Scenarios for Net-Zero Emission Basic Materials Processing Industries in the EU

International Expert Workshop: Deep Decarbonization in Industry
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Three key strategies to net-zero GHG emission processing industries

<table>
<thead>
<tr>
<th>NEW PROCESSES</th>
<th>CIRCULAR ECONOMY</th>
<th>CARBON CAPTURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Processes relies heavily on new core industrial processes, often driven by electricity.</td>
<td>Circular Economy hinges on the potential of a more circular economy for materials recirculation and increased materials efficiency.</td>
<td>Carbon Capture emphasises a greater role for carbon capture and storage (CCS).</td>
</tr>
</tbody>
</table>

Source: Industrial Transformation 2050 - Report by Material Economics with Wuppertal Institut and VUB, 2019
Emission reductions from Steel, Chemicals and Cement

Three Pathways for the EU
(in Mt CO2 per year)

- New Processes
- Circular Economy
- Carbon Capture

Source: Industrial Transformation 2050 - Report by Material Economics with Wuppertal Institut and VUB, 2019
Share of the strategies in Net Zero GHG emission pathways

NEW PROCESSES: 44% 26%
CIRCULAR ECONOMY: 65% 26%
CARBON CAPTURE: 8% 43%

Source: Industrial Transformation 2050 - Report by Material Economics with Wuppertal Institut and VUB, 2019
Clean energy requirements per pathway, EU 2050

- **NEW PROCESSES**
  - **LECTRICITY**
    - Year, 2050: 965
  - **BIOMASS**
    - TWh per year, 2050: 1.3 / 361
  - **HYDROGEN**
    - TWh per year, 2050: 1 / 433 / 618 *

- **CIRCULAR ECONOMY**
  - **LECTRICITY**
    - Year, 2050: 659
  - **BIOMASS**
    - TWh per year, 2050: 1 / 306
  - **HYDROGEN**
    - TWh per year, 2050: 293 / 419 *

- **CARBON CAPTURE**
  - **LECTRICITY**
    - Year, 2050: 693
  - **BIOMASS**
    - TWh per year, 2050: 361
  - **HYDROGEN**
    - TWh per year, 2050: 226 / 323 *
  - **CO₂**
    - Capture, Year, 2050: 45 / 47 / 235

*Energy content / electricity needed (70% efficiency of electrolysis)

Source: Industrial Transformation 2050 - Report by Material Economics with Wuppertal Institut and VUB, 2019
Energy mix changes in net-zero GHG scenarios
(EJ per year)

Source: Industrial Transformation 2050 - Report by Material Economics with Wuppertal Institut and VUB, 2019
Possible locations of future industrial energy needs
Site specific EU map of steel, chemical and cement

Legend
- Grid bound energy carriers
  - Electricity
  - Steam
  - Hydrogen
- CO2 captured
  - Mt of CO2 p.a.
  - 2
  - 4
  - 6
  - 8
  - 10

Institut and VUB, 2019
Possible locations of future industrial CO₂ sources
Site specific EU map of steel, chemical and cement

Legend
- grid bound energy carriers
  - electricity
  - steam
  - hydrogen
- CO₂ captured
  - Mt of CO₂ p.a.
  - 2
  - 4
  - 6
  - 8
  - 10

Source: Industrial Transformation 2050 - Report by Material Economics with Wuppertal Institut and VUB, 2019
Over 70% of the potential RE power in six countries GB, FR, ES, NO, SE, PL and IT (e-Highways 2050)

Slightly more than 60% of electric demand (w/o additional industry demand) is in five countries DE, FR, SP, UK and IT (e-Highways 2050)

Different location of sweet spots and hot spots leads to considerable energy transport needs
CO₂ storage potential seems sufficient on an aggregate level

- Mt/a CO₂ captured in 2050
- Effective CO₂ storage potential

storage capacities according to RECCS+ (WI, 2010), capture demands according to CCS scenario (WI, 2019)
Costs of providing bulk materials in 2050
(in Billion Euro per year)

Costs of materials increase but not of products

<table>
<thead>
<tr>
<th>Material</th>
<th>Current Production Cost</th>
<th>Cost of Low-CO Production Technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel</td>
<td>EUR / tonne</td>
<td>547</td>
</tr>
<tr>
<td>Cost of Low-CO Production Technologies</td>
<td>EUR / tonne</td>
<td>189-466</td>
</tr>
<tr>
<td>Plastic</td>
<td>EUR / tonne</td>
<td>1,282</td>
</tr>
<tr>
<td>Cost of Low-CO Production Technologies</td>
<td>EUR / tonne</td>
<td>1,481-1,822</td>
</tr>
<tr>
<td>Airnova</td>
<td>EUR / tonne</td>
<td>354</td>
</tr>
<tr>
<td>Cost of Low-CO Production Technologies</td>
<td>EUR / tonne</td>
<td>418-633</td>
</tr>
<tr>
<td>Cement</td>
<td>EUR / tonne</td>
<td>91</td>
</tr>
<tr>
<td>Cost of Low-CO Production Technologies</td>
<td>EUR / tonne</td>
<td>85-108</td>
</tr>
</tbody>
</table>

- Integrated Blast furnace over (BF-BOP)
- Elastic arc furnaces, direct smelting with CCS, hydrogen direct reduction, CCS
- Steam cracking
- Steam cracking with CCS, electrolysis: bio-based plastics production, chemical recycling
- Steam methane reforming
- Steam methane reforming with CCS, electrolysis
- Current cement production
- CCS, electrified heat and CCS

Source: Industrial Transformation 2050 - Report by Material Economics with Wuppertal Institut and VUB, 2019
Investment needs in steel, chemicals, cement
(in Billion Euro per year)

Source: Industrial Transformation 2050 - Report by Material Economics with Wuppertal Institut and VUB, 2019
Potential reduction of steel demand in the EU (vs. Baseline demand of 193 Mt in 2050)

- Less home scrap due to use of intermediates closer to final products, 3D printing etc.
- Car-sharing and similar concepts as well as lifetime extension of cars
- Reduction of overdimensioning and high strength
- Re-use of building components
- Lifetime expansion and better use of buildings

Steel production routes in the three pathways (in Mt per year)

Source: Industrial Transformation 2050 - Report by Material Economics with Wuppertal Institut and VUB, 2019
Conclusion

There is a mix of strategies available and necessary to achieve net-zero GHG emission materials production.

A combination of strategies can make them feasible from a technical and energy system perspective.

Costs to society and consumers are low but investment needs for basic industries double and production costs of materials increase significantly.

Material efficiency and circularity appear to be potentially strong (and cost efficient) levers, but imply new value chains and business models.
Thank you!

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- CCIRIT Operation of the Secretariat of the Platform for Coal and Carbon-intensive Regions in Transition
- INFRA-NEEDS Infrastructure Needs of an EU Industrial Transformation towards Deep Decarbonisation
- SCI4climate.NRW Scientific Competence in Industry
- KoVI SGW Competence Centre Virtual Institute Power to Gas and Heat
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