

PORTFOLIO: 01

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SOURCE:

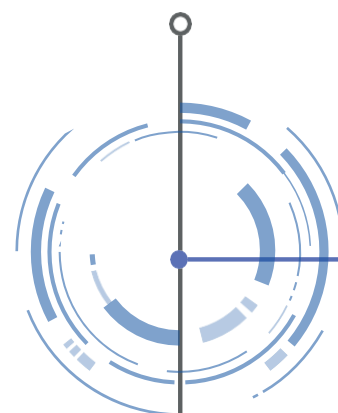


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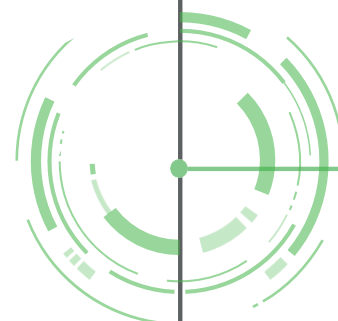


Key Business Areas

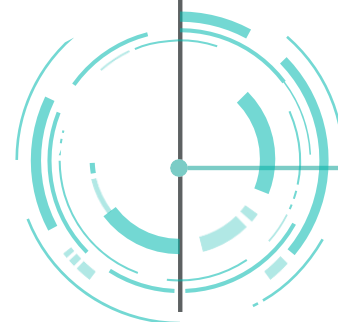
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Power



Enabled
Circular



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Catalysts



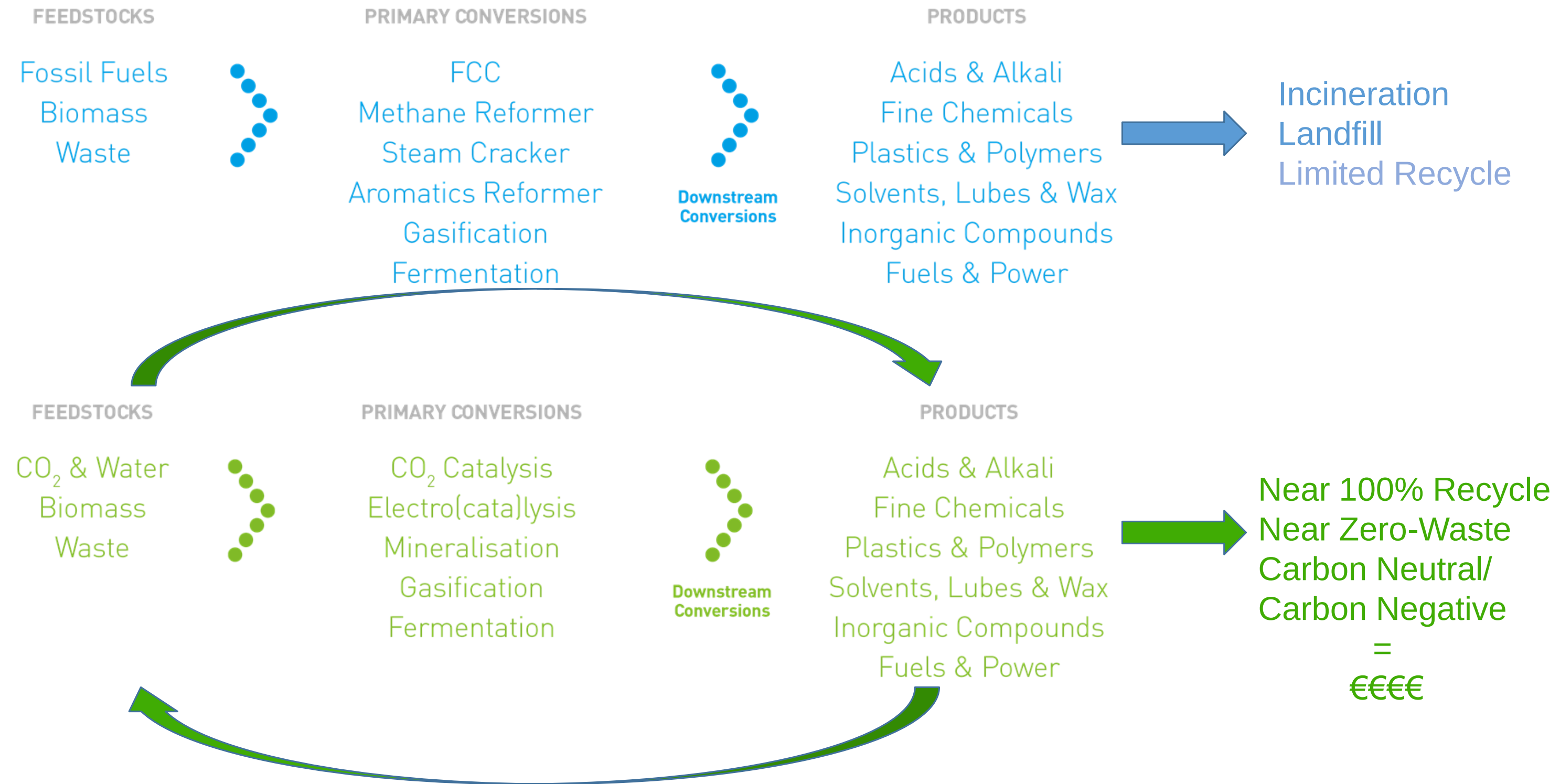
➞ *Optimising Technology*
Portfolios For a Sustainable Future

➞ *Enabling technologies for clean power including:
production and recycling of fuel cells, water
electrolysers, batteries and emission control catalysts.*

➞ *Circular Economy projects for sustainable production
and recycling of plastics, rubbers, fibres, foams,
coatings, adhesives, sealants and elastomers (CASE).*

➞ *Catalysis for manufacture of petrochemicals,
specialty fine chemicals and renewables via efficient
conversion of fossil fuels, waste, biomass and CO2.*

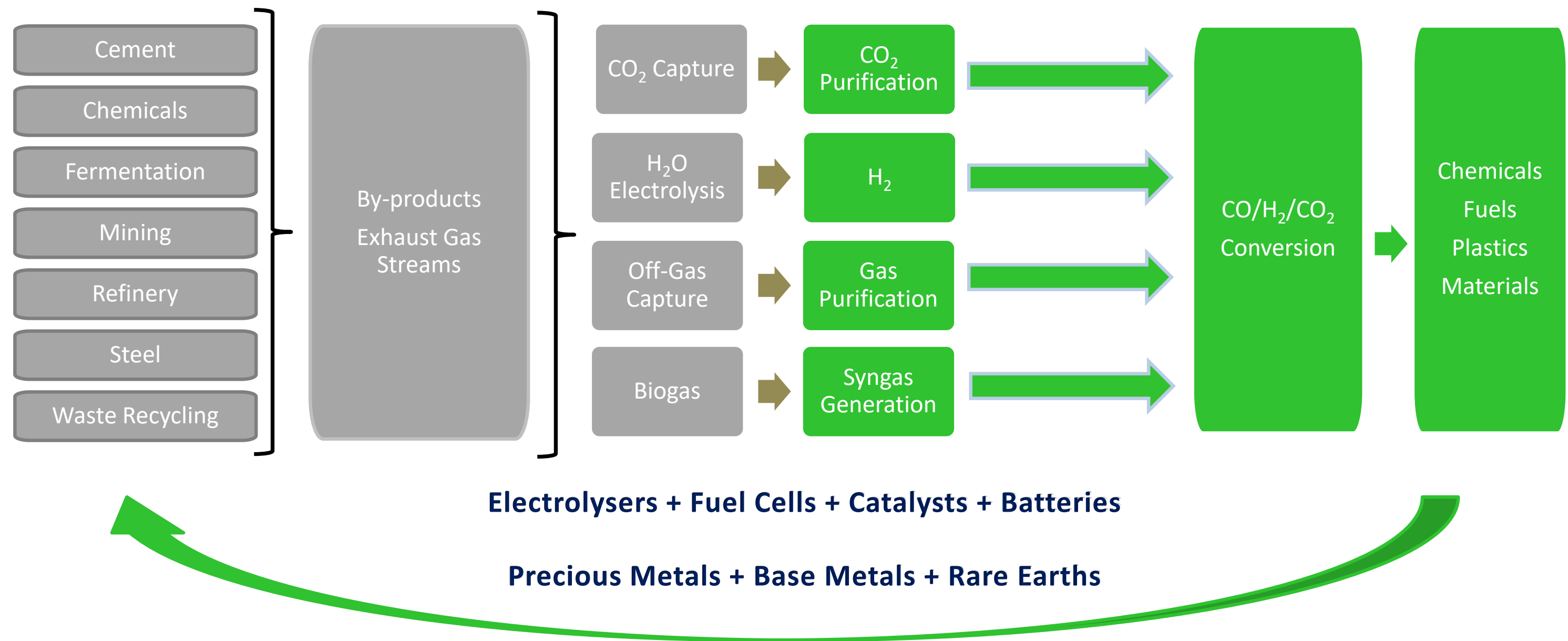
The Changing Value Chain Paradigm



Source Enabled Future Limited, 2017

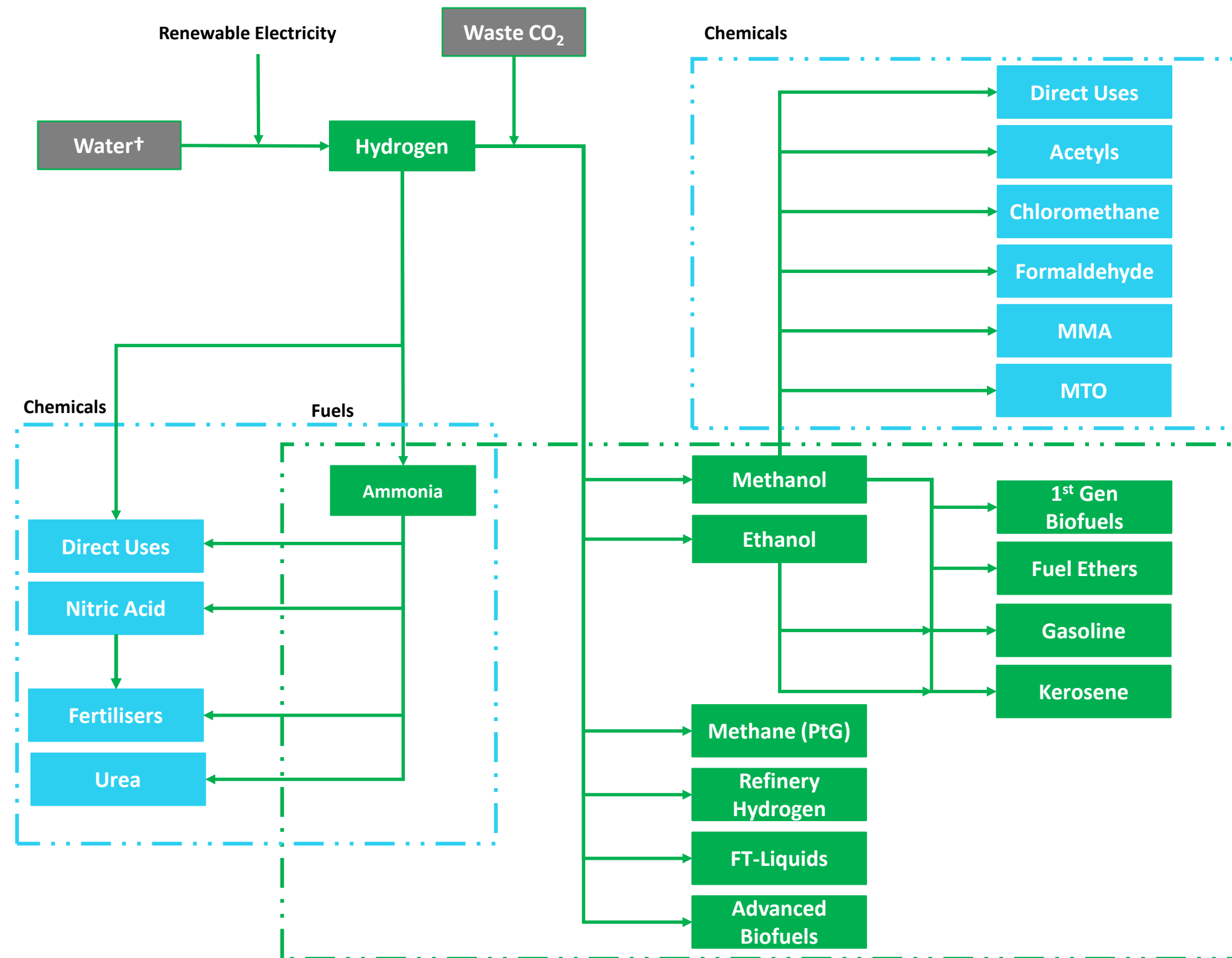
The Advent of Circular Carbon

Model for Circular Carbon Pathways via Waste CO₂ Utilisation & Power-To-X



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Key Routes to Sustainable Fuels



Source Enabled Future Limited, 2022

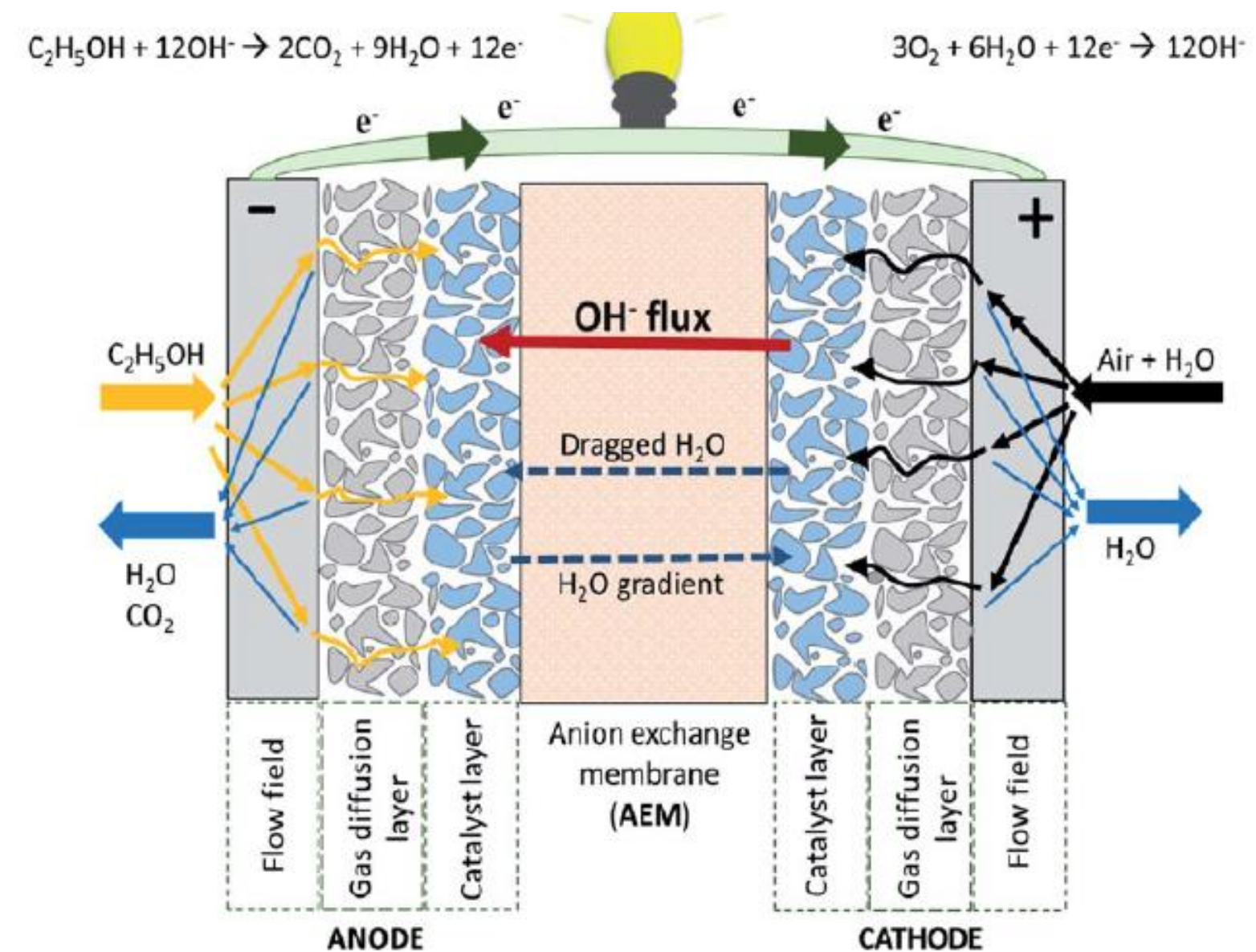
Innovations in Water Electrolysis

→ ***There are four main types of water electrolysis: AEL, PEMEL, SOEC and AEM. AEL is favoured due to its low cost and precious metal free electrodes although it requires alkaline liquids. PEMEL has a range of benefits and is especially suited to transport applications however it has a high PGM burden. AEM's are of great interest for solving both of these shortcomings.***

→ *AEM consist of nickel and nickel alloy cathodes and nickel, iron, and cobalt anodes. The electrolyte is based on solid anion exchange ionomer membranes*

→ *The AEL membrane shown on the right allows the transport of hydroxide formed at the cathode while blocking fuel and electrons. The GDL is a porous carbon with a microporous layer (MPL) e.g., a carbon felt, form or woven material which has a microporous binder and a hydrophobic layer e.g., PTFE. AEM's are reported to have faster electrochemical kinetics, and fewer corrosion issues than PEM systems.*

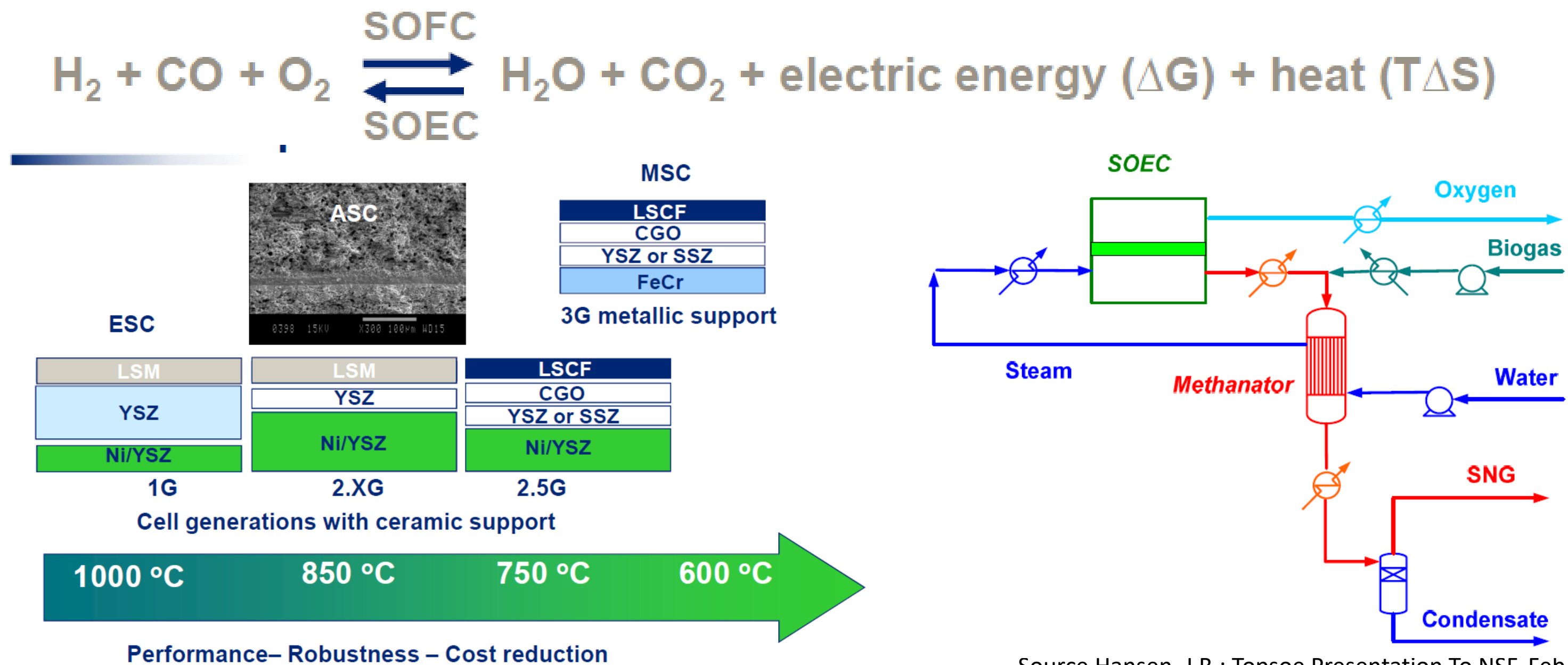
→ *Enapter in Italy has made progress in commercializing its AEM. Other AEM developers include Evonik, Proton Onsite, the EU, NREL and the Dalian Institute*



Source Liang & Zhao, 2018

Syngas and CH₄ via CO₂ Electrolysis

➔ Both water and CO₂ electrolysis are highly endothermic reactions and require considerable energy inputs. SOEC's employed run at very high temperatures >800°C and development of advanced perovskite materials has been necessary to reduce these temperatures, and to achieve the desired performance and unit lifetime. The example below is the Topsoe SOFC/SOEC technology and application in biogas upgrading.

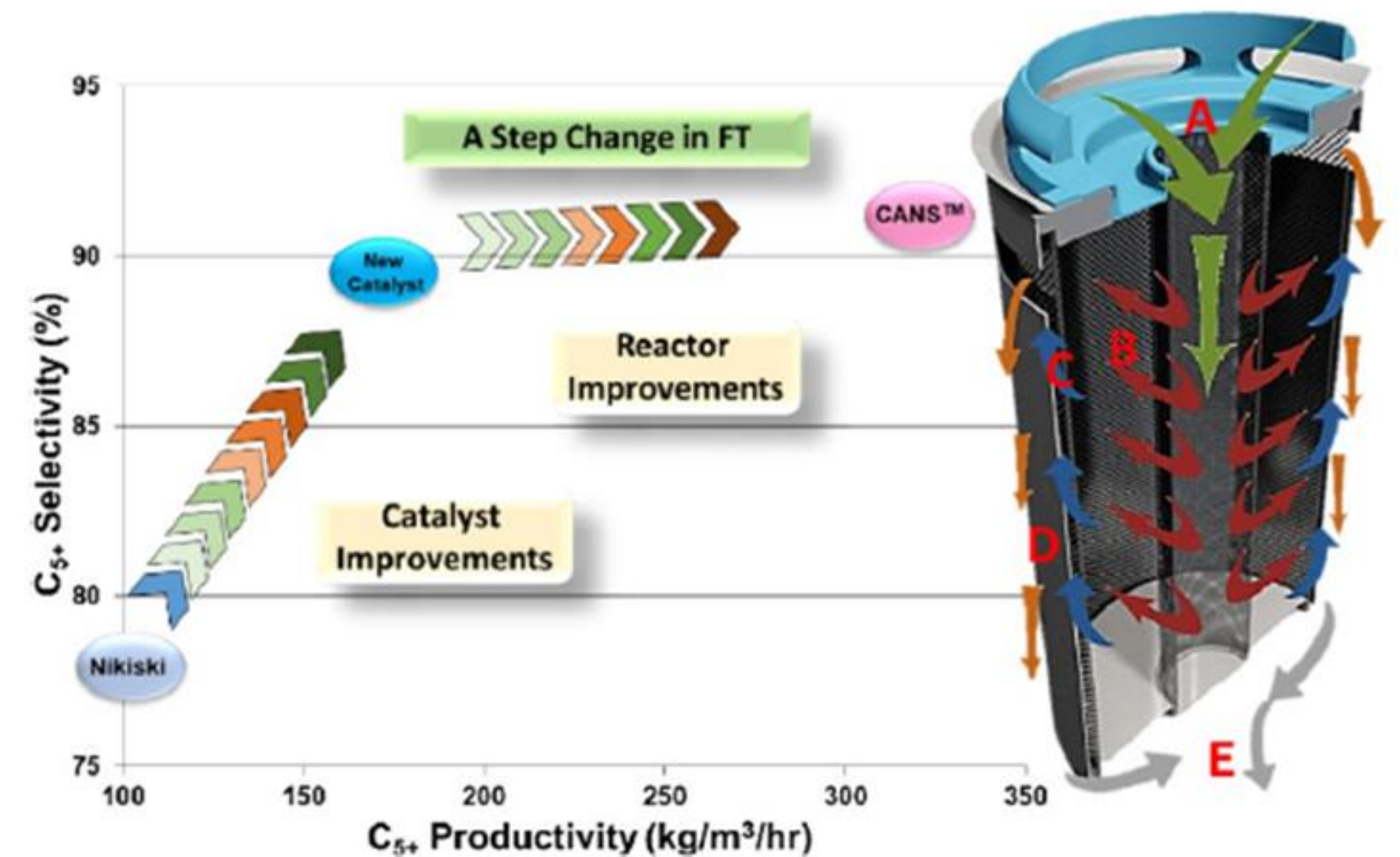


Source Hansen, J B.; Topsoe Presentation To NSF, Feb 2 2018

Fuels via Fischer-Tropsch Routes

➔ **Fischer-Tropsch is a highly versatile chemistry for converting syngas derived from a wide-range of sources into fuel-range hydrocarbons and chemical building blocks. In the past it suffered from high CAPEX, high energy requirements and lower than desired carbon efficiency. However advanced materials development has enabled new technology paradigms e.g. the Johnson Matthey /BP CANS™ system.**

- ➔ Specially designed small particle size Co catalyst
- ➔ 50% lower CAPEX
- ➔ Half the number of reactor tubes
 - 95% fewer reactor tubes due to the larger tube diameter
- ➔ 3-fold increase in productivity for the same reactor size
- ➔ Half as much catalyst volume
- ➔ No need to filter catalyst from the wax product
 - Excellent heat and mass transfer to and from the catalyst particles
- ➔ Safer unloading of catalyst and no contact with the cobalt



Source: Peacock, M et al, Topics in Catalysis (2020), P328-329

Key Points and Future Outlook

- ➔ *Advanced material developments are paramount to improving the outlook for CO₂ utilisation*
- ➔ *There is much upside on the potential for production of sustainable fuels via several different routes and catalyst improvements are continuing to create favourable techno-economic pathways*
- ➔ *Exponential growth is expected for the production of green hydrogen – reaching GW scale by 2030 and TW scale will be needed by 2050 and this will be pivotal to enabling production of sustainable fuels*
- ➔ *Many different industries must work closely together in order to ensure the success of CO₂ utilisation*
- ➔ *Policy support is a must in order to facilitate scale up and commercial use of sustainable fuels*

THANK YOU FOR YOUR ATTENTION!

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