EXPLORING TECHNOLOGY CHOICES IN INDUSTRIAL DECARBONISATION

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AGENDA

- Introduction
- Aim
- Swedish industry
- Modelling approach
- Scenario description
- Results and conclusions

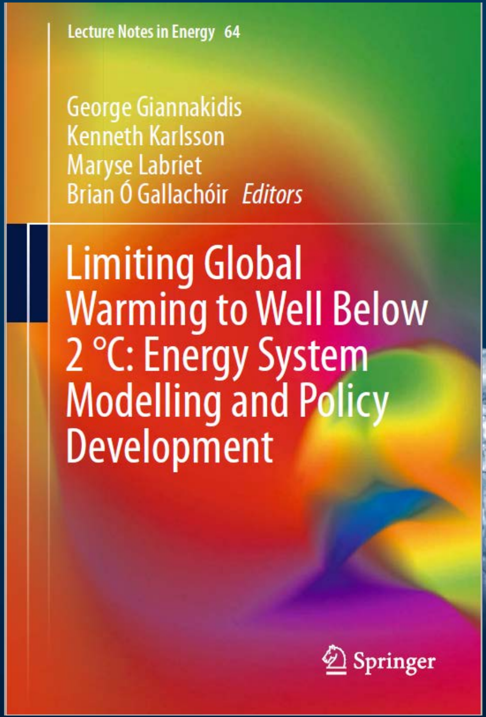
INTRODUCTION

How to decarbonise the industry is one of the main challenges in order to limit global warming to well below 2ºC. For Sweden see e.g. Krook-Riekkola & Sandberg 2018 in →

Industry can be described by: Large investments (easier to change parts instead of the whole site), many potential routes, integrated with the surrounding industries and energy system, new options that has not been fully tested: CCS, Biomass and/or Electricity
→ LARGE FLEXIBILITY and MANY POSSIBILITIES and big UNCERTAINTIES!

Process Integration Modeling

Comprehensive ESOM



AIM

To identify cost-efficient site-specific options and new process solutions when decarbonizing the industrial sector.

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MODELLING APPROACH (I)

TIMES-Sweden Industry model

- A stand alone module of the TIMES-Sweden model. Starting to be merged/incorporated into TIMES-Sweden.

TIMES an energy system optimization model

- Suitable for analyzing large comprehensive energy systems, such as national energy systems.

MODELLING APPROACH (II)

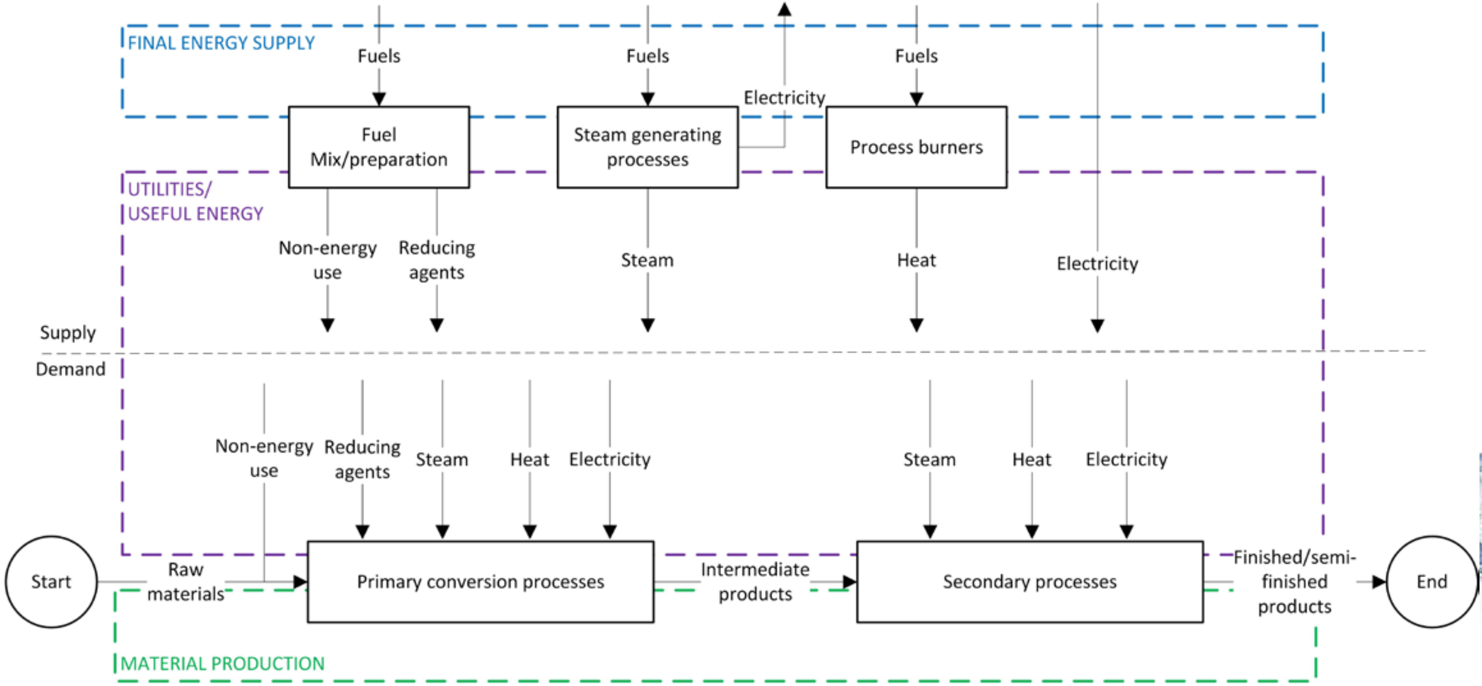
Wants to capture:

- Process integration potentials
- Use of industry (site) specific energy- and material flows
- SITE SPECIFIC POTENTIALS – limiting process integration possibilities by site specific flows

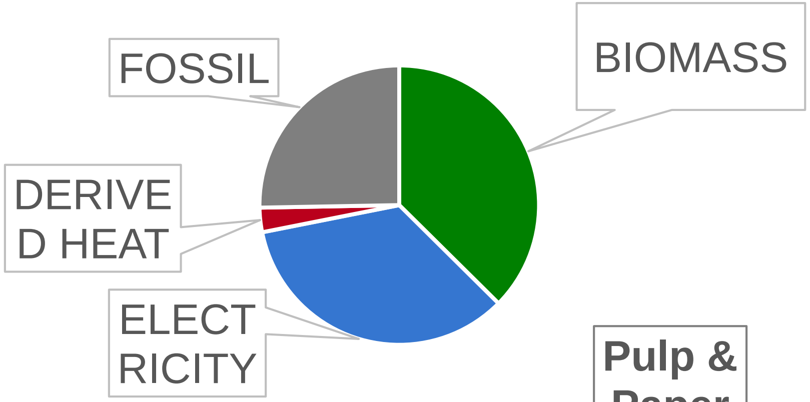
→ Focus on industrial clusters/sites

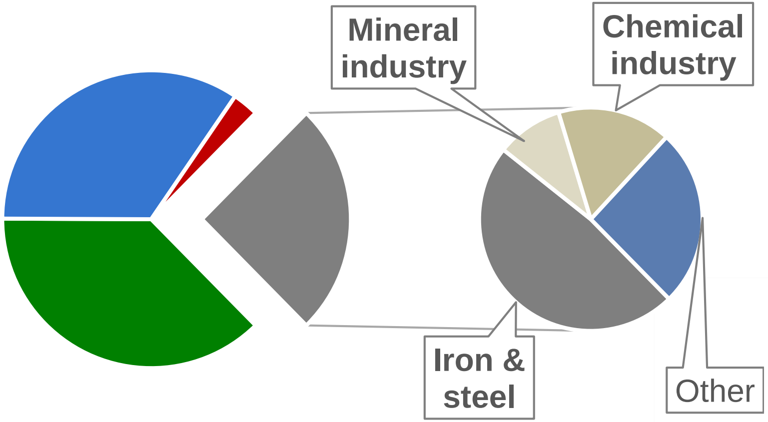
MODELLING APPROACH (III)

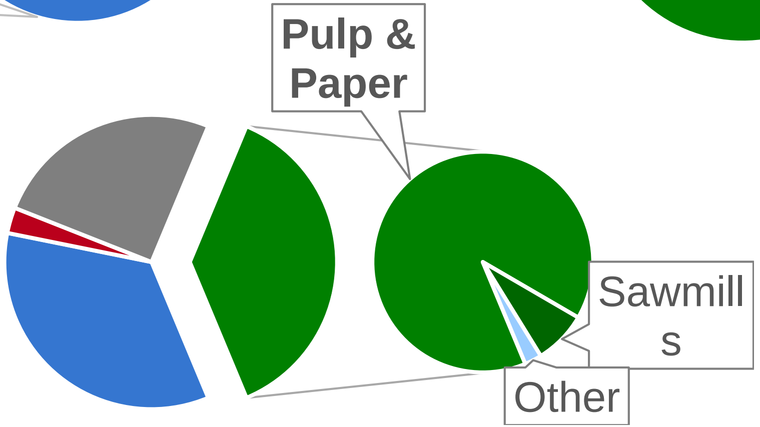
- Optimized for process integration
  - Treats final energy and useful energy separately for all processes



SWEDISH INDUSTRY





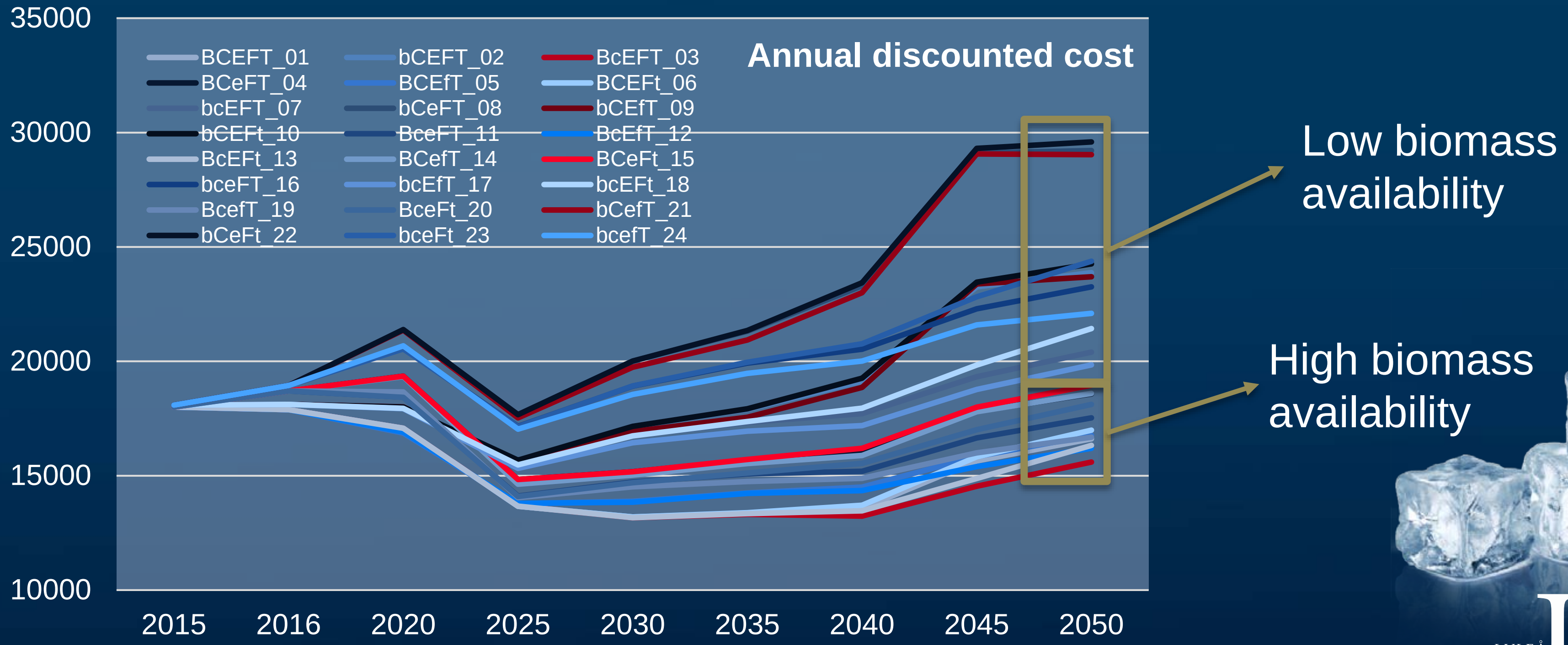


SCENARIO DESCRIPTION

ALL SCENARIOS AIM AT REACHING THE SWEDISH NET- OR SUB-ZERO GHG-EMISSIONS BY 2045, BUT ARE LIMITED TO CO_2-EMISSION AND ASSUMES A LINEAR REDUCTION FROM 2020 TO 2045

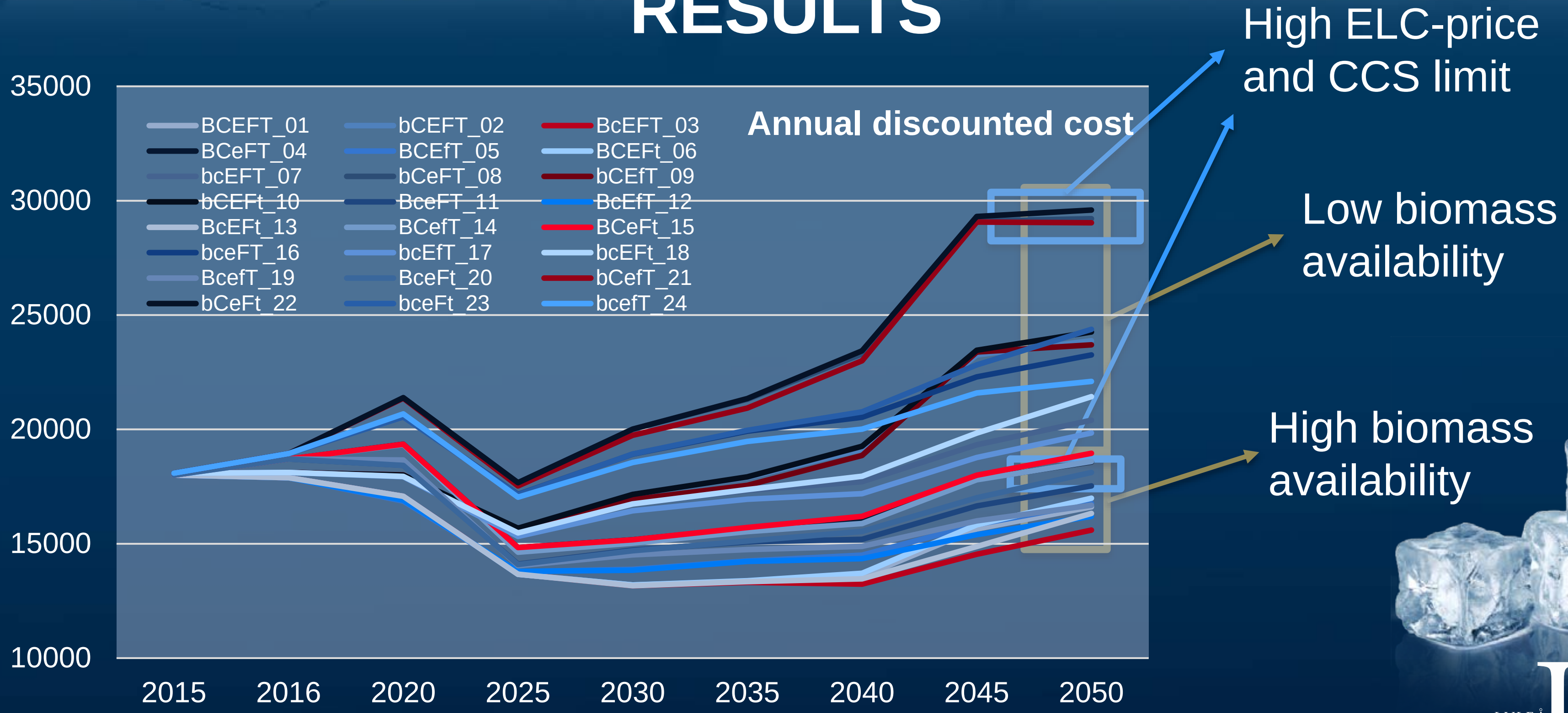
Resource	Central case	Sensitivity
Biomass resources (B)	• HIGH biomass availability for the industry (HIGH resource availability, LOW demand from other sectors) (B)	• Low biomass availability for the industry (LOW resource availability, HIGH demand from other sectors) (b)
CCS (only storage solutions) (C)	• Low storage acceptance and potential (equal to material based emissions) (C)	• High storage acceptance and potential (c)
Electricity (E)	• Reference price (E)	• High price (e)
International fuel markets (F)	• Fossil fuel price based on IEA New Policies (REF-level) • Reference CO_2 price level • Biofuel price follows fossil price (FT)	• Fossil fuel price based on IEA Sustainable Development (LOW-level) • Reference CO_2 price level • Biofuel price follows fossil fuel price • Reference CO_2 price level (fT)
		• Fossil fuel price based on IEA New Policies (REF-level) • Biofuel price follows fossil fuel price • High CO_2 price level (Ft)

RESULTS



Annual discounted cost
BCEFT_01
bCEFT_02
BcEFT_03
BCeFT_04
BCEfT_05
BCEFt_06
bcEFT_07
bCeFT_08
bCEfT_09
bCEFt_10
BceFT_11
BcEfT_12
BcEFt_13
BCefT_14
BCeFt_15
bceFT_16
bcEfT_17
bcEFt_18
BcefT_19
BceFt_20
bCefT_21
bCeFt_22
bceFt_23
bcefT_24
35000
30000
25000
20000
15000
10000
2015
2016
2020
2025
2030
2035
2040
2045
2050
Low biomass availability
High biomass availability

RESULTS



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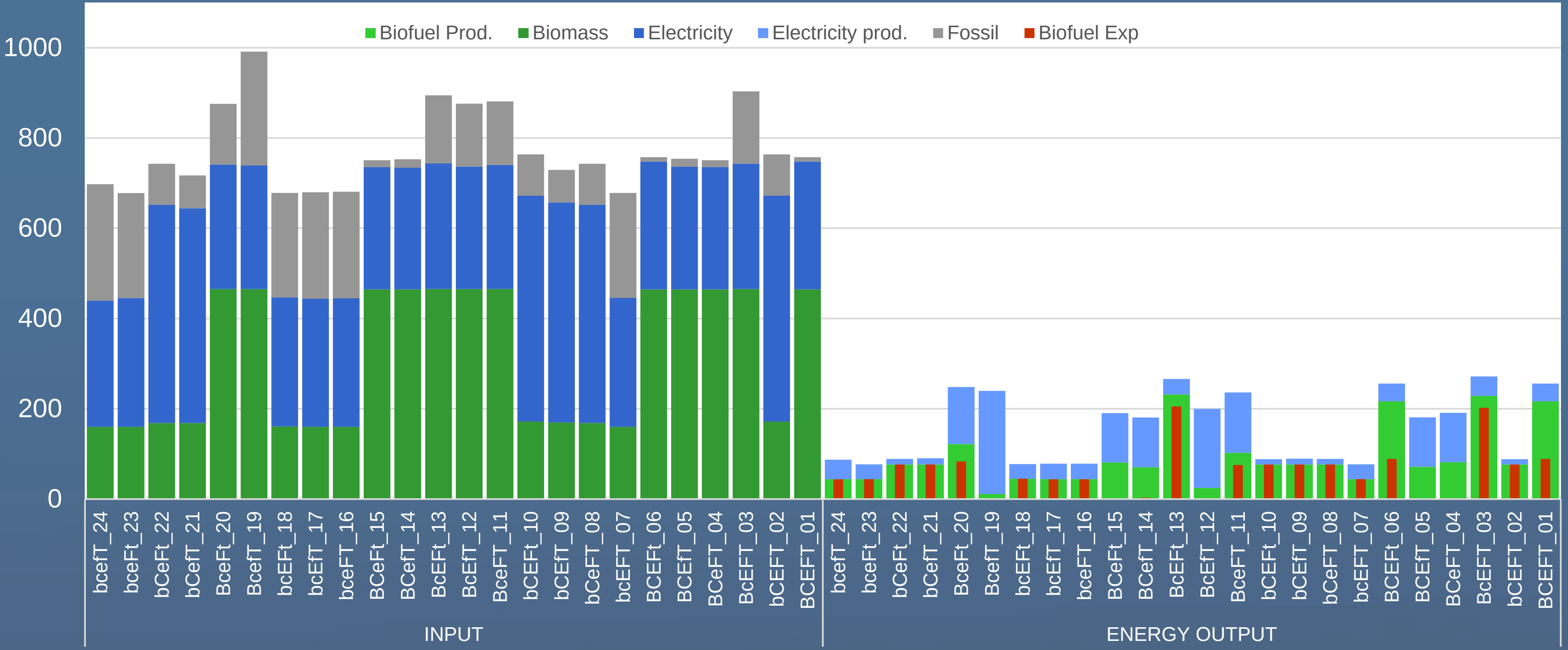
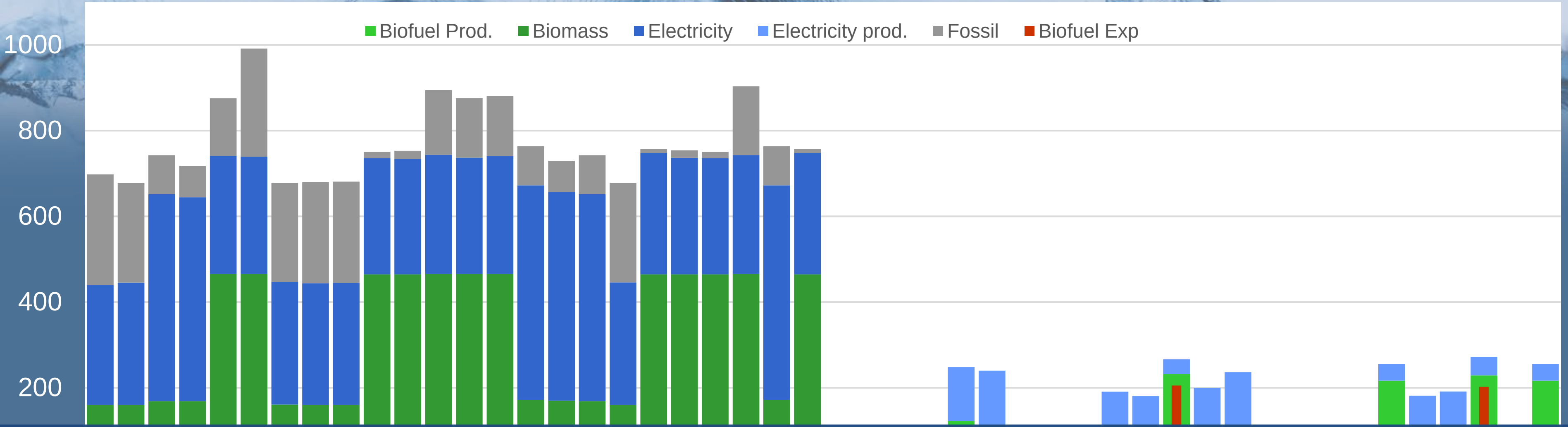
RESULTS

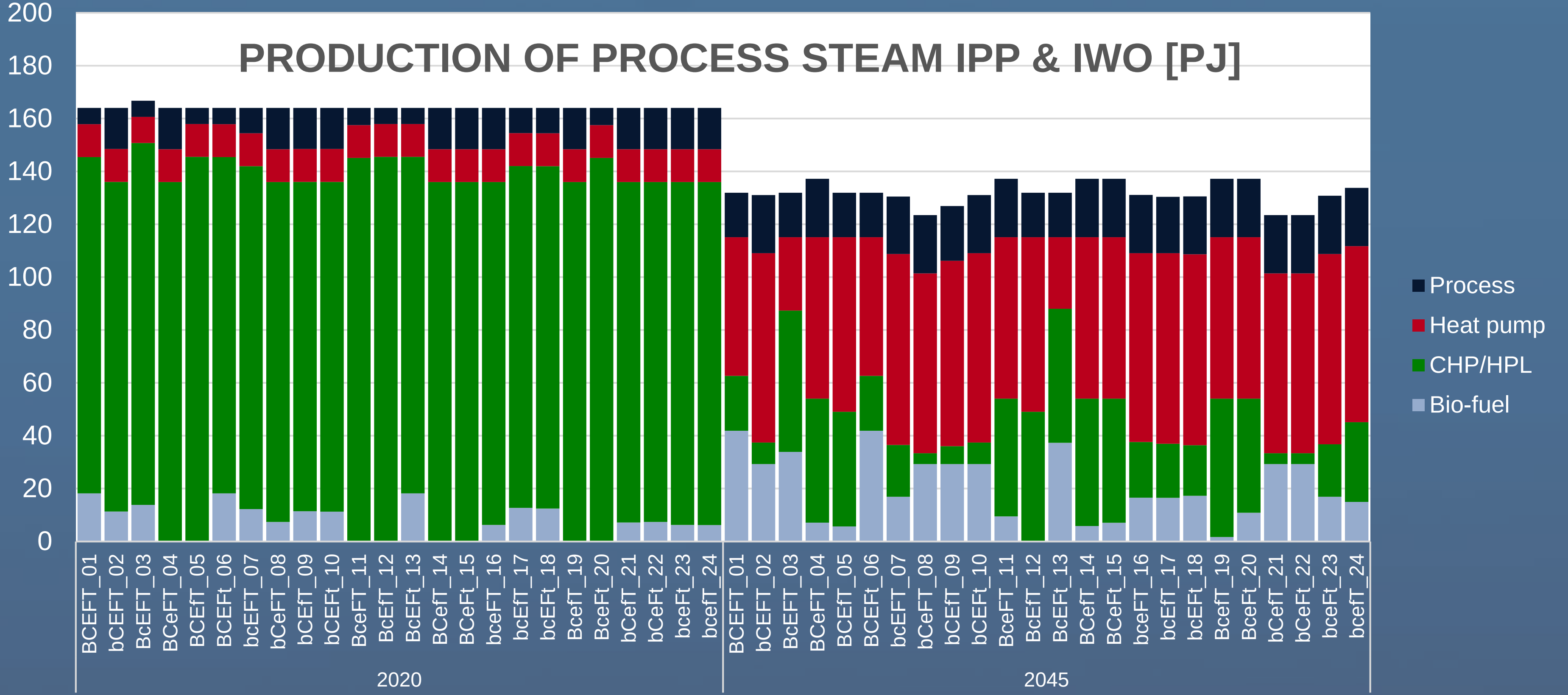


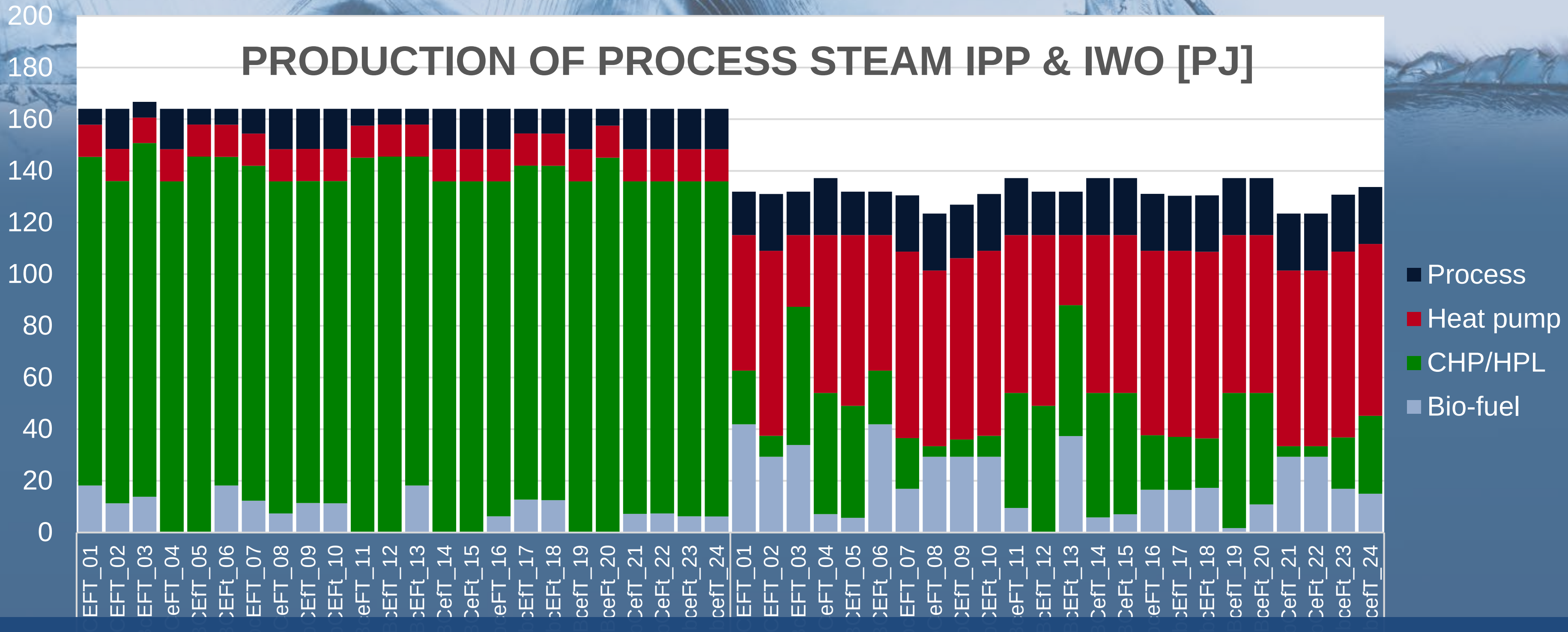
Biofuel Prod.
Biomass
Electricity
Electricity prod.
Fossil
Biofuel Exp
1000
800
600
400
200
0
bcefT_24
bceFt_23
bCeFt_22
bCeFT_21
BceFt_20
BcefT_19
bcEFt_18
bcEfT_17
bceFT_16
BCeFt_15
BCefT_14
BcEFt_13
BcEfT_12
BceFT_11
bCEFt_10
bCEfT_09
bCeFT_08
bcEFT_07
BCEFt_06
BCEfT_05
BCeFT_04
BcEFT_03
bCEFT_02
BCEFT_01
INPUT
bcefT_24
bceFt_23
bCeFt_22
bCeFT_21
BceFt_20
BcefT_19
bcEFt_18
bcEfT_17
bceFT_16
BCeFt_15
BCefT_14
BcEFt_13
BcEfT_12
BceFT_11
bCEFt_10
bCEfT_09
bCeFT_08
bcEFT_07
BCEFt_06
BCEfT_05
BCeFT_04
BcEFT_03
bCEFT_02
BCEFT_01
ENERGY OUTPUT



- Integrated biofuel or electricity production always utilized
  - Minimizes cost by export or by replacing import
  - Priorities investment in larger industries -> economy of scale
- Unlimited CCS and high biomass availability leads to cheap electricity with natural gas (BECCS offsets remaining emissions).
- **CONCLUSION:** Industrial biomass use is a multi-purpose tool of the energy system. Efficient use is crucial for reaching net-zero emissions.

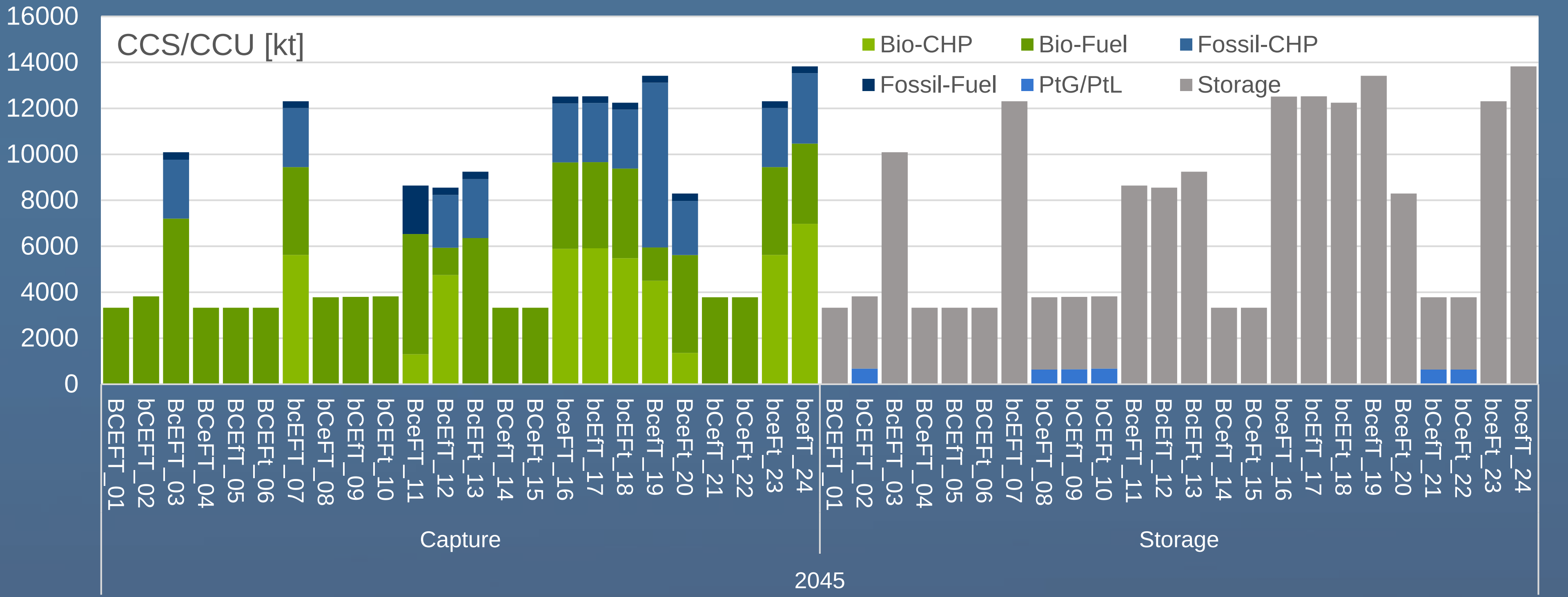
RESULTS-HEAT PUMPS





- **HEAT PUMPS** minimize steam supplied from biomass/black liquor in sawmills and pulp and paper industries (for drying applications).
- **CONCLUSION:** Heat pumps are very important as they allow more biomass to be used where it is needed!

RESULTS-CCS



CCS/CCU [kt]
Bio-CHP
Bio-Fuel
Fossil-CHP
Fossil-Fuel
PtG/PtL
Storage
16000
14000
12000
10000
8000
6000
4000
2000
0
BCEFT_01
bCEFT_02
BcEFT_03
BCeFT_04
BCEfT_05
BCEFt_06
bcEFT_07
bCeFT_08
bCEfT_09
bCEFt_10
BceFT_11
BcEfT_12
BcEFt_13
BCefT_14
BCeFt_15
bceFT_16
bcEfT_17
bcEFt_18
BcefT_19
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bCeFt_22
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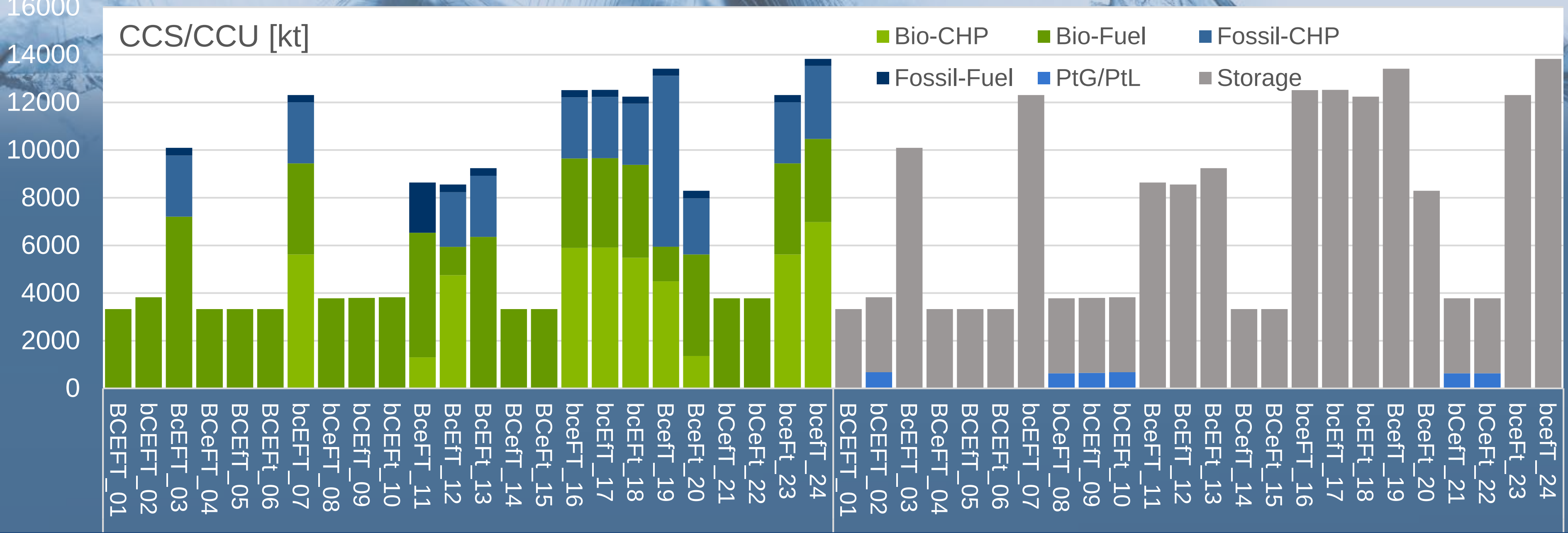
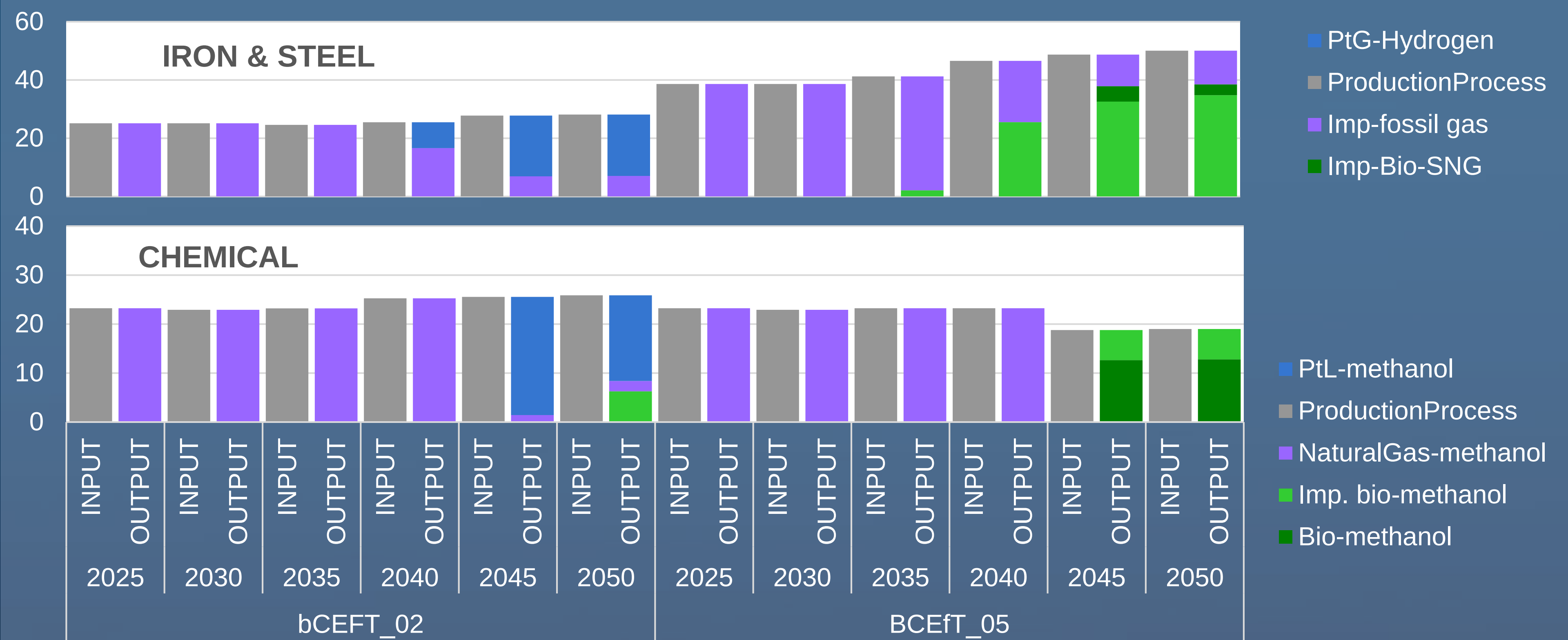
Capture
Storage
2045



- **BECCS** combined with gasification-based fuel- or electricity production
  - No investment in CCS made for Mineral industries (e.g. Cement) in any scenario
- **CONCLUSION:** CCS/-U required for reaching emission targets, but not necessarily at the site causing emissions!

INDUSTRIAL TECHNOLOGY CHOICES



- **IRON & STEEL:** Uses gas or hydrogen for ore-based steel
- **CHEMICAL:** Uses ethanol and methanol for olefin production
- **CONCLUSION:** Industrial production technologies are choosen so that feedstock/fuel production can be adapted to the energy market

CONCLUSIONS

- **The process-oriented modelling approach** captures site specific integration possibilities very well – and is important for estimating potential benefits and costs when integrating new processes.
- **Integrated production** of biofuels very important to ensure an efficient use of biomass, which is key for reaching net zero target when the biomass availability is low. **Heat-pumps** are very important to further facilitate biofuel-production and overall biomass use.
- **CCS/-U solutions** required to reach the emission target. The most efficient way of mitigating non-energy related emissions is to combine CCS with gasification based production of biofuels and electricity.
- The industry has the possibility to become a **facilitator** of a sustainable energysystem through e.g. fuel production, but will most likely require new polices aimed at establishing competitive prices for biofuels and electrofuels.

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