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Etienne de Chambost, G. Boissonnet, Louis Merceron. From biofuels to e-fuels: a review and techno-economic assessment. 6th Research and Development 20 (RD20) for Clean Energy Technologies, Dec 2024, New delhi, India. cea-04874204

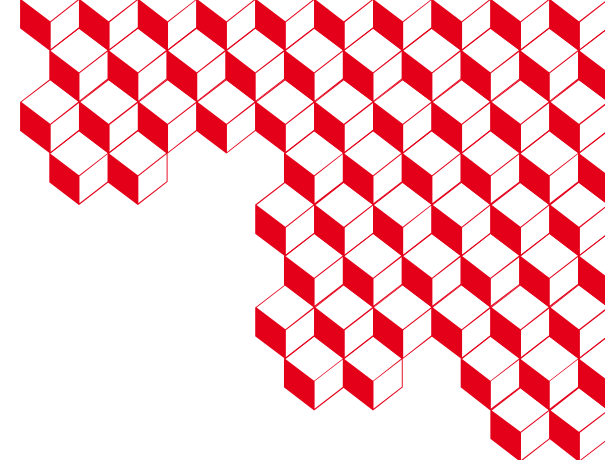
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From biofuels to e-fuels: a review and techno-economic assessment

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- B. Methodology : what to measure ? How ?**
- C. Results : technical and economic performances**
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A ■ Sustainable fuels,

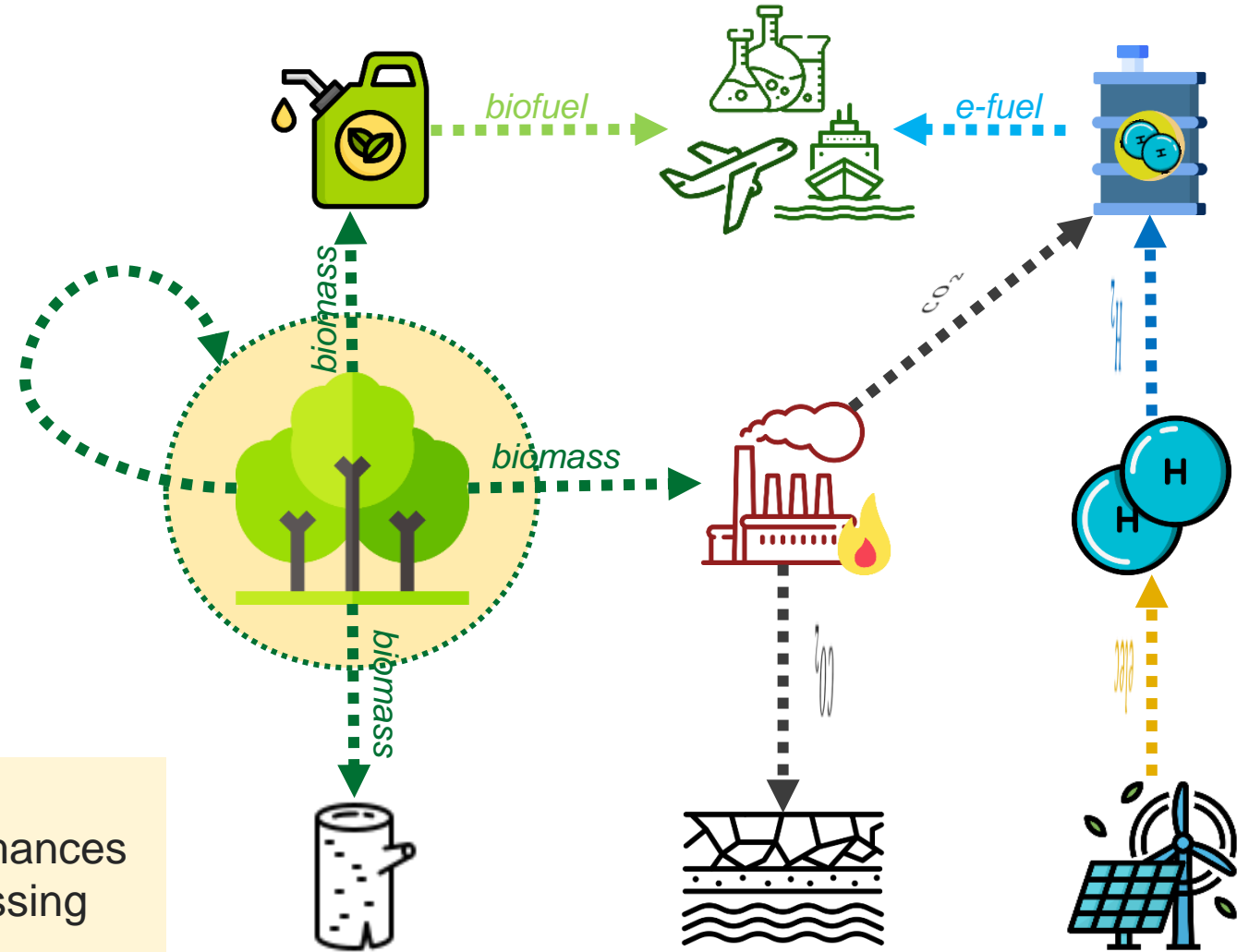
what is at stake ?

Context

- Achieving carbon neutrality by 2050
- Substituting fossil fuels
- Integrating 70 % of SAF in 2050

- Resource availability
- GHG emissions reduction
- Economic performance

What are the **technical and economic** performances of **biofuel**, **e-fuel**, and **e-biofuel** main processing routes?

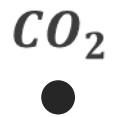
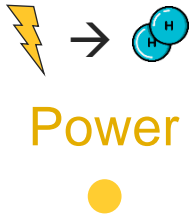
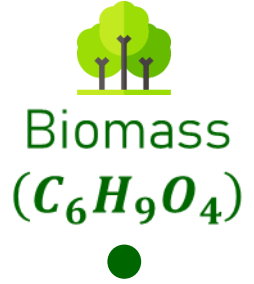




B ■ Methodology

What to measure ? How ?

Scope

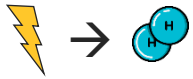
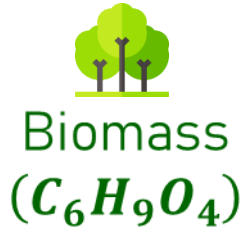


●
B = biofuel

● ●
PB = e-biofuel

● ●
P = e-fuel

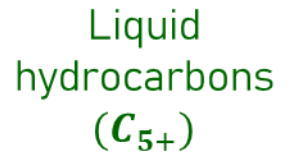
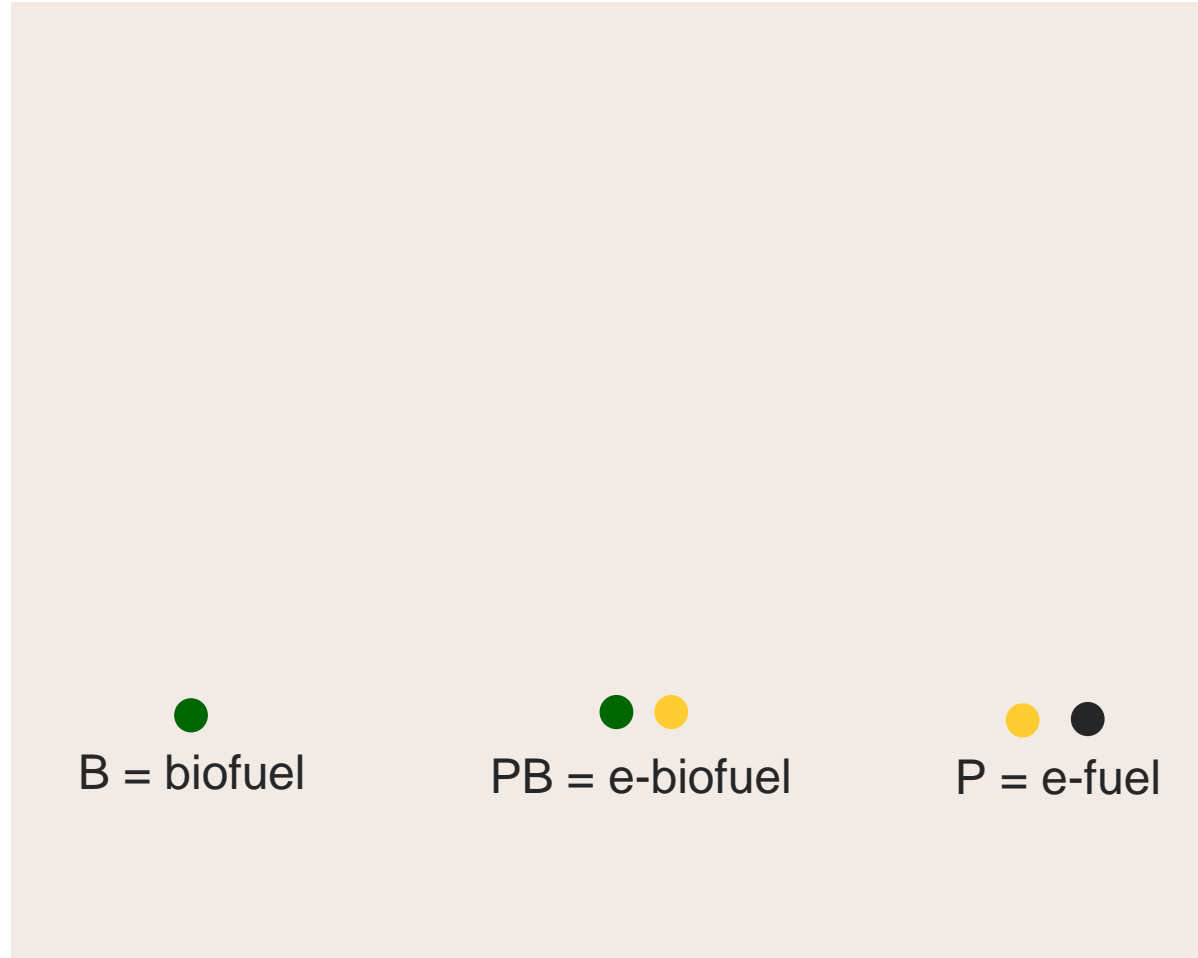
Scope



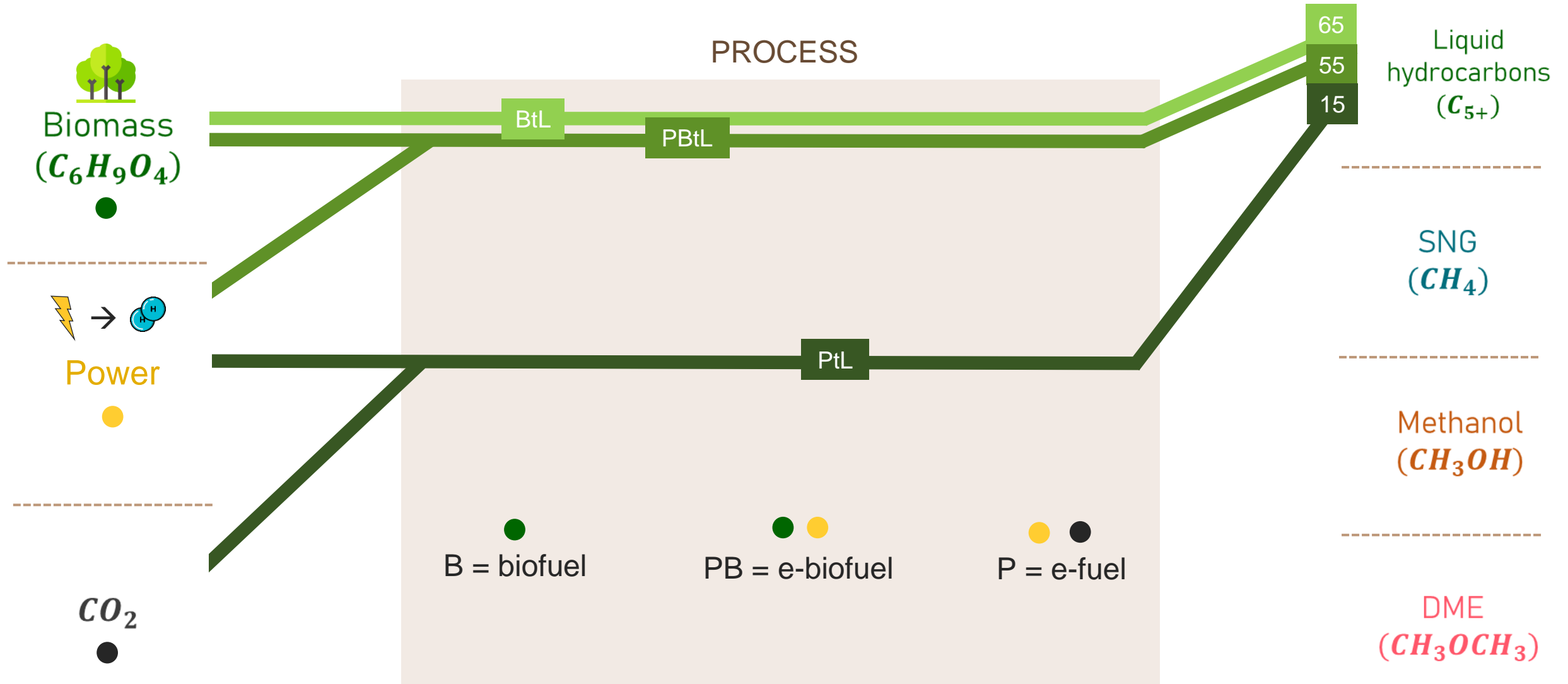
Power



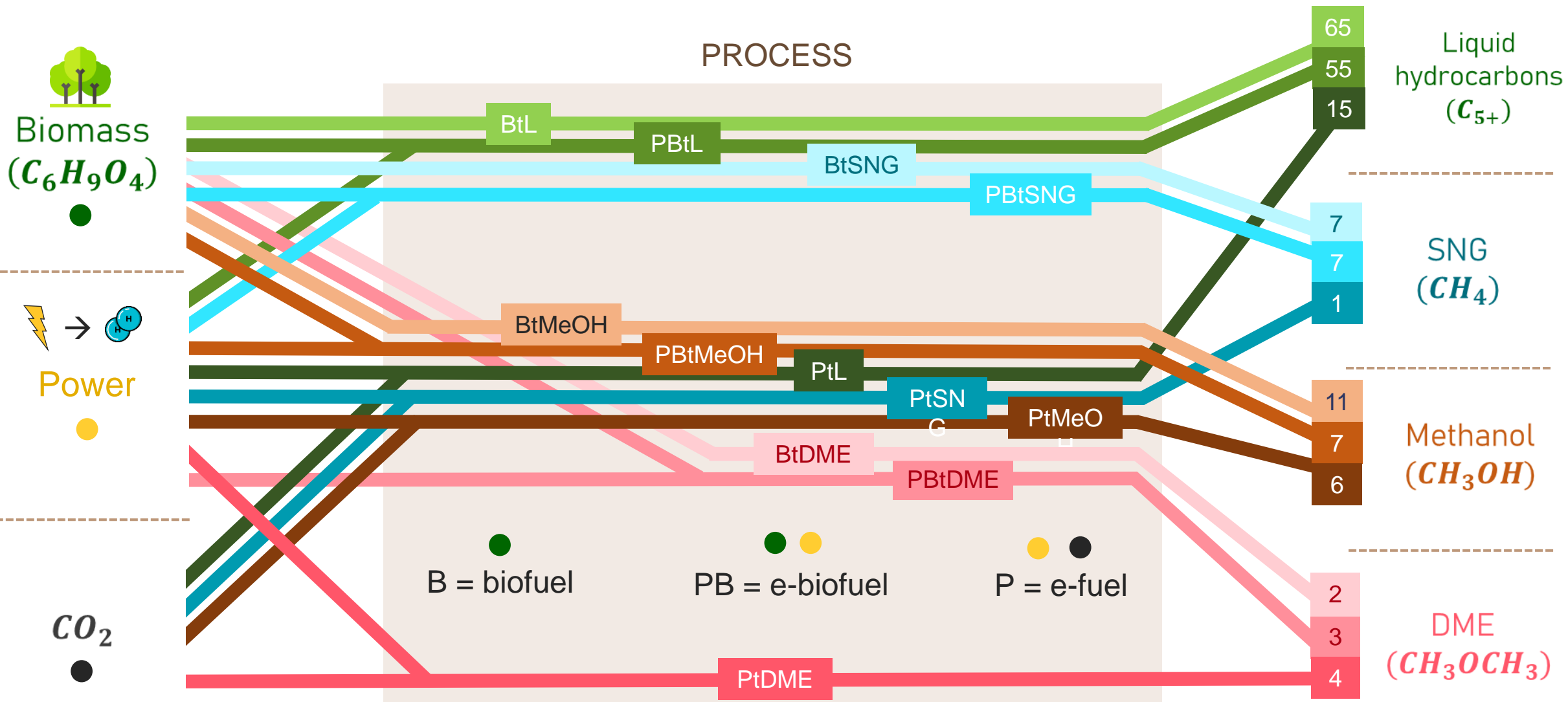
PROCESS



Scope



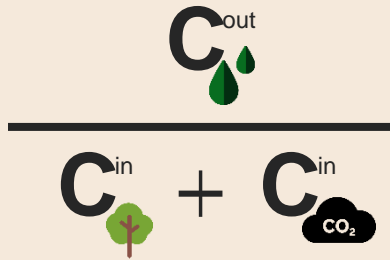
Scope



Key performance indicators



Carbon conversion



How to minimize carbon losses?

Key performance indicators



Carbon conversion

Energy efficiency

$$\frac{C^{\text{out}}}{C^{\text{in}} + C^{\text{in}}_{\text{CO}_2}}$$

How to minimize carbon losses?

What combination of energy sources is the most efficient?

$$\frac{P^{\text{out}}}{P^{\text{in}} + P^{\text{in}} + P^{\text{net}}}$$

Key performance indicators



Carbon conversion

$$\frac{C^{\text{out}}}{C^{\text{in}} + C^{\text{in}}_{\text{CO}_2}}$$

Energy efficiency

How to minimize carbon losses?

What combination of energy sources is the most efficient?

$$\frac{P^{\text{out}}}{P^{\text{in}} + P^{\text{in}} + P^{\text{net}}}$$

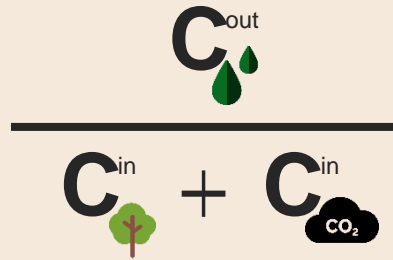
Investments

$$\frac{\text{€} \cdot f_{TIC} + \text{€}}{P^{\text{out}}}$$

What is industrial-scale capital intensity?

Key performance indicators

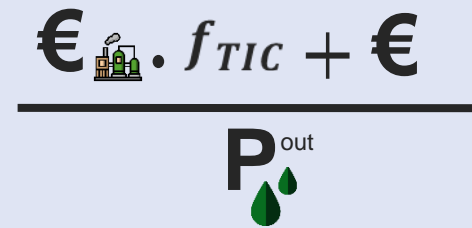
Carbon conversion

$$\frac{C^{\text{out}}}{C^{\text{in}} + C^{\text{in}}_{\text{CO}_2}}$$


Energy efficiency

How to minimize carbon losses?

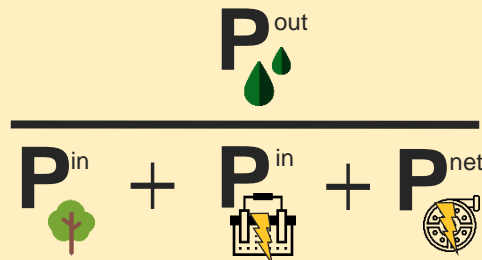
Investments

$$\frac{\text{€} \cdot f_{TIC} + \text{€}}{P^{\text{out}}}$$


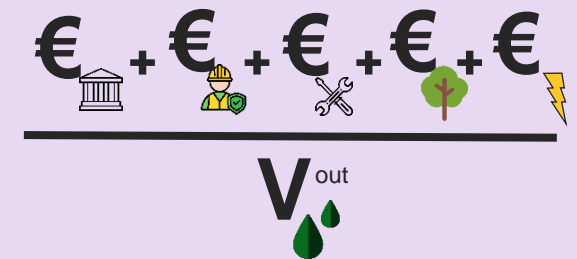
Production costs

What is industrial-scale capital intensity?

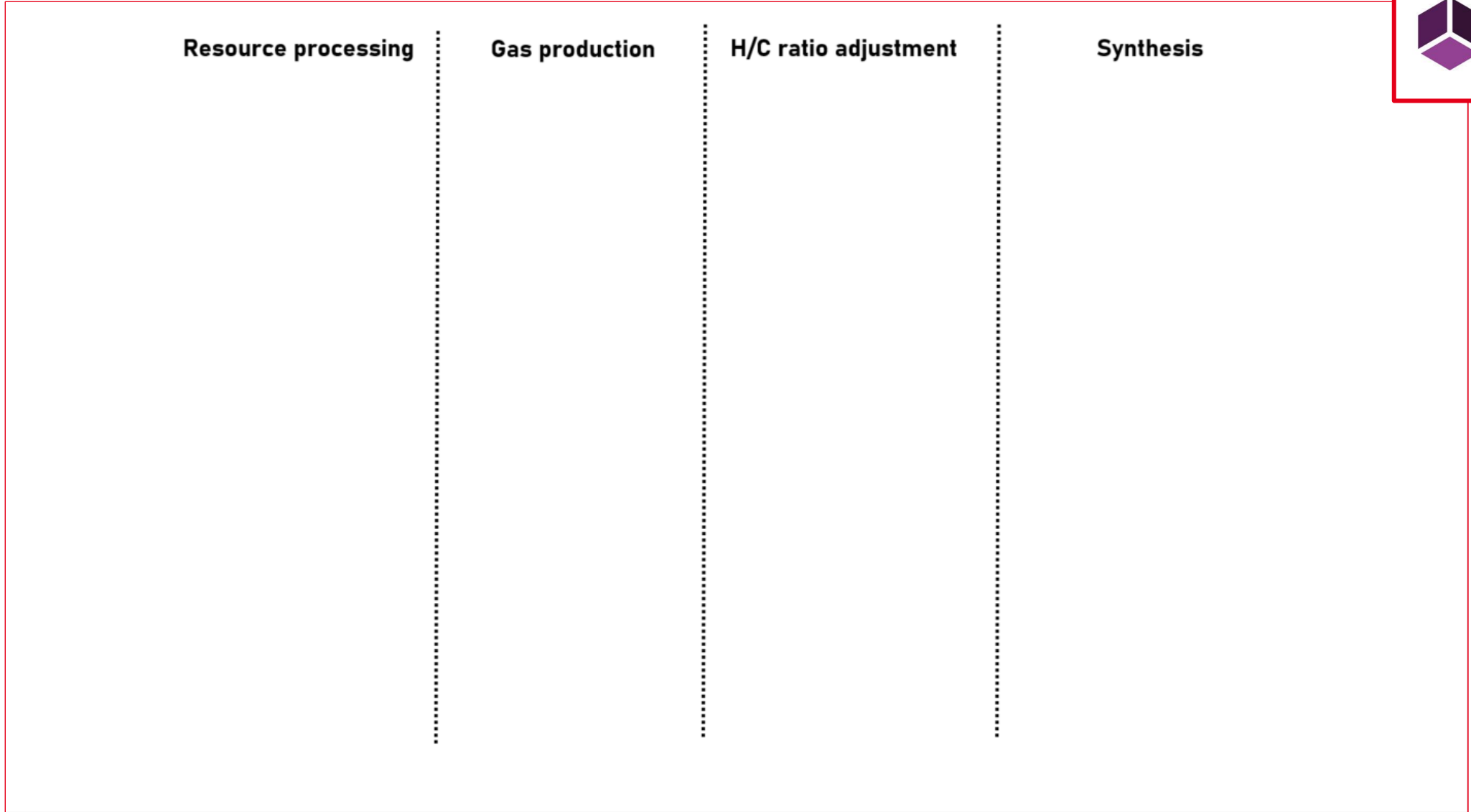
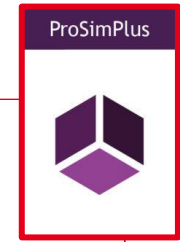
What combination of energy sources is the most efficient?

$$\frac{P^{\text{out}}}{P^{\text{in}} + P^{\text{in}} + P^{\text{net}}}$$


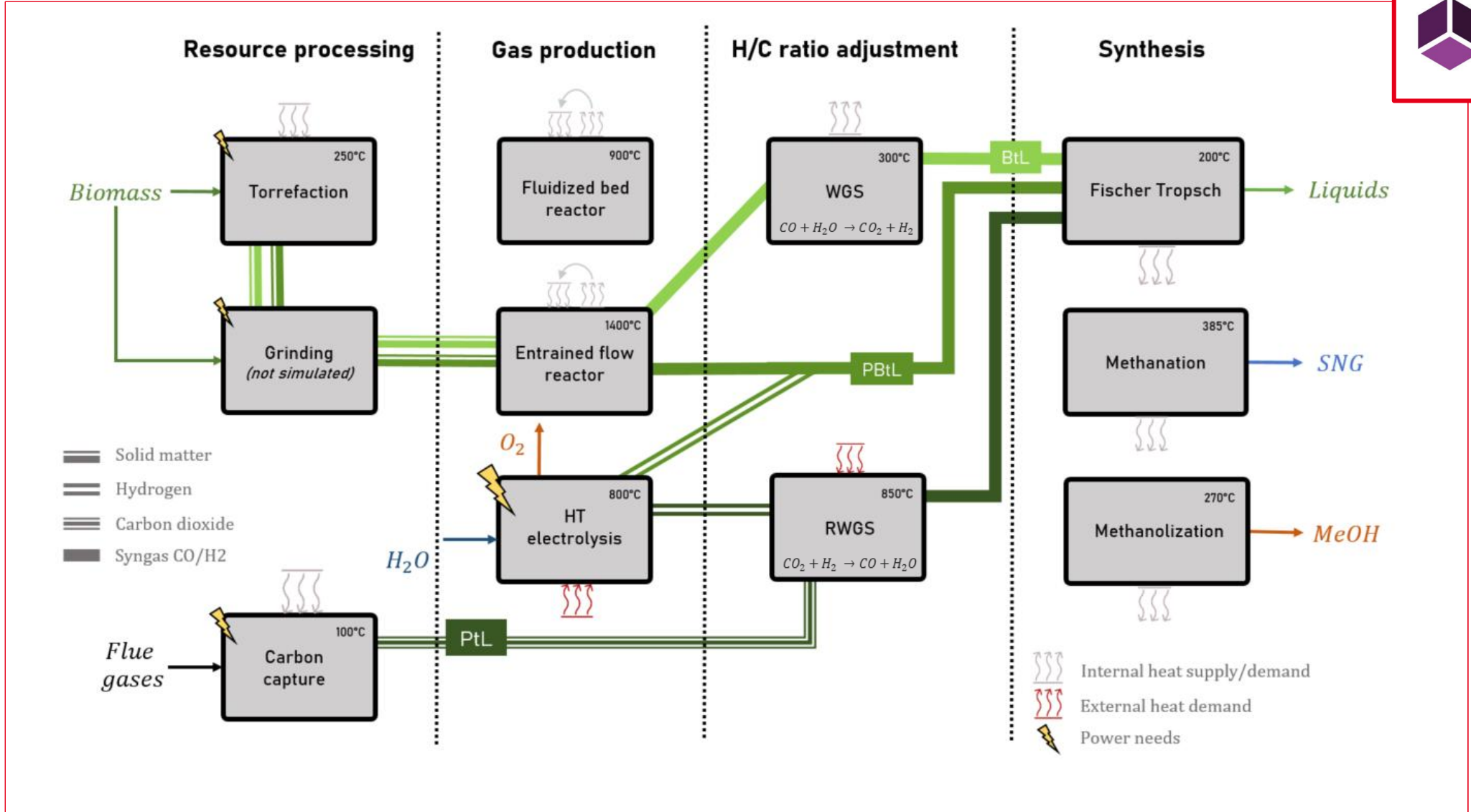
What main drivers of production cost sensitivity?

$$\frac{\text{€} + \text{€} + \text{€} + \text{€} + \text{€}}{V^{\text{out}}}$$


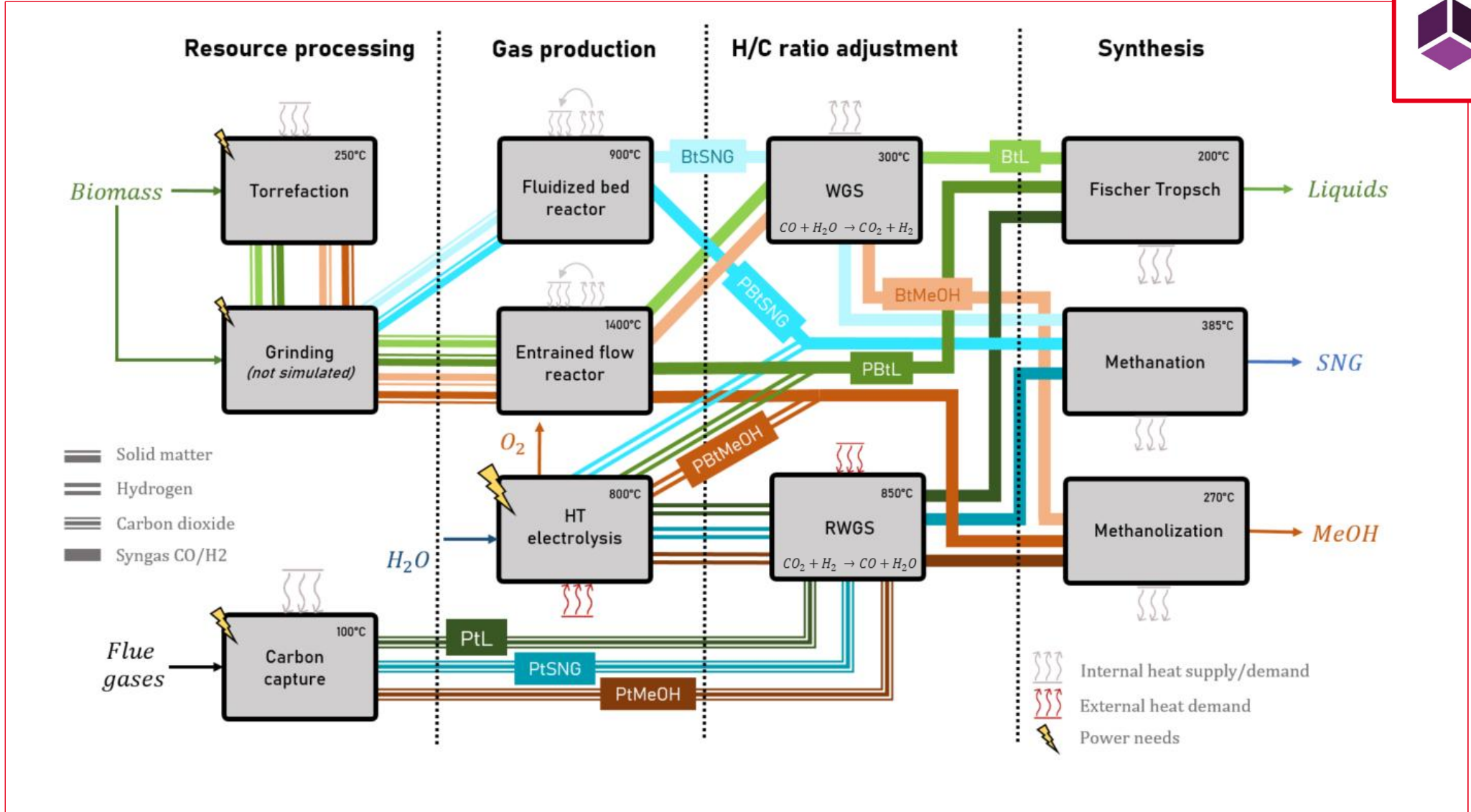
Modeling



Modeling



Modeling

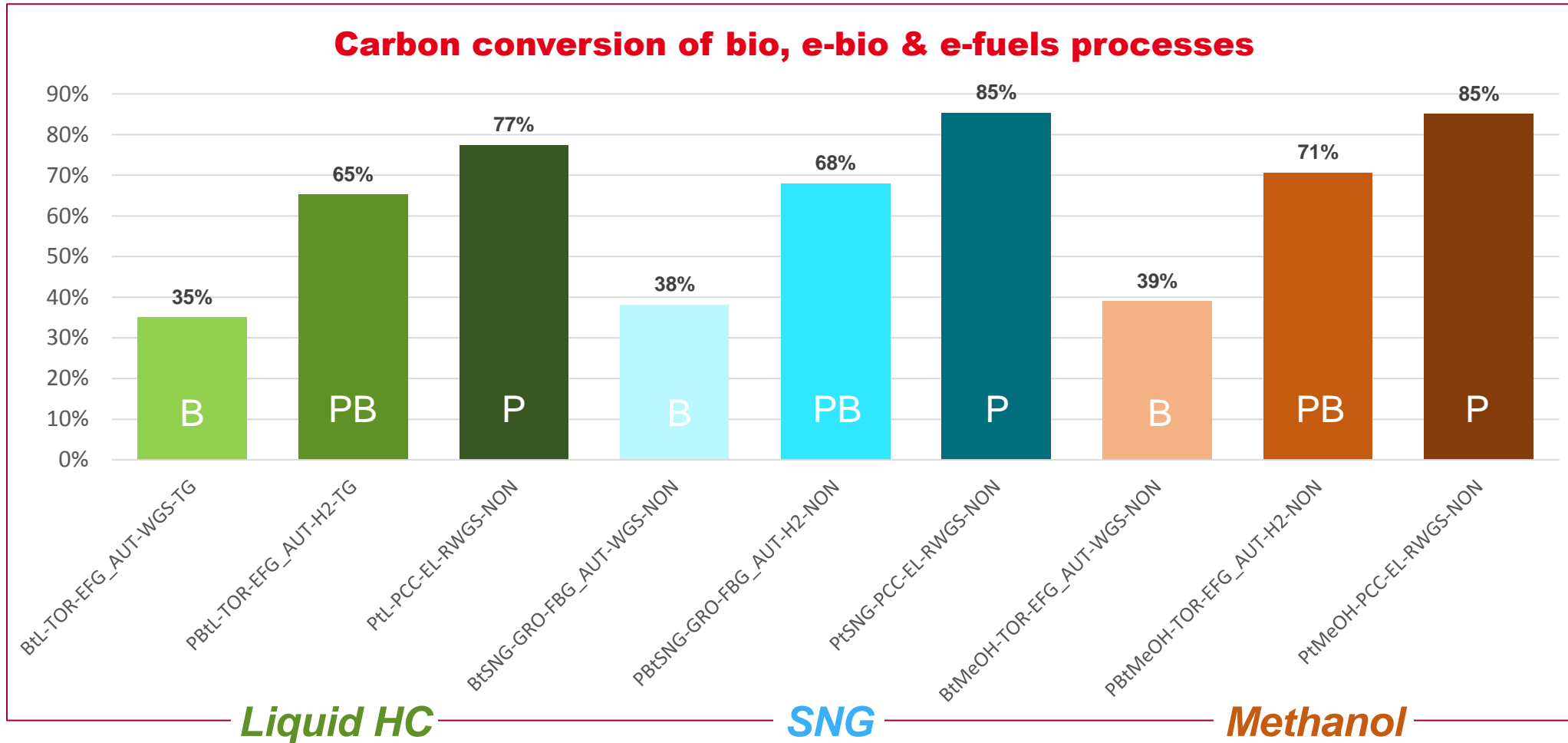




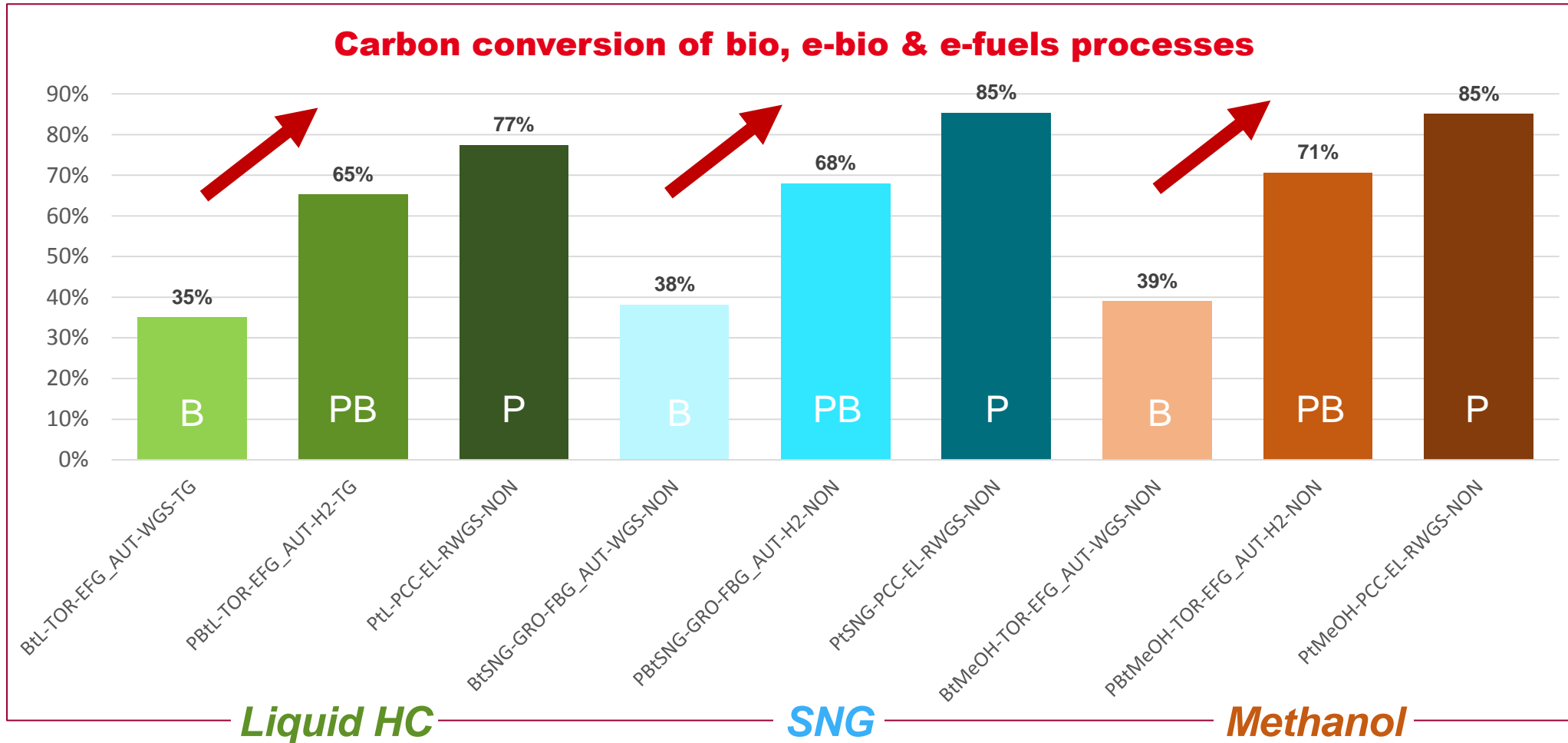
C ■ Results

Technical and economic performances

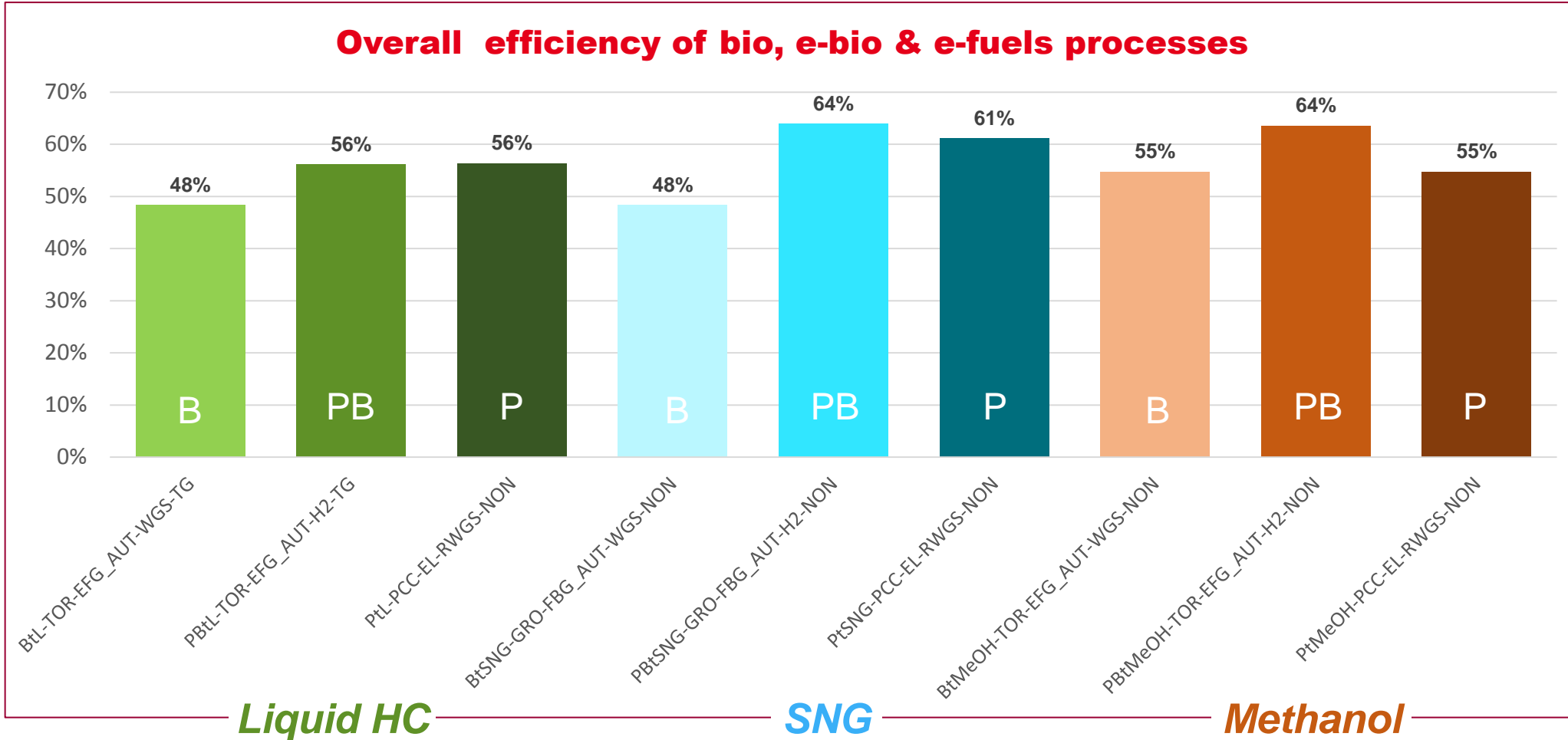
Carbon conversion



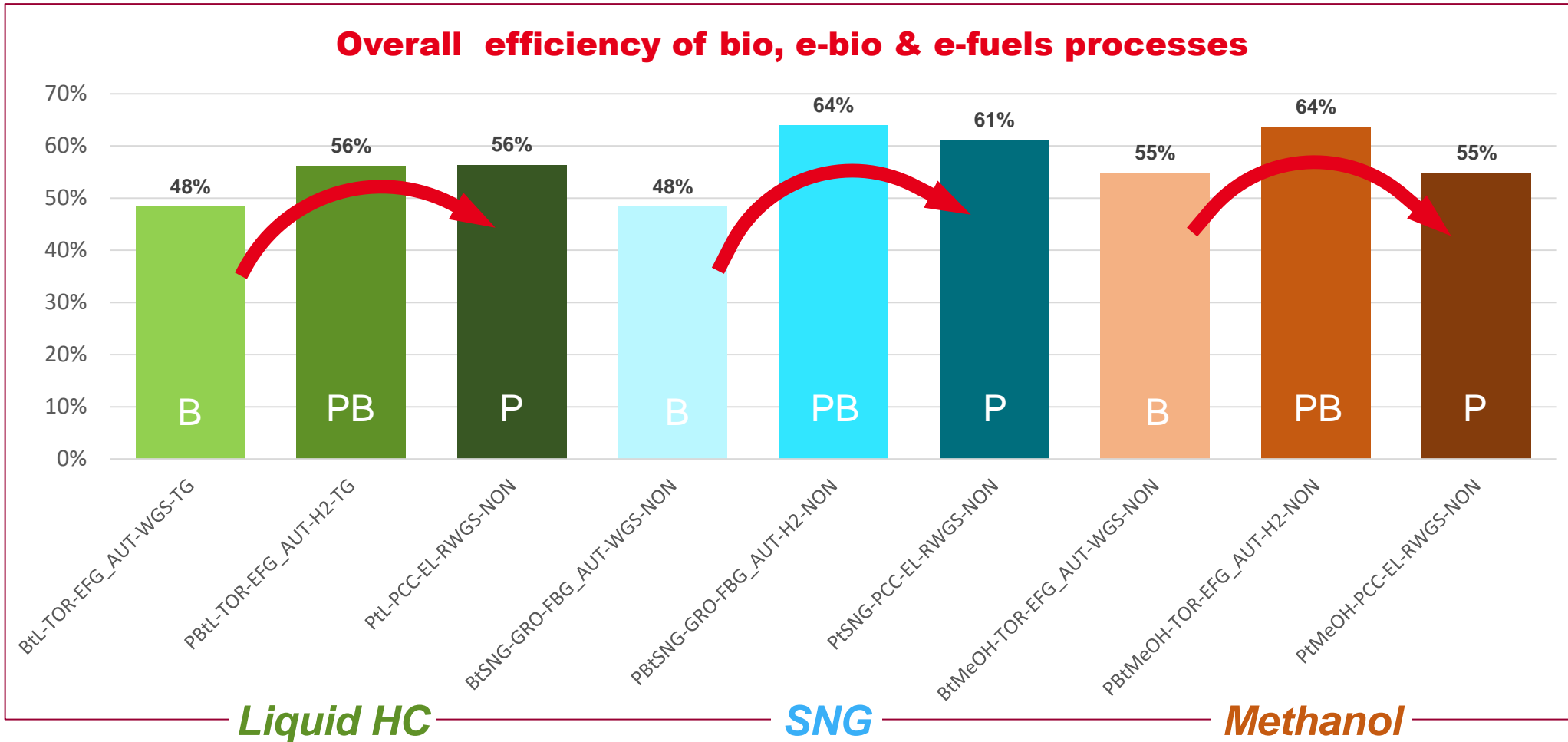
Carbon conversion



Energy efficiencies

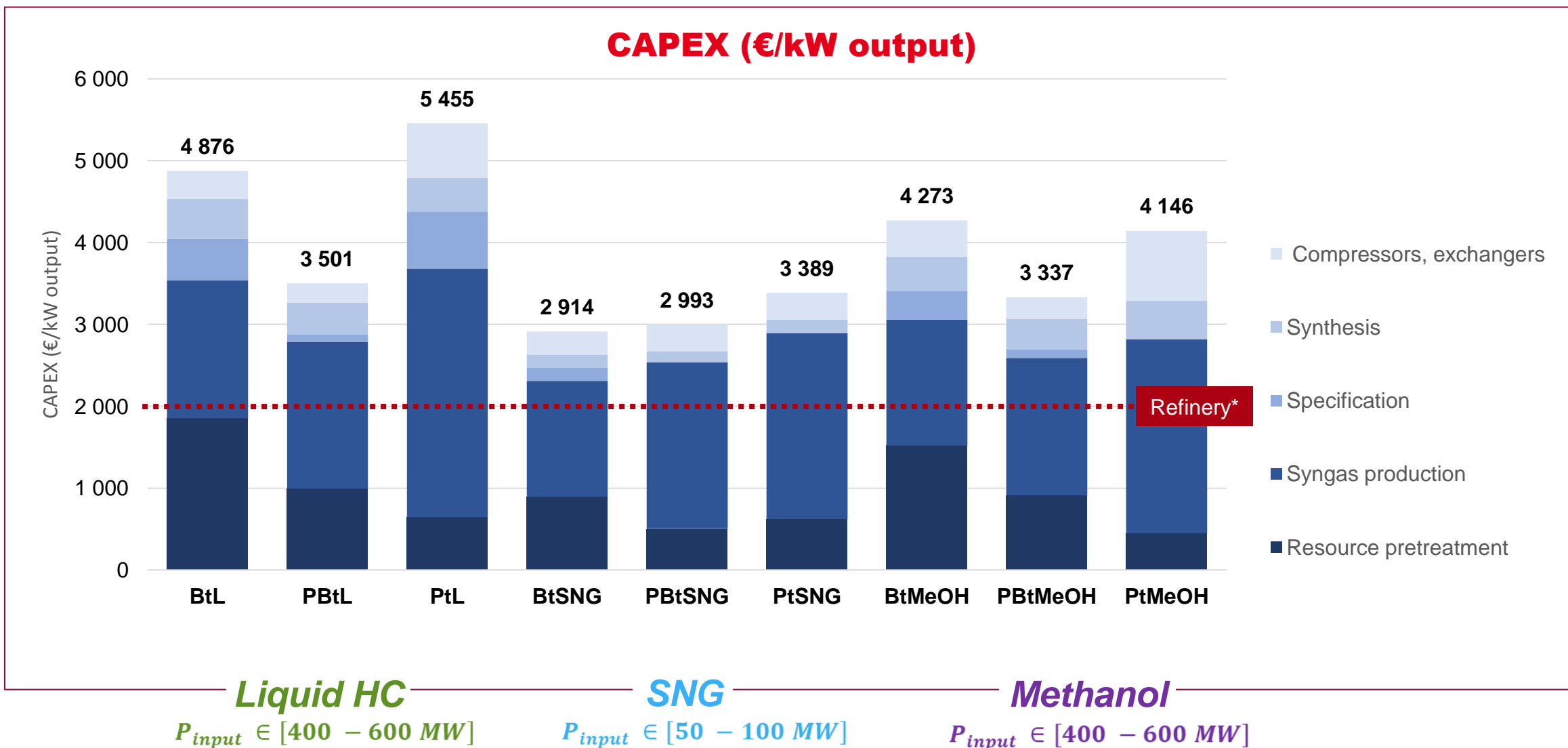


Energy efficiencies



CAPEX

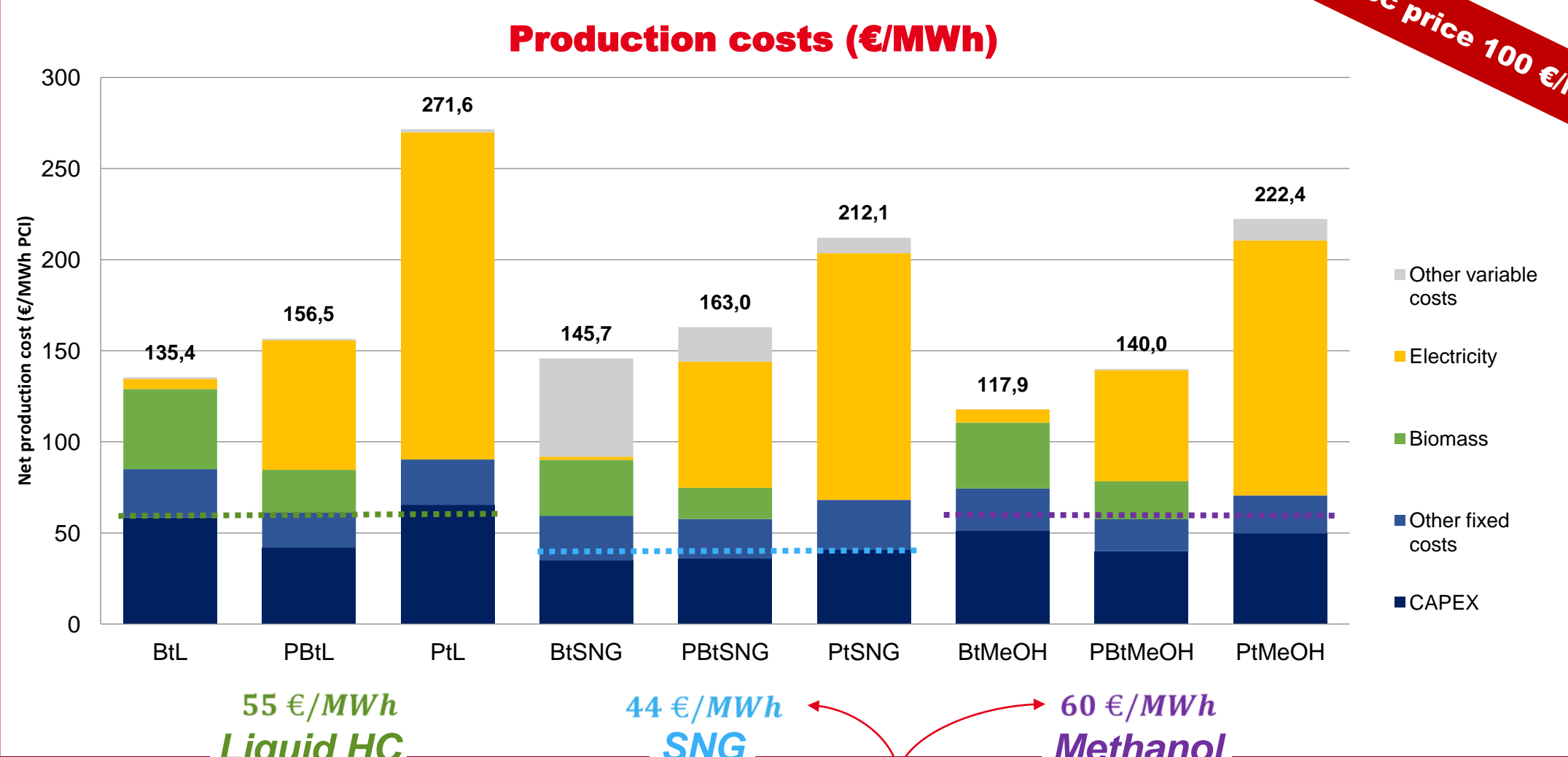
*Source : The Palgrave handbook of International Energy Economics



Production costs

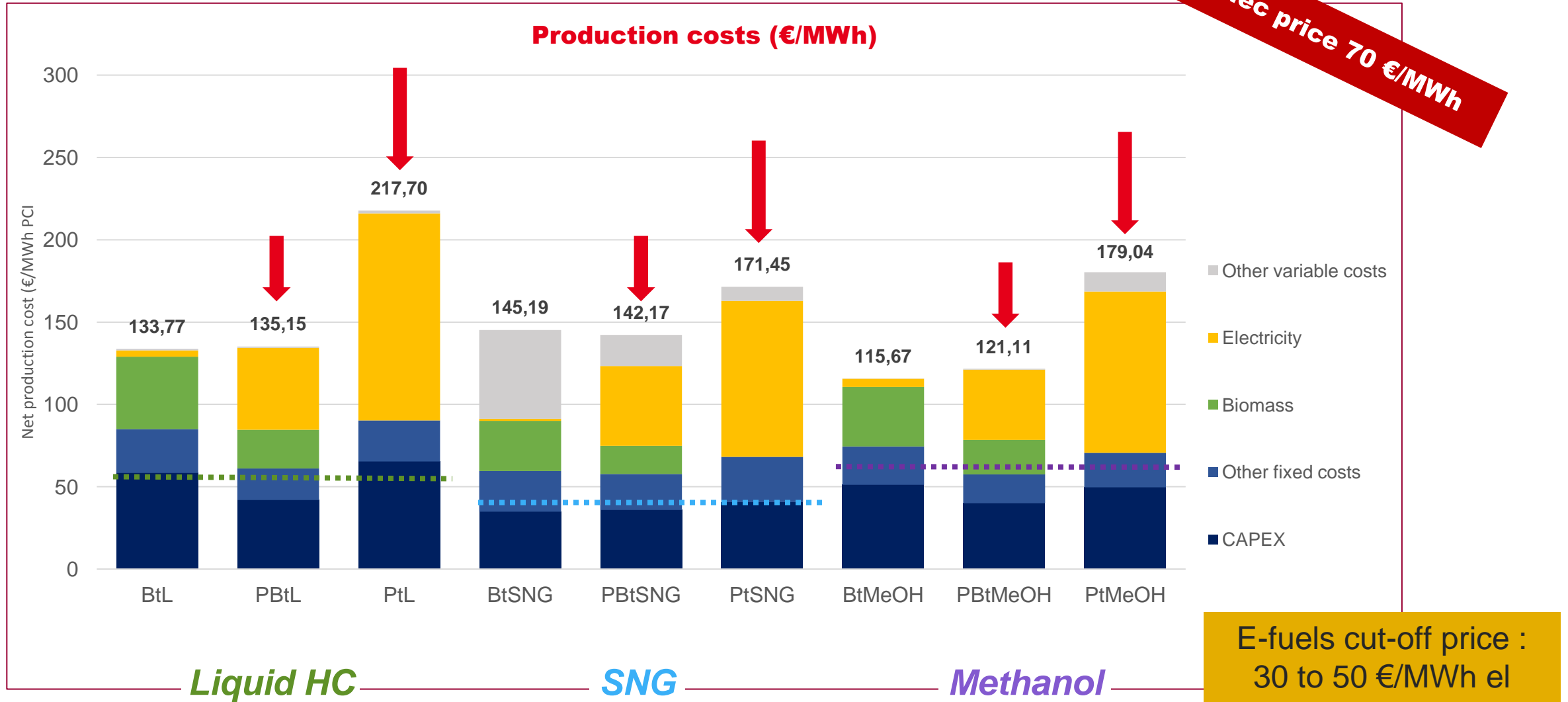


Elec price 100 €/MWh



Market price

Production costs





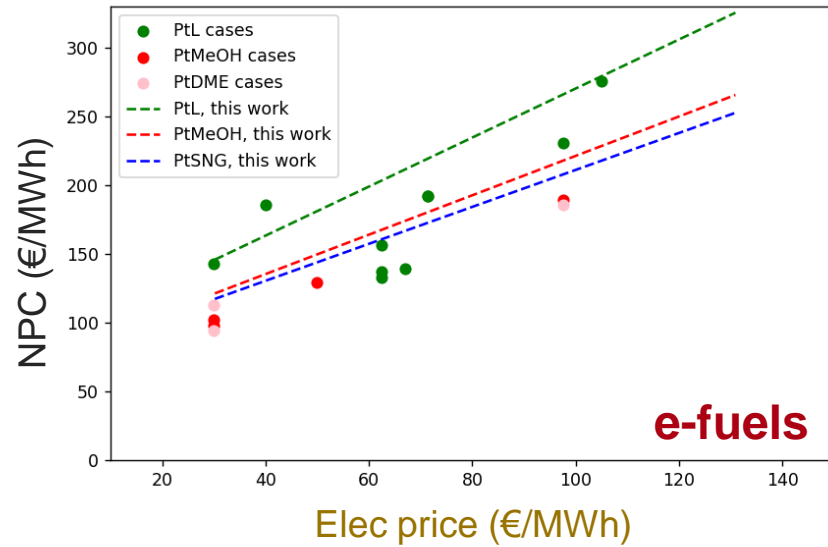
D ■ Stepping back

To analyze global trends

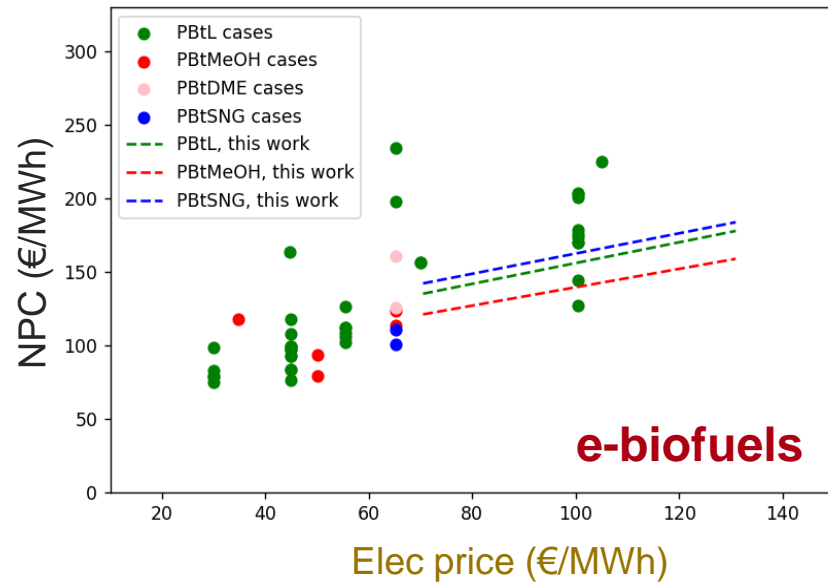
Positioning within the literature



1



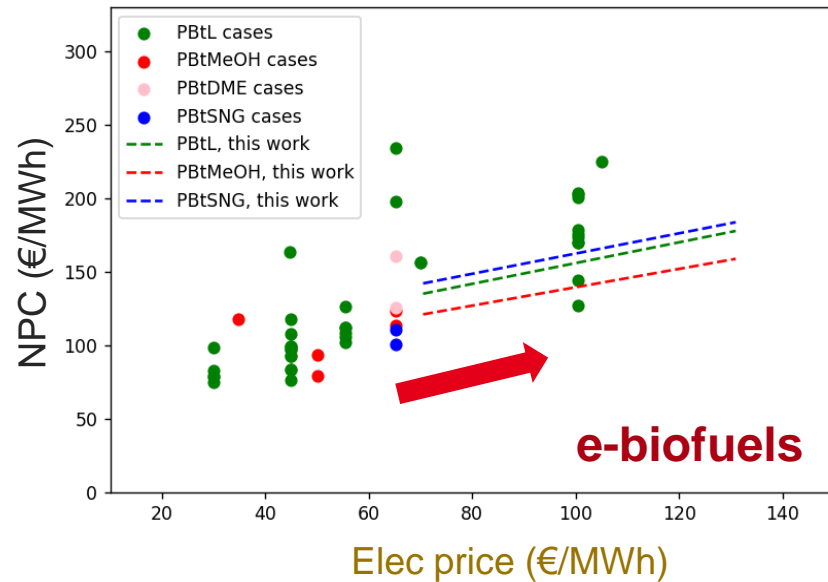
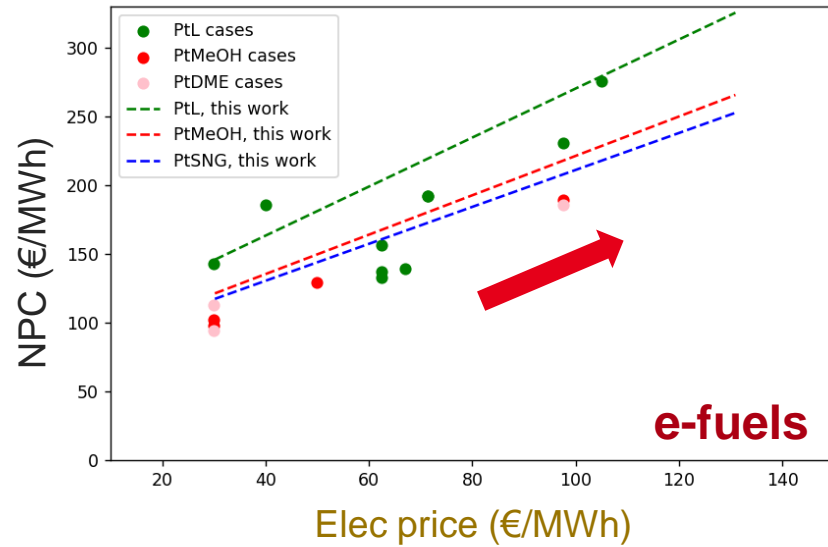
❖ Net production cost € [50 → 250 €/MWh]



Positioning within the literature

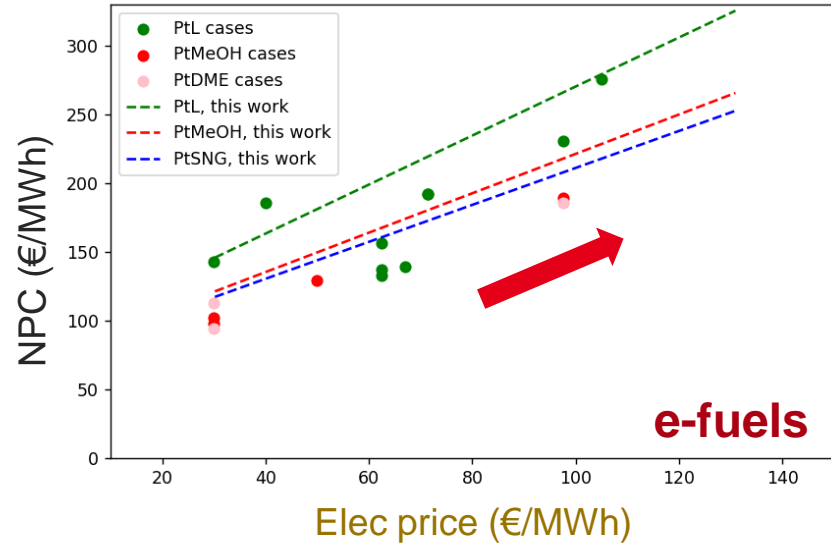


1

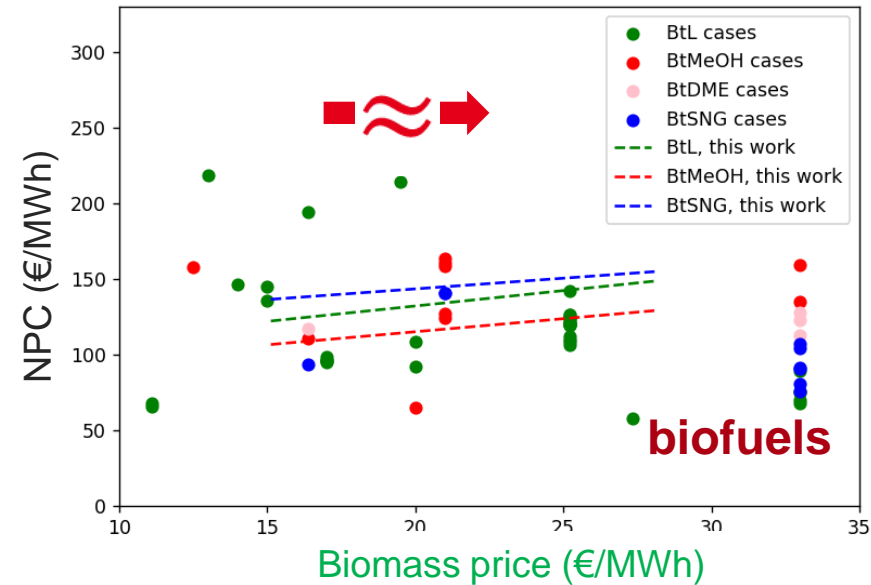
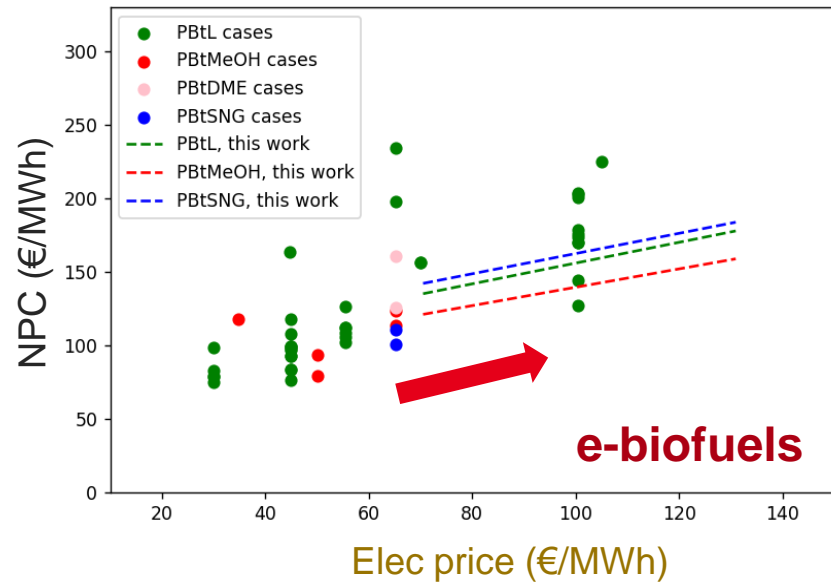


- ❖ Net production cost € [50 → 250 €/MWh]
- ❖ A strong influence of **electricity** input price on NPC for **e-fuels** and **e-biofuels**

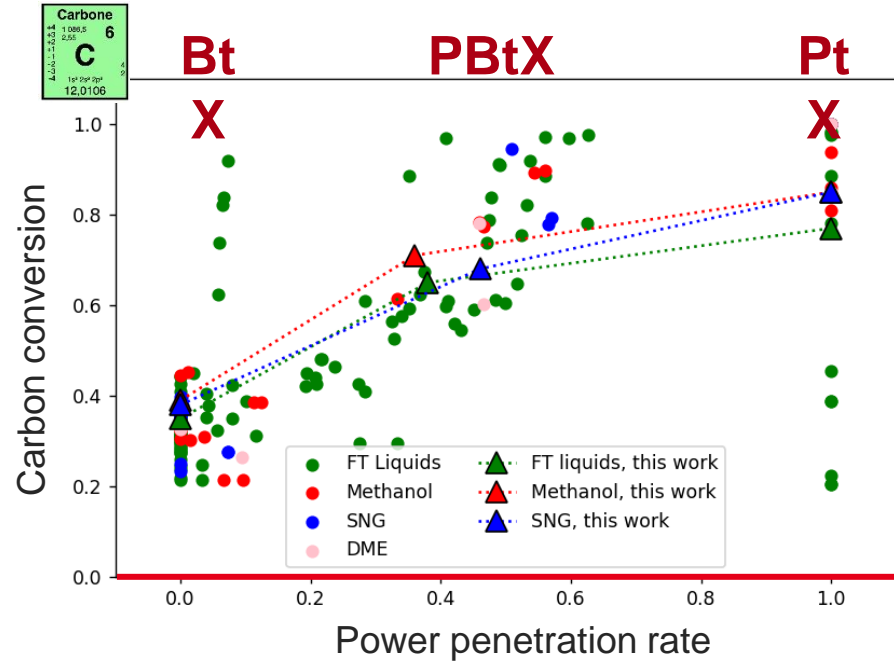
Positioning within the literature



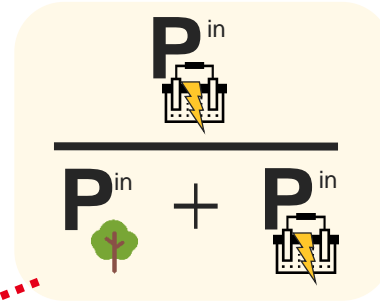
- ❖ Net production cost € [50 → 250 €/MWh]
- ❖ A strong influence of **electricity** input price on NPC for **e-fuels** and **e-biofuels**
- ❖ No visible correlation between **biomass** input price and **biofuel** NPC



Influence of energy sources on efficiency

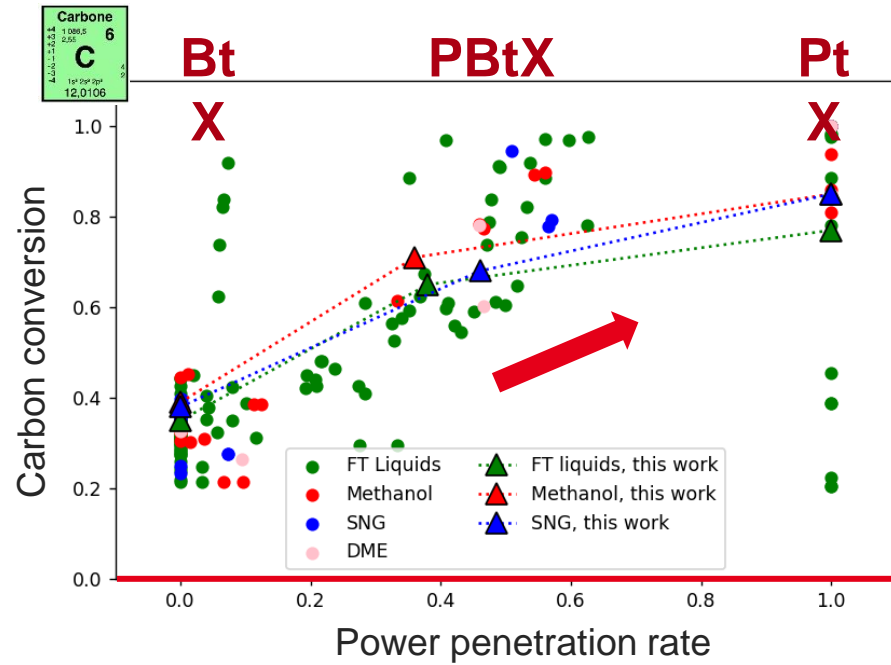


Definition of power penetration rate :

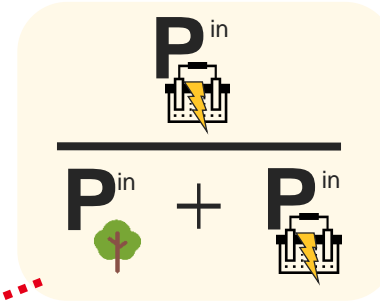


2

Influence of energy sources on efficiency



Definition of power penetration rate :



Biofuels (BtX) $\rightarrow 0$

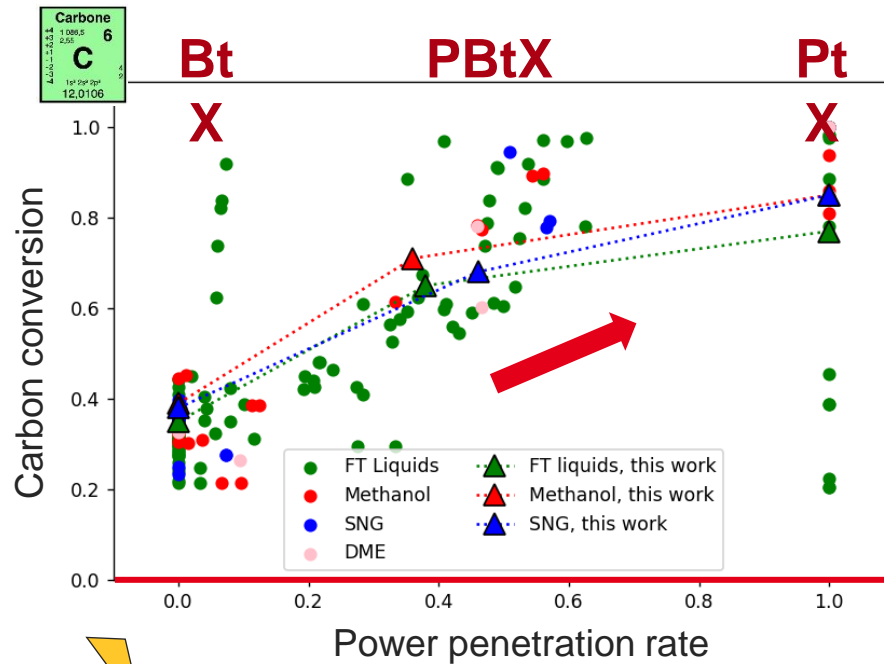
E-biofuels (PBtX) $\rightarrow [0.36 - 0.46]$

E-fuels (PtX) $\rightarrow 1$

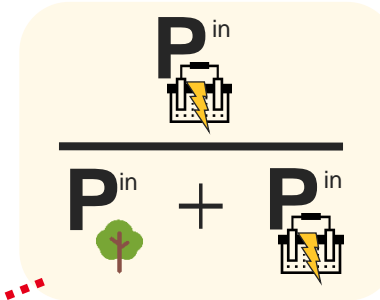
2

❖ From biofuels to e-fuels: increase of **carbon conversion**

Influence of energy sources on efficiency



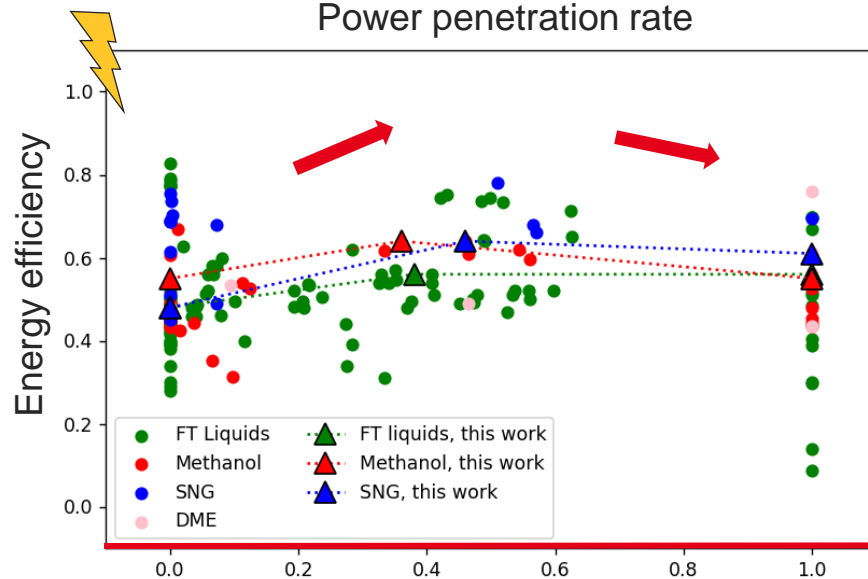
Definition of power penetration rate :



Biofuels (BtX) $\rightarrow 0$

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2

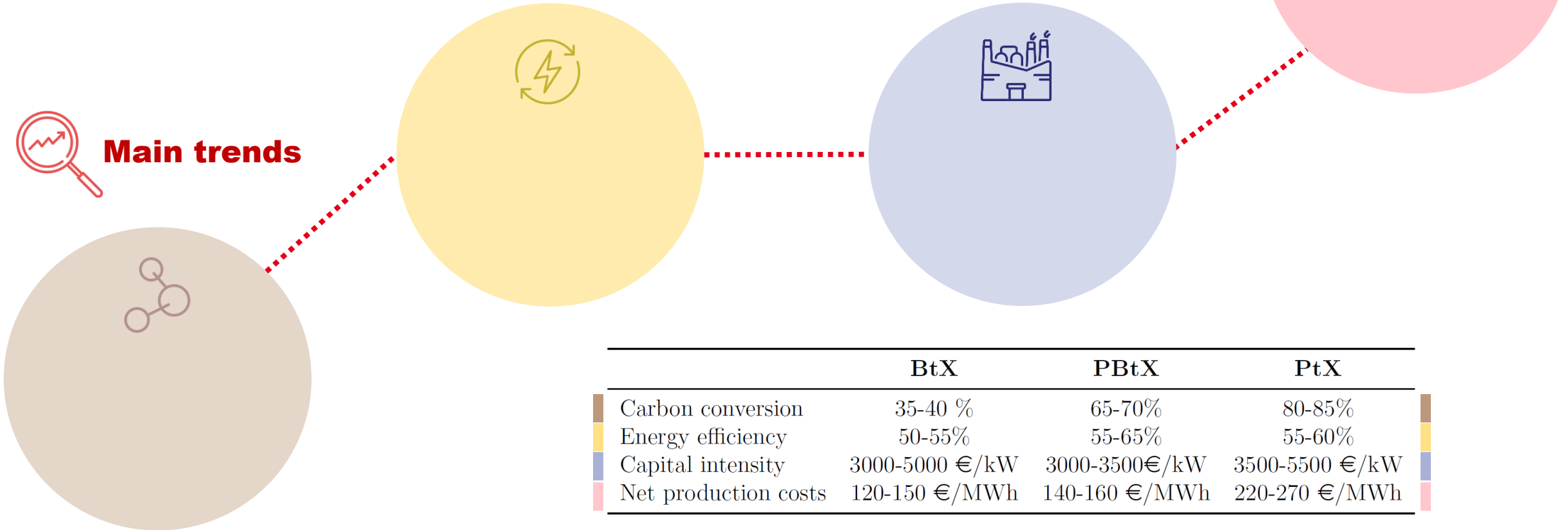
❖ From biofuels to e-fuels: increase of **carbon conversion**

❖ From biofuels to e-fuels: maximum **overall energy efficiency** for hybrid **e-biofuel** processes

Conclusions

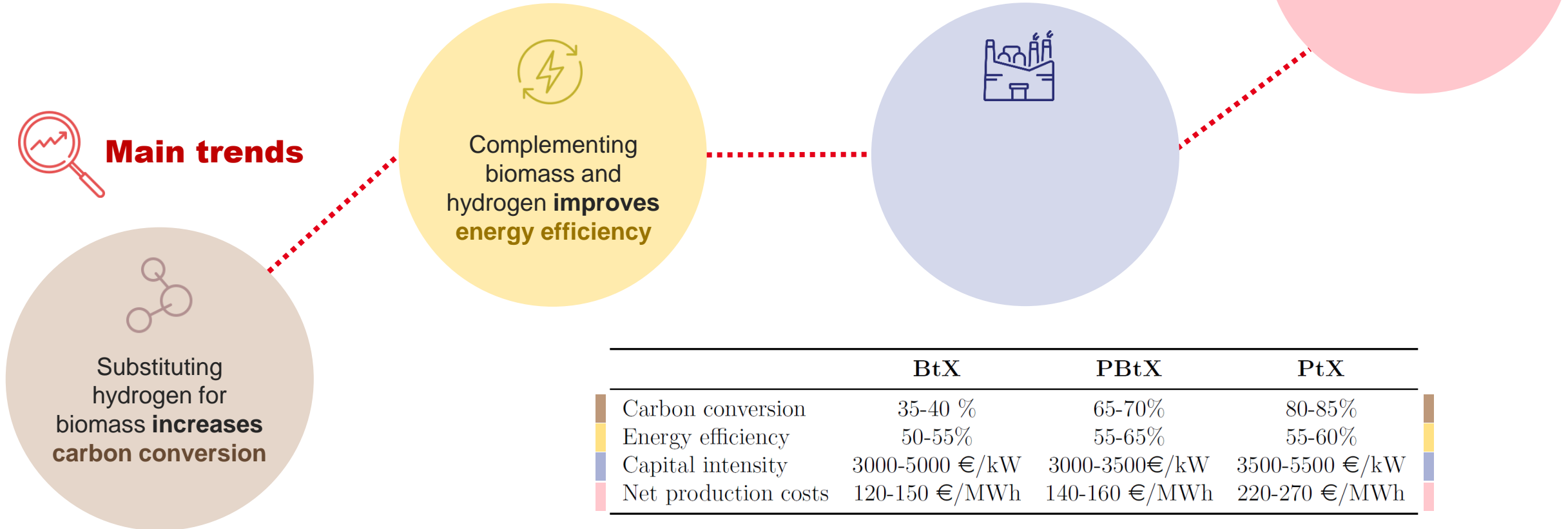


Conclusions

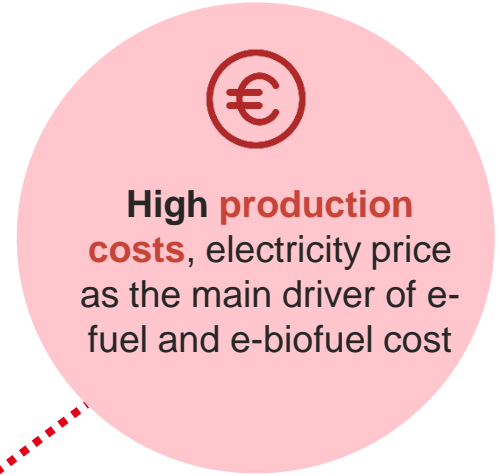


	BtX	PBtX	PtX
Carbon conversion	35-40 %	65-70%	80-85%
Energy efficiency	50-55%	55-65%	55-60%
Capital intensity	3000-5000 €/kW	3000-3500€/kW	3500-5500 €/kW
Net production costs	120-150 €/MWh	140-160 €/MWh	220-270 €/MWh

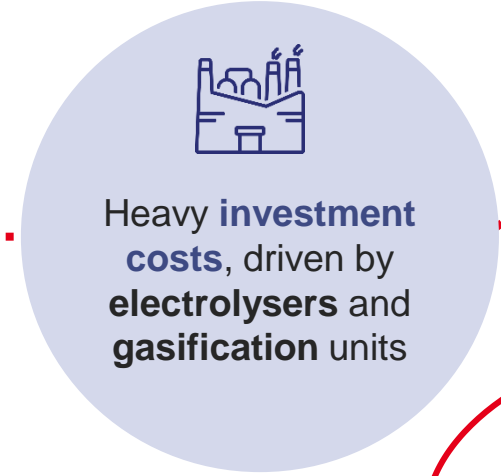
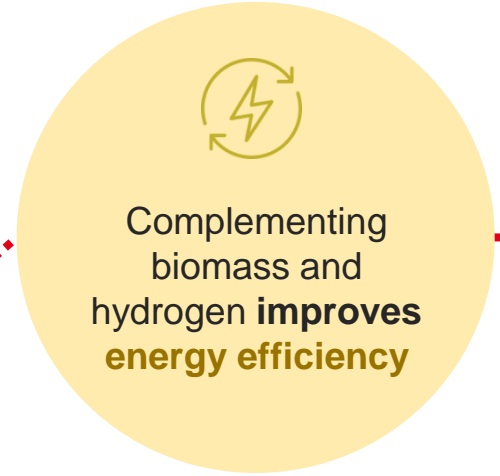
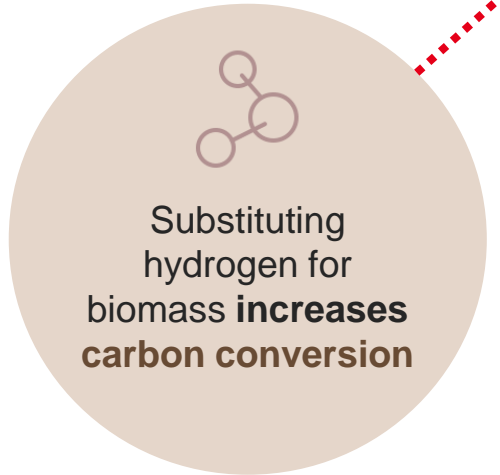
Conclusions



Conclusions



Main trends



Interesting trade-off!

	BtX	PBtX	PtX
Carbon conversion	35-40 %	65-70%	80-85%
Energy efficiency	50-55%	55-65%	55-60%
Capital intensity	3000-5000 €/kW	3000-3500€/kW	3500-5500 €/kW
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Selective bibliography

- ❑ *Levelised cost of hydrogen, Making the application of the LCOH more consistent and more useful, Agora industry, July 2023*
- ❑ *Coûts des énergies renouvelables et de récupération en France, ADEME, 2019*
- ❑ *Manuel d'évaluation économique des procédés, A. Chauvel, 2001*
- ❑ *Thermo-economic analysis and multi-objective optimisation of lignocellulosic biomass conversion to Fischer–Tropsch fuels, E. Peduzzi et al., 2018*
- ❑ *Sustainability Assessment of an Integrated High Temperature Steam Electrolysis-Enhanced Biomass to Liquid Fuel Process, Bernical et al., 2013*
- ❑ *Thermochemical production of liquid fuels from biomass: Thermo-economic modeling, process design and process integration analysis, Tock et al., 2010*
- ❑ *Thermo-economic process model for thermochemical production of Synthetic Natural Gas (SNG) from lignocellulosic biomass, Gassner et al., 2009*
- ❑ *Comprehensive techno-economic assessment of dimethyl ether (DME) synthesis and Fischer–Tropsch synthesis as alternative process steps within biomass-to-liquid production, Trippe et al., 2013*
- ❑ *CYRCEE : Etude technico-économique de filières de valorisation de CO2 sous forme de produits chimiques liquides à partir de la technologie SOEC, Le Goff, 2019*
- ❑ *VEGAZ : 2.3c Note de synthèse sur l'évaluation des chiffres clés de la filière bioSNG de 2ème génération, Jarry, 2011*
- ❑ *Technical and economical evaluation of enhanced biomass to liquid fuel processes, Seiler et al., 2010*
- ❑ *Investment and production costs of synthetic fuels – A literature survey, Haarlemmer et al., 2014*
- ❑ *Investment cost estimates for gasification-based biofuel production systems, Holmgren, 2015*
- ❑ Albrecht, Friedemann G., Daniel H. König, Nadine Baucks, et Ralph-Uwe Dietrich. « A Standardized Methodology for the Techno-Economic Evaluation of Alternative Fuels – A Case Study ». *Fuel* 194 (avril 2017): 511-26. <https://doi.org/10.1016/j.fuel.2016.12.003>.
- ❑ Anetjärvi, Eemeli, Esa Vakkilainen, et Kristian Melin. « Benefits of Hybrid Production of E-Methanol in Connection with Biomass Gasification ». *Energy* 276 (août 2023): 127202. <https://doi.org/10.1016/j.energy.2023.127202>.
- ❑ Barbuzza, Eleonora, Giuliano Buceti, Alfonso Pozio, Massimo Santarelli, et Silvano Tosti. « Gasification of Wood Biomass with Renewable Hydrogen for the Production of Synthetic Natural Gas ». *Fuel* 242 (avril 2019): 520-31. <https://doi.org/10.1016/j.fuel.2019.01.079>.
- ❑ Becker, W.L., R.J. Braun, M. Penev, et M. Melaina. « Production of Fischer–Tropsch Liquid Fuels from High Temperature Solid Oxide Co-Electrolysis Units ». *Energy* 47, n° 1 (novembre 2012): 99-115. <https://doi.org/10.1016/j.energy.2012.08.047>.
- ❑ Colelli, Leonardo, Valentina Segneri, Claudia Bassano, et Giorgio Vilardi. « E-Fuels, Technical and Economic Analysis of the Production of Synthetic Kerosene Precursor as Sustainable Aviation Fuel ». *Energy Conversion and Management* 288 (juillet 2023): 117165. <https://doi.org/10.1016/j.enconman.2023.117165>.
- ❑ Delgado, Herman E., Vincenzo Cappello, Guiyan Zang, Pingping Sun, Clarence Ng, Pradeep Vyawahare, Amgad A. Elgowainy, Daniel S. Wendt, Richard D. Boardman, et Jason Marcinkoski. « Techno-Economic Analysis and Life Cycle Analysis of e-Fuel Production Using Nuclear Energy ». *Journal of CO2 Utilization* 72 (juin 2023): 102481. <https://doi.org/10.1016/j.jcou.2023.102481>.
- ❑ Dimitriou, Ioanna, Harry Goldingay, et Anthony V. Bridgwater. « Techno-Economic and Uncertainty Analysis of Biomass to Liquid (BTL) Systems for Transport Fuel Production ». *Renewable and Sustainable Energy Reviews* 88 (mai 2018): 160-75. <https://doi.org/10.1016/j.rser.2018.02.023>.
- ❑ Dossow, Marcel, Vincent Dieterich, Andreas Hanel, Hartmut Spliethoff, et Sebastian Fendt. « Improving Carbon Efficiency for an Advanced Biomass-to-Liquid Process Using Hydrogen and Oxygen from Electrolysis ». *Renewable and Sustainable Energy Reviews* 152 (décembre 2021): 111670. <https://doi.org/10.1016/j.rser.2021.111670>.
- ❑ Fournas, Nicolas de, et Max Wei. « Techno-Economic Assessment of Renewable Methanol from Biomass Gasification and PEM Electrolysis for Decarbonization of the Maritime Sector in California ». *Energy Conversion and Management* 257 (avril 2022): 115440. <https://doi.org/10.1016/j.enconman.2022.115440>.
- ❑ Hillestad, M., M. Ostadi, G.d. Alamo Serrano, E. Rytter, B. Austbø, J.G. Pharoah, et O.S. Burheim. « Improving Carbon Efficiency and Profitability of the Biomass to Liquid Process with Hydrogen from Renewable Power ». *Fuel* 234 (décembre 2018): 1431-51. <https://doi.org/10.1016/j.fuel.2018.08.004>.
- ❑ Pérez-Fortes, Mar, Jan C. Schöneberger, Aikaterini Boulamanti, et Evangelos Tzimas. « Methanol Synthesis Using Captured CO2 as Raw Material: Techno-Economic and Environmental Assessment ». *Applied Energy* 161 (janvier 2016): 718-32. <https://doi.org/10.1016/j.apenergy.2015.07.067>.
- ❑ Trippe, Frederik, Magnus Fröhling, Frank Schultmann, Ralph Stahl, Edmund Henrich, et Ajay Dalai. « Comprehensive Techno-Economic Assessment of Dimethyl Ether (DME) Synthesis and Fischer–Tropsch Synthesis as Alternative Process Steps within Biomass-to-Liquid Production ». *Fuel Processing Technology* 106 (février 2013): 577-86. <https://doi.org/10.1016/j.fuproc.2012.09.029>.
- ❑ Weyand, Julia, Felix Habermeyer, et Ralph-Uwe Dietrich. « Process Design Analysis of a Hybrid Power-and-Biomass-to-Liquid Process – An Approach Combining Life Cycle and Techno-Economic Assessment ». *Fuel* 342 (juin 2023): 127763. <https://doi.org/10.1016/j.fuel.2023.127763>.
- ❑ Zang, Guiyan, Pingping Sun, Amgad A. Elgowainy, Adarsh Bafana, et Michael Wang. « Performance and Cost Analysis of Liquid Fuel Production from H2 and CO2 Based on the Fischer–Tropsch Process ». *Journal of CO2 Utilization* 46 (avril 2021): 101459. <https://doi.org/10.1016/j.jcou.2021.101459>.



**“ Thank you for your
attention !**