbon to reach the estimated decarbonisation potential**
  - **The required hydrogen and CO2 infrastructures to reach the estimated decarbonisation potential**
- This roadmap reflects the current status of the Luxembourg Manufacturing Industry regarding foreseen decarbonisation projects, which are expected to evolve in the coming years

Scope and methodology

63 decarbonisation projects, out of a total of 92 identified projects, have been quantified to assess the decarbonisation potential of the Luxembourg Manufacturing Industry

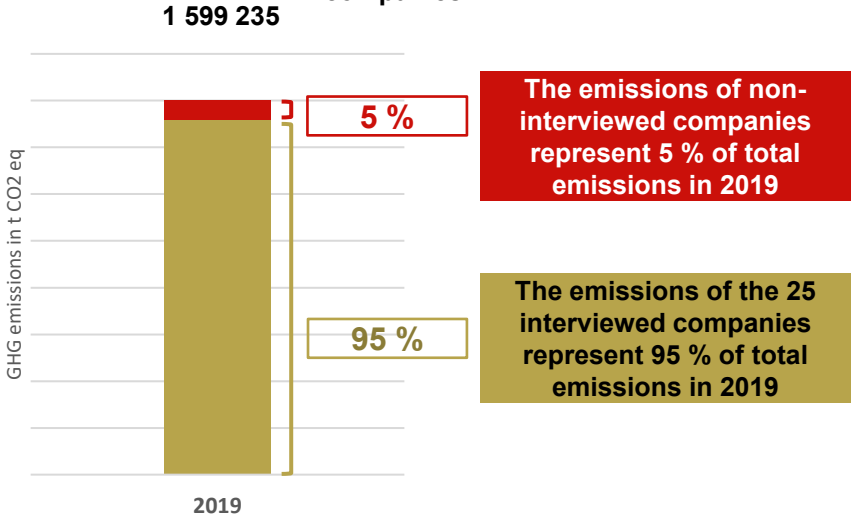
Scope of the roadmap

- The roadmap addresses the Luxembourg manufacturing industry :
  - As defined by the statistical classification NACELUX revision 2, which includes **24 categories at the upper level (C10 to C33)**
  - Supplemented with **4 paving road asphalt production companies (F42)**
- This scope is denominated **the Manufacturing Industry** in the roadmap

Decarbonisation potential estimation

- The decarbonisation potential of the Manufacturing Industry has been estimated through :
  - **Interviews/Surveys with 25 industry top GHG emitters** leading to the documentation of company specific decarbonisation projects (84 projects identified in total)
  - **The design of typical decarbonisation projects** (8 in total) for the rest of the companies, applicable to relevant industry sectors
- Based on the projects' maturity level, 55 out of the 84 specific projects and 8 typical projects have been quantified

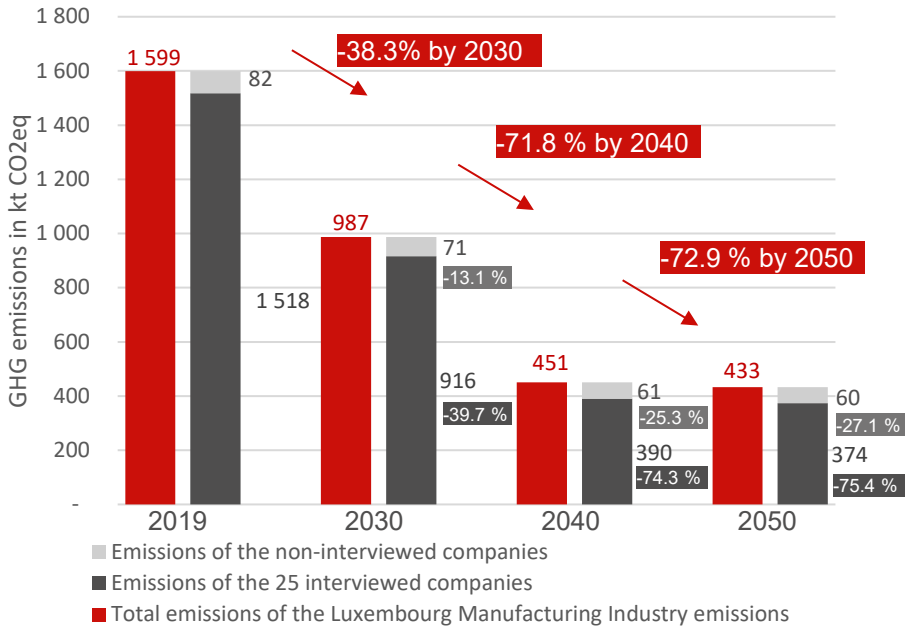
2019 GHG emissions of the Luxembourg Manufacturing Industry and split between interviewed and non interviewed companies



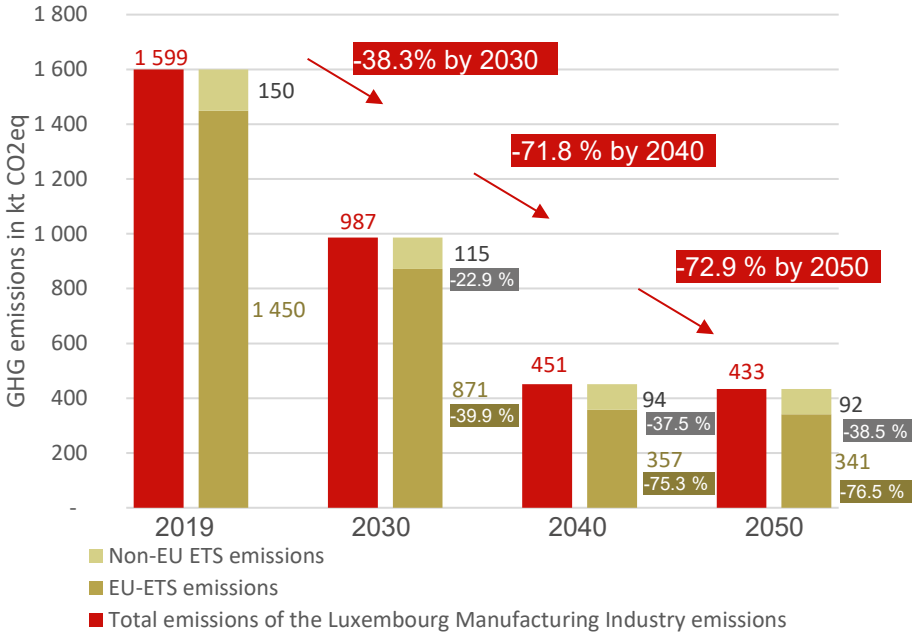
Estimation of the decarbonisation potential for the Luxembourg Manufacturing Industry

Reflecting the current status, the identified decarbonisation potential of the Luxembourg Manufacturing Industry is estimated at 38.3 % in 2030, 71.8 % in 2040 and 72.9 % in 2050, compared to the 2019 GHG emissions*

Decarbonisation potential of the Luxembourg Manufacturing Industry, interviewed and non-interviewed companies



Decarbonisation potential of the Luxembourg Manufacturing Industry, EU-ETS and non EU-ETS emissions



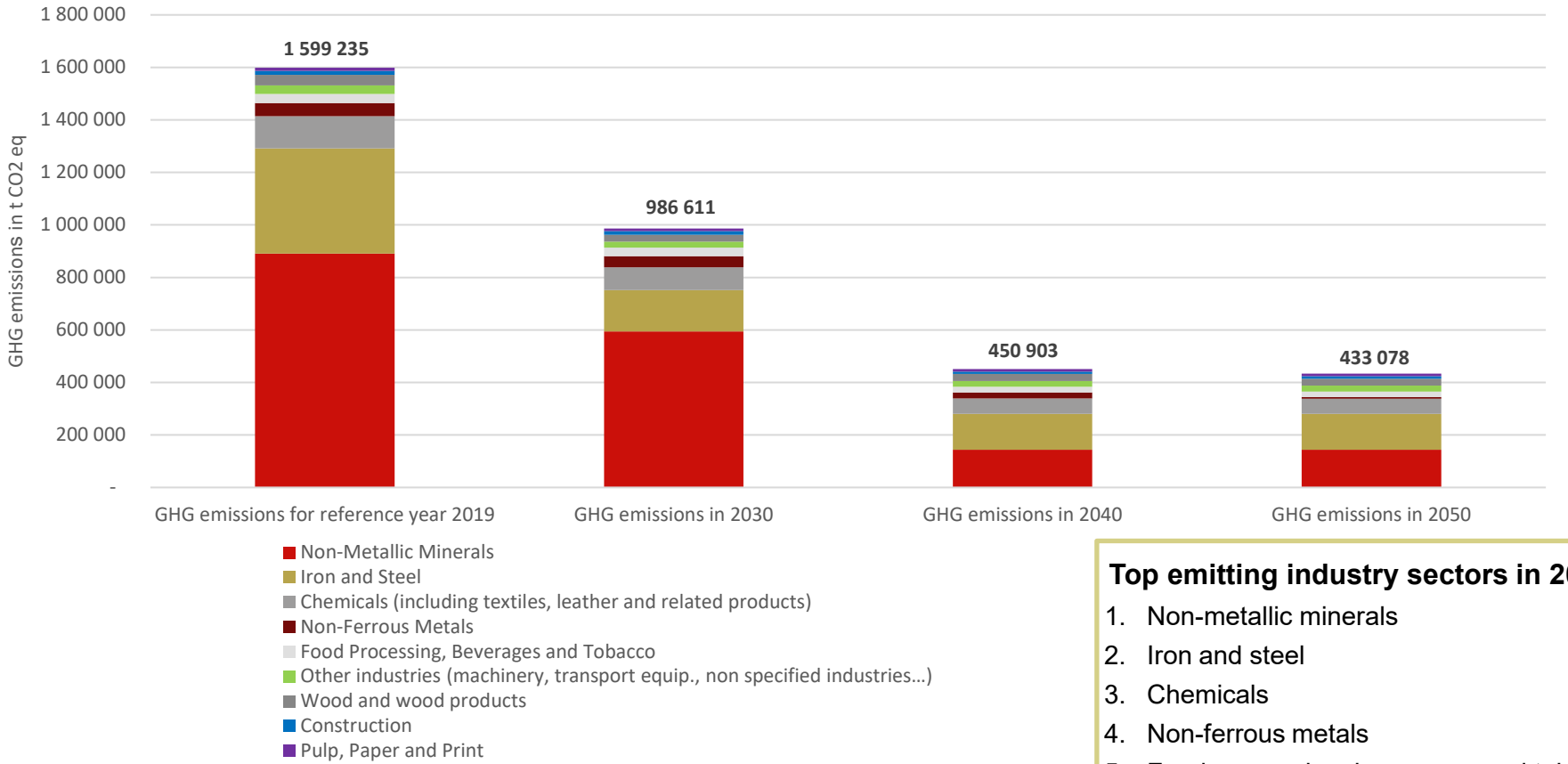
- The **25 interviewed companies include the largest industry players with a high maturity level regarding decarbonisation;** they also **encompass almost all companies** with at least one site subject to the EU-ETS**
- The decarbonisation potential identified is higher for these 2 groups than for non-interviewed companies and non-EU ETS emissions

*Source : 2019 emissions basis computed from Luxembourg's GHG emission inventory 2022 (CO_2 eq conversion using AR5 GWPs, and excluding CO_2 from biomass) and direct inputs of interviewed companies
**10 out of the 11 companies of the Luxembourg Manufacturing Industry with at least one site subject to the EU-ETS have been interviewed

Decarbonisation potential by industry sector (1/3)

Overall results

The top 2 emitting industry sectors have a well-defined decarbonisation roadmap representing 88.2 % of the overall identified decarbonisation potential in 2030, 88.1 % in 2040 and 86.8 % in 2050 compared to 2019



Top emitting industry sectors in 2019:

1. Non-metallic minerals
2. Iron and steel
3. Chemicals
4. Non-ferrous metals
5. Food processing, beverages and tobacco

Decarbonisation potential by industry sector (2/3)

Major decarbonisation areas for the top 4 emitting sectors

The top 4 emitting sectors have the highest identified decarbonisation potentials by 2050, cutting their emissions by 53 % up to 87 % compared to 2019

1 Non-metallic minerals

2019 emissions: 891 138 t CO_2 eq

- Decarbonisation potential in 2030: **33 %**
- Decarbonisation potential in 2040: **84 %**
- Decarbonisation potential in 2050: **84 %**

Major decarbonisation areas:

- Install carbon capture plant on site to use the captured carbon or to connect the plant to the required CO2 infrastructure for final storage
- Deployment of melting furnaces using oxy-firing technology
- Install new clinker kiln, increase energy efficiency, the share of low-carbon fuel and the share of decarbonated raw materials for clinker production

2 Iron and steel

2019 emissions: 400 652 t CO_2 eq

- Decarbonisation potential in 2030: **61 %**
- Decarbonisation potential in 2040: **66 %**
- Decarbonisation potential in 2050: **66 %**

Major decarbonisation areas:

- Substitution of natural gas by green hydrogen for high-temperature processes
- Revamping of existing furnaces and optimization of shell concept
- Electrification with the deployment of induction heating systems
- Design of low-carbon products production lines

3 Chemicals*

2019 emissions: 122 686 t CO_2 eq

- Decarbonisation potential in 2030: **29 %**
- Decarbonisation potential in 2040: **53 %**
- Decarbonisation potential in 2050: **53 %**

Major decarbonisation areas:

- Electrification of steam production
- Replace the gas burners to enable hydrogen use
- Increase energy efficiency with the transformation of regenerative thermal oxidation solutions by high-efficiency ones

*Chemicals industry including textiles, leather and related products

4 Non-ferrous metals

2019 emissions: 49 781 t CO_2 eq

- Decarbonisation potential in 2030: **14 %**
- Decarbonisation potential in 2040: **55 %**
- Decarbonisation potential in 2050: **87 %**

Major decarbonisation areas:

- Substitution of natural gas by green hydrogen in melting furnaces
- Replace natural gas by biogas for casting and melting furnaces
- Electrification of medium-temperature processes, for example, by deploying electric or hybrid annealing furnaces

Decarbonisation potential by industry sector (3/3)

Major decarbonisation areas for other sectors

Other industry sectors are expected to cut their GHG emissions by 23 % up to 41 % by 2050, compared to 2019

5 Food processing, beverages and tobacco

2019 emissions: 34 634 t CO_2 eq

- Decarbonisation potential in 2030: **8 %**
- Decarbonisation potential in 2040: **37 %**
- Decarbonisation potential in 2050: **40 %**

Major decarbonisation areas:

- Electrification of steam boilers
- Replacement of fuel oil burners by micro ondulating gas burners, partially powered by biogas
- Equipment upgrades to improve energy efficiency (e.g. variable speed compressor)

6 Other industries*

2019 emissions: 32 766 t CO_2 eq

- Decarbonisation potential in 2030: **30 %**
- Decarbonisation potential in 2040: **32 %**
- Decarbonisation potential in 2050: **32 %**

Major decarbonisation areas:

- Electrification of natural gas boilers where technically possible, or replacement of natural gas boilers by condensing ones
- Waste heat recovery solutions for low and medium-temperature processes for industrial and non-industrial applications
- Electrification of low-temperature processes

7 Wood and wood products industry

2019 emissions: 39 485 t CO_2 eq

- Decarbonisation potential in 2030: **32 %**
- Decarbonisation potential in 2040: **32 %**
- Decarbonisation potential in 2050: **32 %**

Major decarbonisation areas:

- Complete electrification of production lines
- Increase the use of biomass for combustion
- Electrification of industrial vehicle fleets (forklifts, engines, etc.)

8 Road asphalt and PP&P**

2019 emissions: 28 092 t CO_2 eq

- Decarbonisation potential of the road asphalt industry : **8% in 2030, 41% in 2040 and 2050**
- Decarbonisation potential of PP&P in 2030, 2040 & 2050: **23 %**

Major decarbonisation areas:

- Substitution of fossil fuels by green hydrogen to power rotating drum burners
- Increase the production of low-carbon asphalt produced at a lower temperature
- Waste heat recovery solutions for low and medium temperature processes for preheating applications

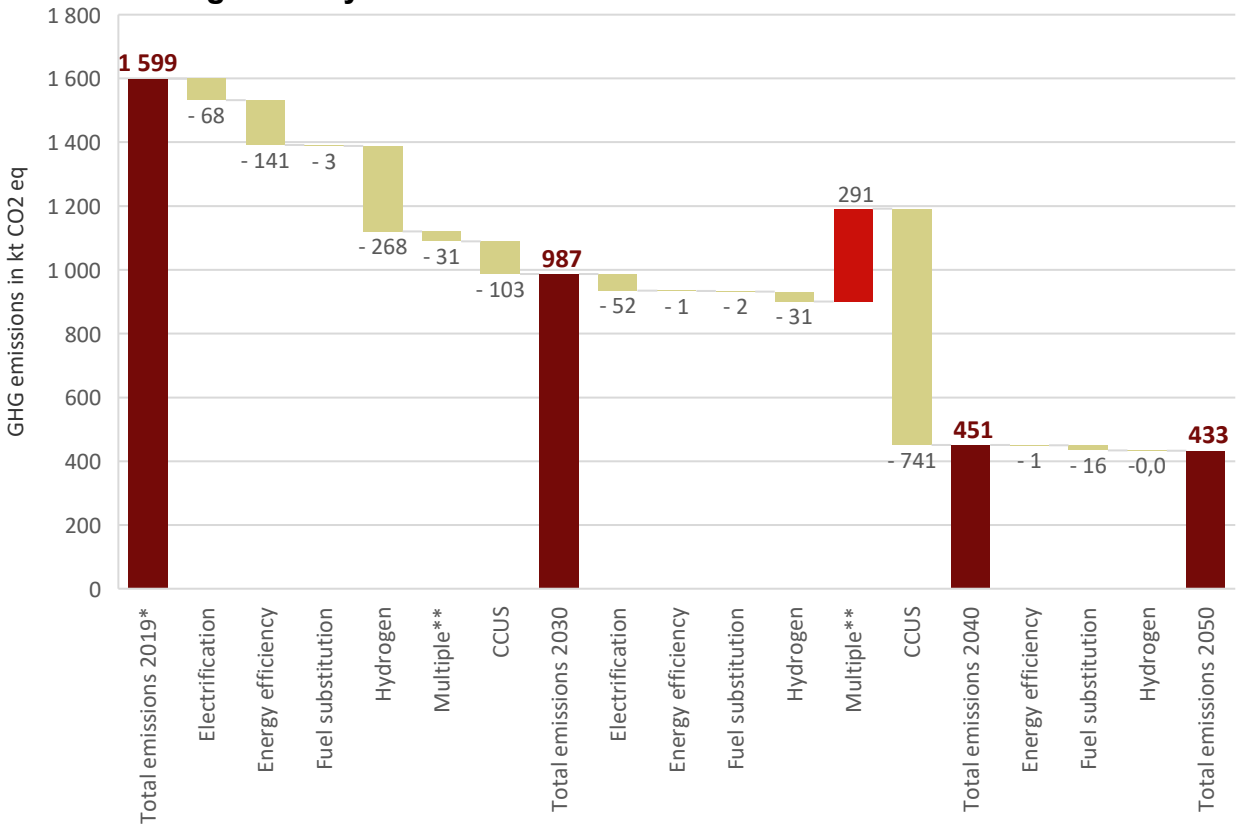
*Including machinery, transport equipment and non-specified industries

** Pulp, Paper and Print

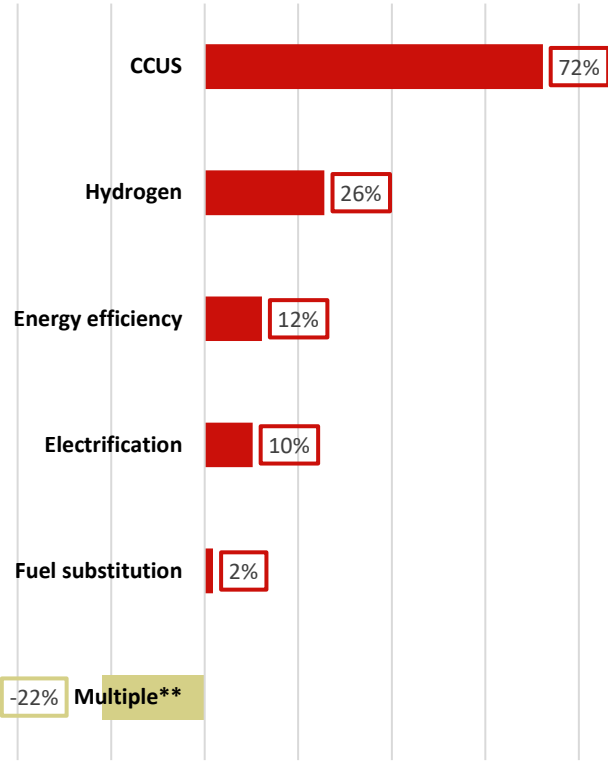
The decarbonisation levers of the Luxembourg Manufacturing Industry

Overall, by 2050, CCUS* appears as the number one decarbonisation lever, followed by hydrogen, energy efficiency and electrification

Potential of each decarbonisation lever applicable to the Luxembourg Manufacturing Industry



Contribution to the decarbonisation potential by 2050



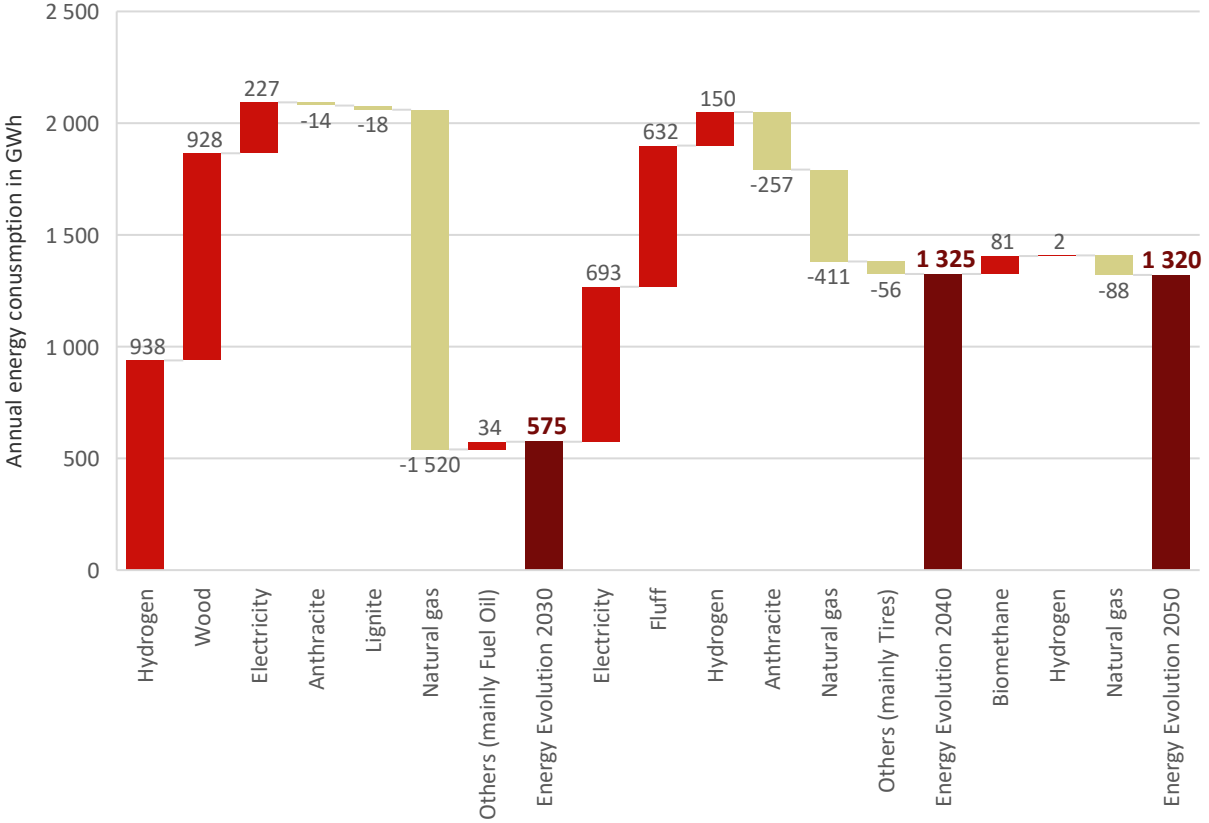
* Carbon Capture Use or Storage

** "Multiple" combines the four following decarbonisation levers : fuel substitution, use of alternative raw material, energy efficiency, electrification ; NB: the emissions for the "Multiple" lever increase between 2030 and 2040 due to the forecasted production capacity increase despite the emissions reduction induced by the identified decarbonisation projects

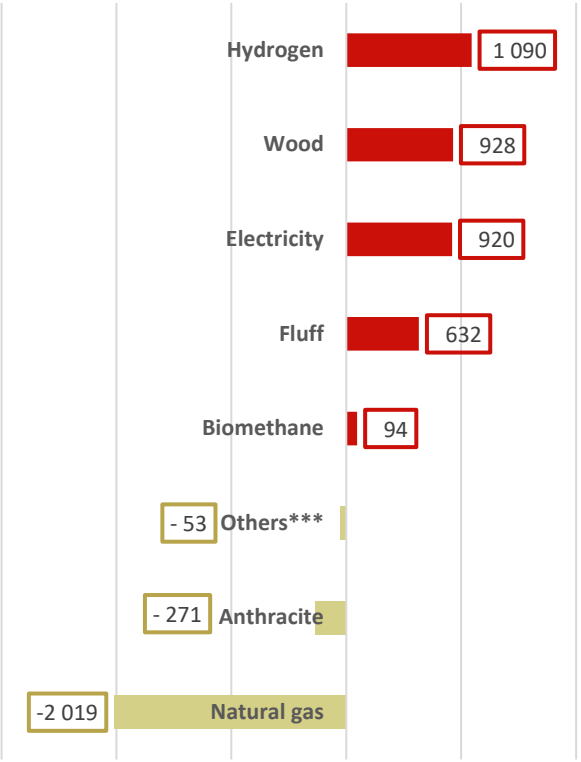
Energy evolution consumption of the Luxembourg Manufacturing Industry

Overall, by 2050, although fossil fuel consumption is decreasing, total energy consumption is increasing by 1 320 GWh, mainly due to the overall increase in production volumes and the commissioning of CCUS projects

Annual energy consumption evolution induced by the decarbonisation projects of the Luxembourg Manufacturing Industry, by energy carriers



Energy consumption evolution to 2050 in GWh



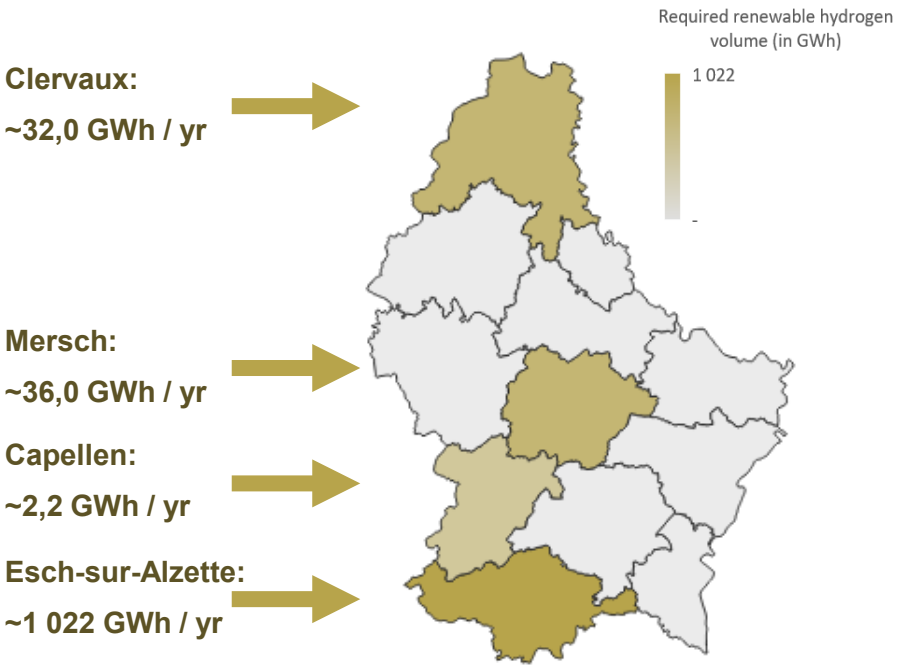
***Others : other energy carriers whose consumption is evolving (mainly tires and solvents)

Required volume of low-carbon energy vectors (1/2)

Renewable / low-carbon hydrogen and renewable electricity

1.1 TWh/yr of renewable / low carbon hydrogen and 0.5 TWh/yr of renewable electricity will be required to achieve the currently assessed decarbonisation potential of the Luxembourg Manufacturing Industry by 2050

Required annual volume of renewable hydrogen per canton by 2050



Renewable / low-carbon hydrogen required volume

- Required volume of renewable / low-carbon hydrogen by milestones to achieve the identified decarbonisation potential:
  - **1 009 GWh / yr** by 2030
  - **1 090 GWh / yr** by 2040
  - **1 092 GWh / yr** by 2050
- Renewable / low-carbon hydrogen needs are entirely distributed between 4 cantons. By 2050:
  - 93.6 % of the demand is located in the Esch-sur-Alzette canton
  - 3.3 % in the Mersch canton
  - 2.9 % in the Clervaux canton
  - 0.2 % in the Capellen canton

Renewable electricity required volume

- Required volume of renewable electricity by milestones to achieve the identified decarbonisation potential:
  - **217 GWh / yr** by 2030 (+227 GWh / yr of additional electricity demand)
  - **462 GWh / yr** by 2040 (+920 GWh / yr of additional electricity demand)
- Main current concerns of industry players regarding their electricity sourcing strategies:
  - **Secure affordable and stable prices**
  - **Security of supply to ensure business continuity**

Required volume of low-carbon energy vectors (2/2)

Biomass, biomethane and avoided natural gas consumption

Based on the identified and quantified decarbonisation potential, 2.0 TWh / yr of natural gas consumption could be avoided by 2050 through its substitution by low-carbon energy vectors and energy efficiency improvements

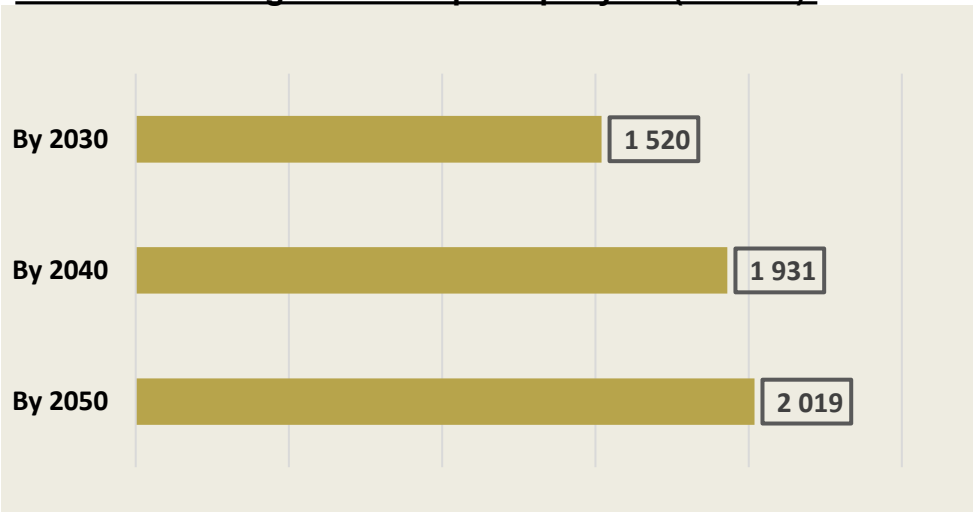
Biomass and biomethane

- By 2030, **928 GWh / yr of biomass** will be required to achieve the identified decarbonisation potential of the Luxembourg Manufacturing Industry
- By 2050, **94 GWh / yr of biomethane** will be required to achieve the identified decarbonisation potential of the Luxembourg Manufacturing Industry
- These two low-carbon energy vectors contribute to the decarbonisation of specific sectors, such as the wood & wood products industry, the food & beverage industries and the non-ferrous metals industry

Avoided natural gas consumption

- The development of low-carbon energy vectors will contribute to the natural gas phase-out of the Luxembourg Manufacturing Industry
- By 2050 **2 019 GWh / yr of natural gas** consumption could be avoided with **energy efficiency** projects and **its substitution** with green hydrogen, biomass, electricity and biomethane

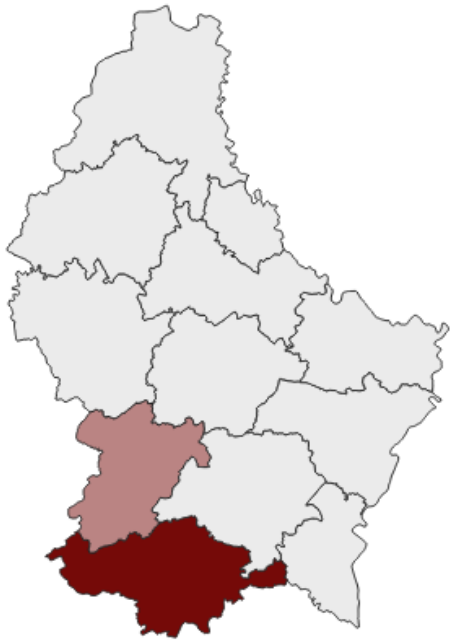
Avoided natural gas consumption per year (in GWh):



Volume of captured CO2

By 2040, the assessed decarbonisation potential of the Luxembourg Manufacturing Industry relies on a volume of 814 ktCO2 / yr of captured CO2 which has to be evacuated from the capture sites to usage or storage sites

Annual volume of captured carbon per canton by 2040



Capellen:
~73.0 ktCO2 / yr

Esch-sur-Alzette:
~740.8 ktCO2 / yr

CO2 captured volume

- Estimated volumes of captured carbon to achieve the identified decarbonisation potential:
  - By 2030, **73.0 ktCO2eq / yr** of CO2 to be captured, resulting in a 40.4 GWh / yr increase of the electricity consumption
  - By 2040, **813.8 ktCO2 / yr** of CO2 to be captured, resulting in a 450.0 GWh / yr increase of the electricity consumption

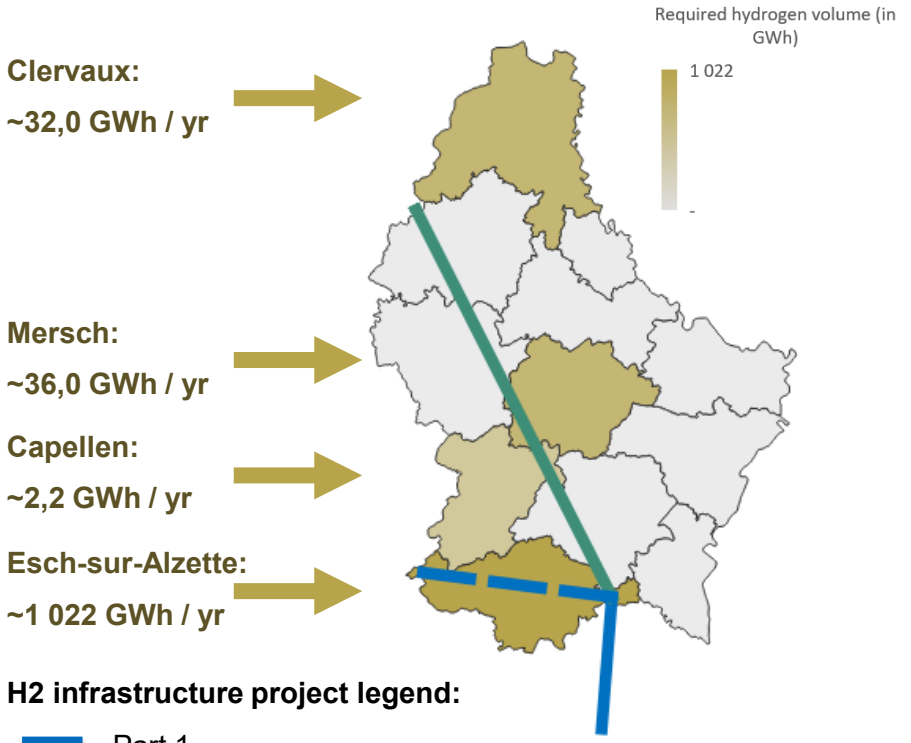
- Captured carbon volumes are entirely distributed between 2 cantons in the south-west of Luxembourg. By 2040:
  - 91.0 % in the Esch-sur-Alzette canton
  - 9.0 % in the Capellen canton

Required infrastructures (1/2)

Hydrogen

Hydrogen connection infrastructures will be required to link consumption sites to the future Luxembourg hydrogen backbone

Required annual volume of hydrogen per canton by 2050 and planned H2 infrastructure projects



Planned H2 infrastructure projects

- The Natran, Creos and Fluxys consortium plans to commission a **hydrogen backbone (the HY4Link project**) in three parts:
  - The first part would connect the Esch-sur-Alzette canton to the French hydrogen network
  - In the meantime, a local infrastructure would cross the Esch-sur-Alzette canton from east to west
  - The second part will cross Luxembourg from south to north, passing through the western cantons to the Belgian border

Additional H2 infrastructure required

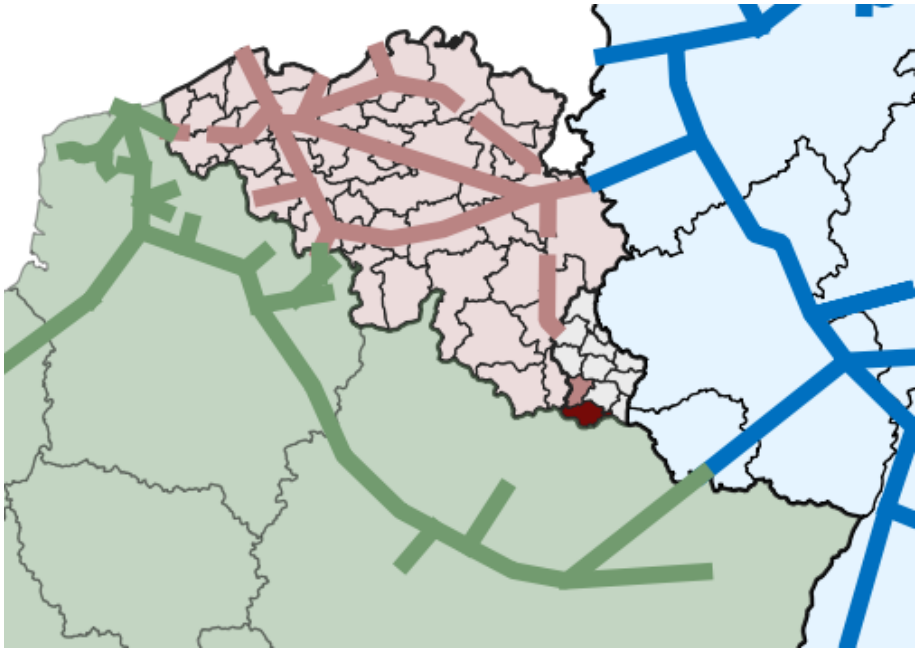
- Hydrogen connection infrastructures will be required **to link consumption sites** in 4 cantons **to the HY4Link hydrogen backbone**
- **The routing of the HY4Link project should be optimised to minimize the overall cost** of the transmission and connection infrastructures

Required infrastructures (2/2)

CO2

A CO2 transmission network linking the CO2 capture sites in the south-west of Luxembourg to the planned Belgian CO2 transmission network is required by 2035

CO2 transportation infrastructure identified projects



CO2 transportation infrastructure legend:

- French project
- German project
- Belgian project
- Belgian extension / alternative route

CO2 transmission infrastructure required

- To date, **the CO2 transmission network projects are still located far from Luxembourg's CO2 capture sites,** situated in the south-west cantons
- To reach the estimated decarbonisation potential, a CO2 transmission network should be developed in Luxembourg to **connect the carbon CO2 sites to CO2 utilisation sites or to final storage sites, by taking advantage of the Belgian extension forecasted, representing the closest identified CO2 transportation grid project:**
  - The Belgian CO2 transmission route is offered by Fluxys to bridge the distance from the CO2 capture sites towards potential CO2 users or final storage sites, situated in the North Sea
  - The development of a Luxembourg CO_2 transmission network to connect the CCU sites to the transmission network planned by OGE in Germany, does not currently appear to be economically viable, as the interconnection is twice as far from the Luxembourg capture sites as the Belgian interconnection

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