Integrating technology innovation in sustainable production processes & systems.

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Systemic vision of a Net-Zero future

Knowledge

Eco-sphere
Geolocalised

Renewable resources

Where-When-How much ?

Techno-sphere
Technology innovation - Infrastructure

Investments

Technologies and storage

Choose - Size - Connect & Operate

Waste-Water-Energy Nexus & Circularity

Waste to products - Waste to energy

Socio-sphere
Needs & Preferences

Needs

Food & Water

Products

Services

- Comfort
- Data
- Mobility

Goals & Constraints

Sustainability metrics

Well being

Environment

Health

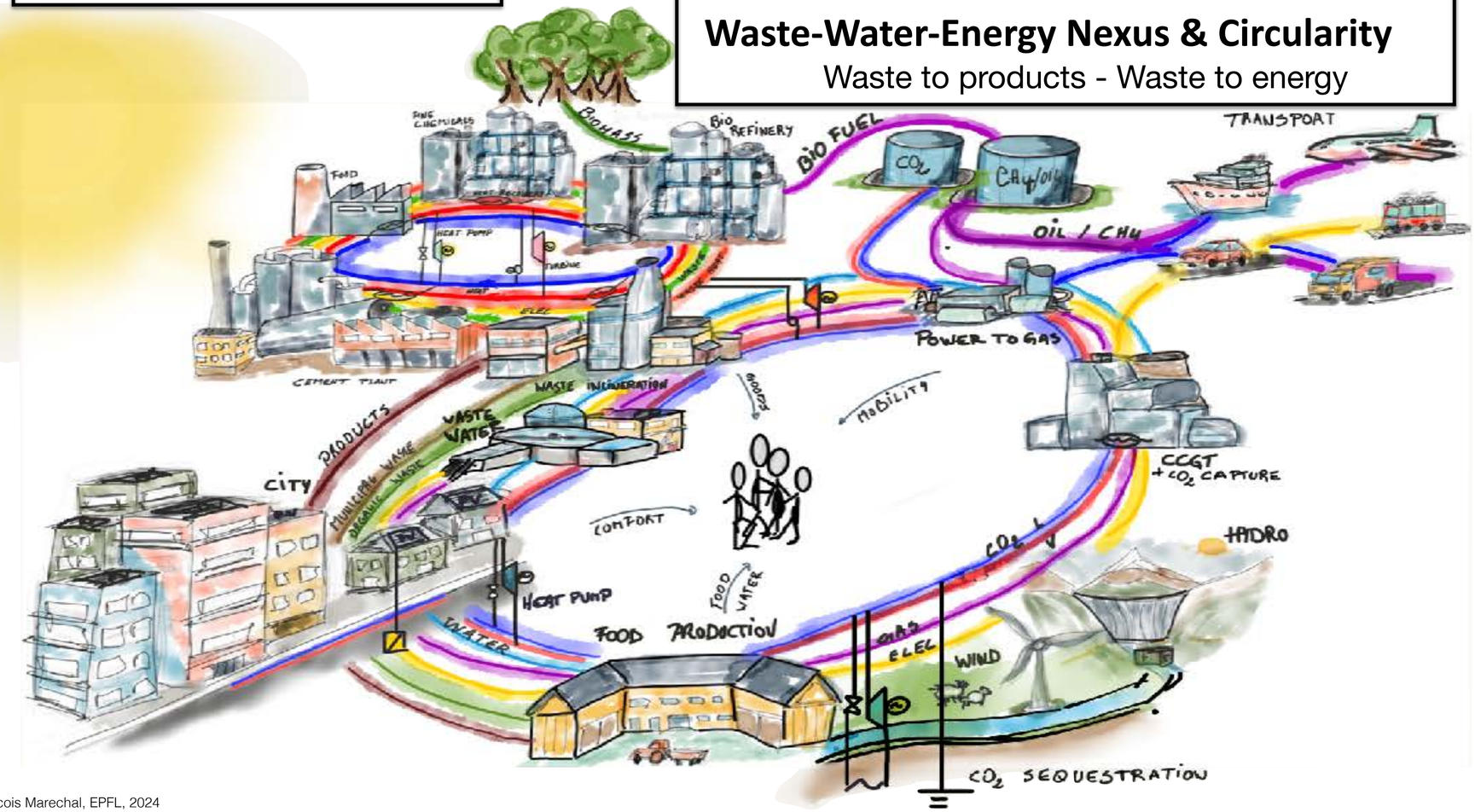
Economy

Planetary limits

Security of supply

Habitability

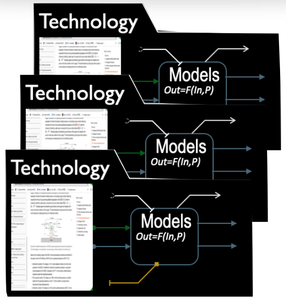
Sustainability



Industrial production systems

Technosphere Knowledge

Technology innovation



Process and system engineering

Production process

Technology innovation
- Materials - Catalysts
- Equipments
- Operating conditions

Process Integration
- *Materials (re)use*
- *Heat recovery*
- *Waste heat valorisation*
- *Waste management*

Energy conversion & storage
- *Renewable energy sources*
- *Combined Heat and Power*
- **CO2** capture

Function

Time of use

End of Life

Raw Materials

Products

Production process

Biomass

Raw Materials
Resources

Waste management

District heating/cooling

Water

Waste & Recycled Products supply chain

Symbiosis
- *District heating/cooling*
- *Waste-water-energy*
- *Circular economy*

H2

Electricity

Gas

CO2

Energy system integration
- *Energy grids*
- *Storage : Power2Tanks2Power*

Sequestration

IPESE
Industrial Process and Energy Systems Engineering

Sustainability goals and constraints

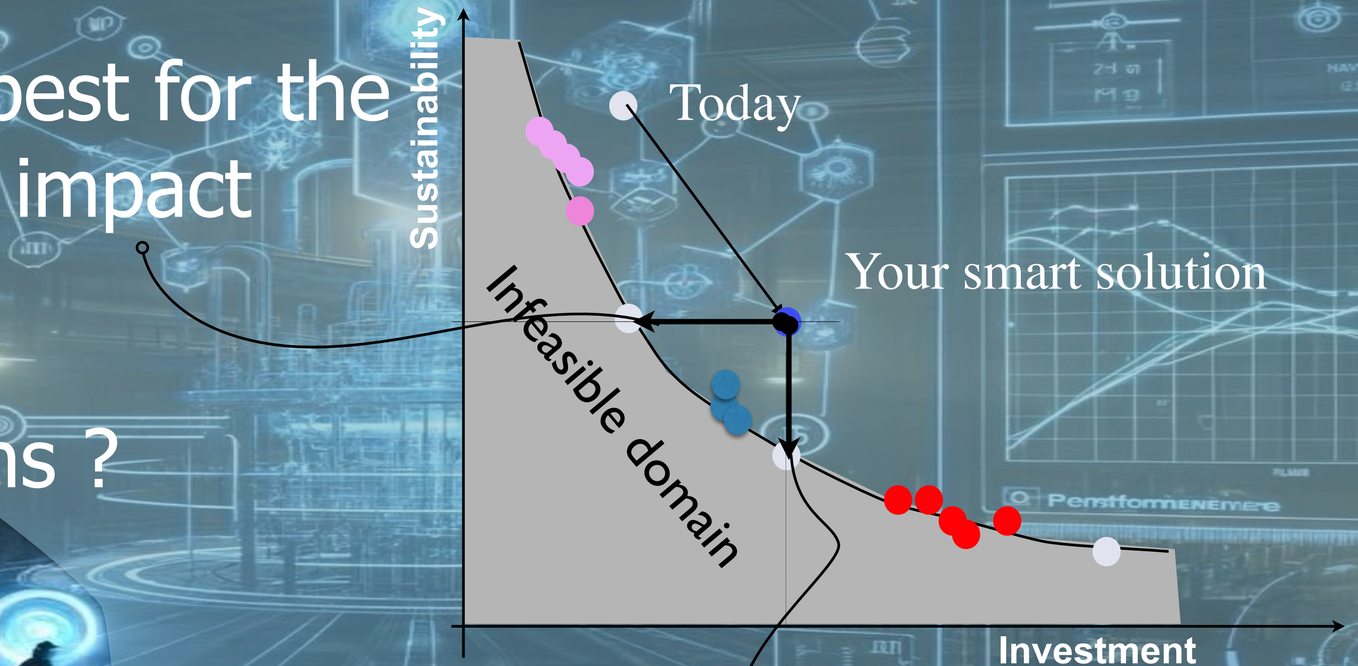
- **Life Cycle Environmental impact & limits**
  - CO2 footprint/climate change
  - Resources usage
  - Human Health
  - Bio-diversity
  - Planetry boundaries
- **Thermodynamic**
  - Mass and Atoms economy
  - Energy Efficiency
  - Exergy
  - Renewable energy

- **Life Cycle Economics**
  - CAPEX : value of the mobilised capital
  - OPEX : value of the flows exchanged
  - Technology Readiness
  - Transition dynamics
- **Social**
  - Acceptance
  - Business models & Markets
  - Supply chains
  - Jobs
  - Regulation and Tarrifs

DIGITAL TWINS
YOUR DECISION'S SPACE

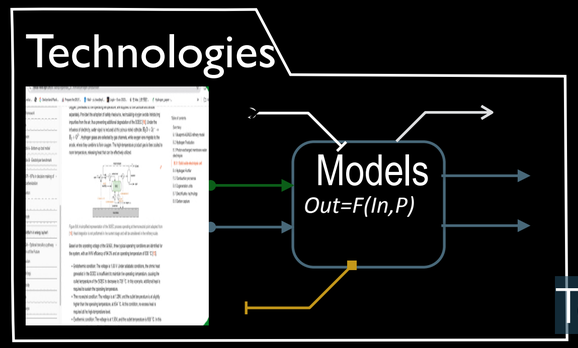
Cheapest for the same impact

Competing solutions ?

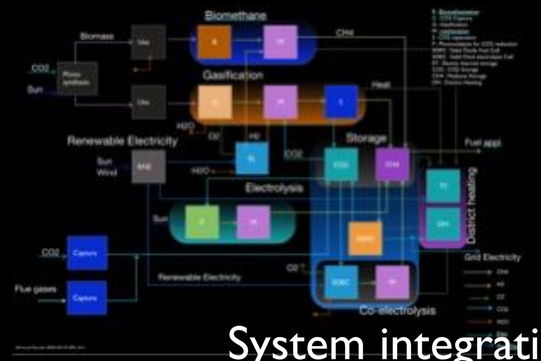


Lowest impact for the same cost

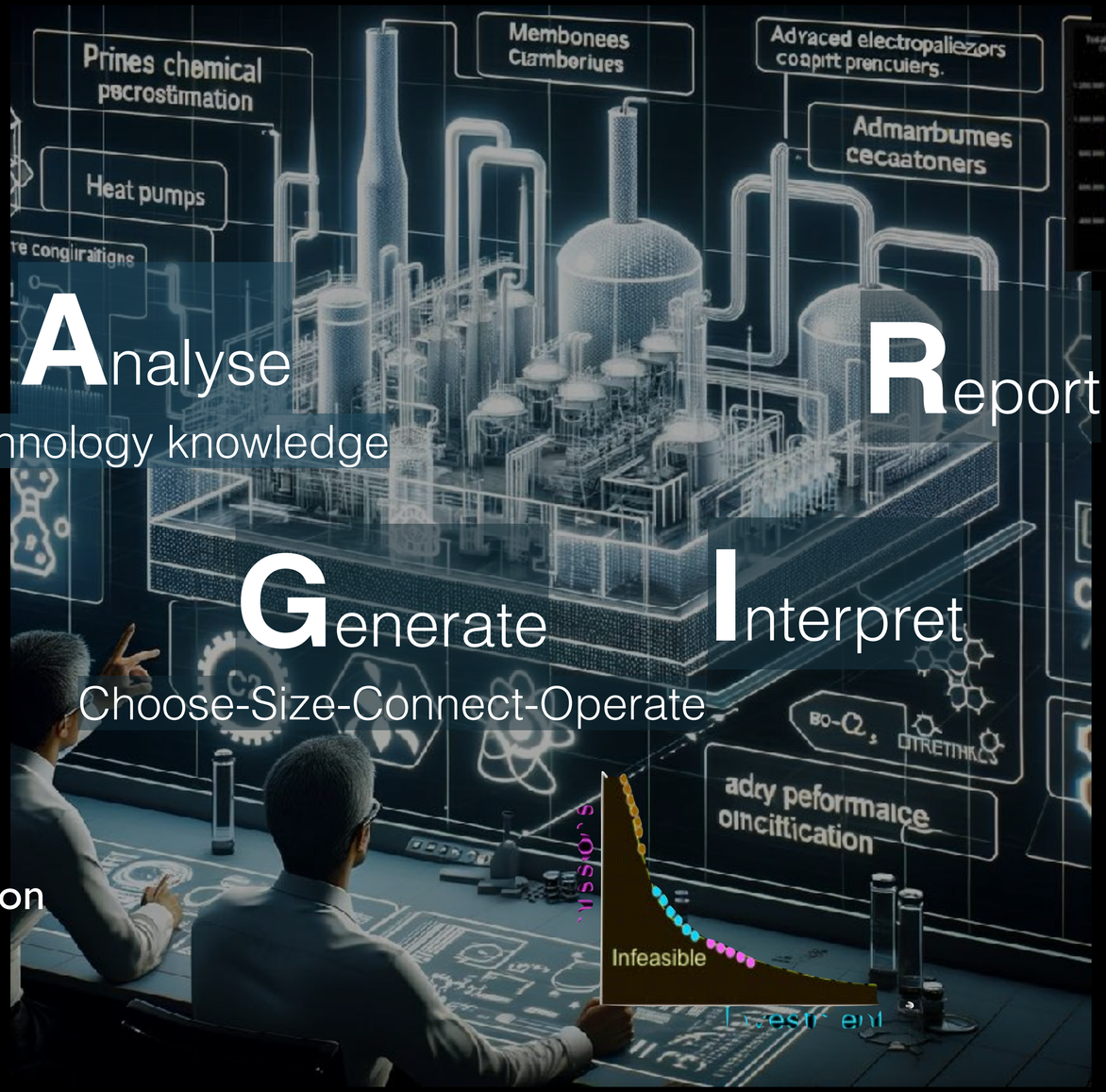
Our research : Digital Twins for process and energy systems engineering



Superstructure



System integration



System configurations

Decisions

- Multi-criteria
- Explain differences
- Assess the Risk
- Sustainable Development Goals
- Planetary boundaries

Performances

- Economic
- Thermodynamic
- Environmental impact
- Social
- Risk

*AGIR : to act !

Aluminium industry

Net Zero Lab

Transition of the aluminium production and recycling towards negative emissions

Demo site : Sierre (Vs)

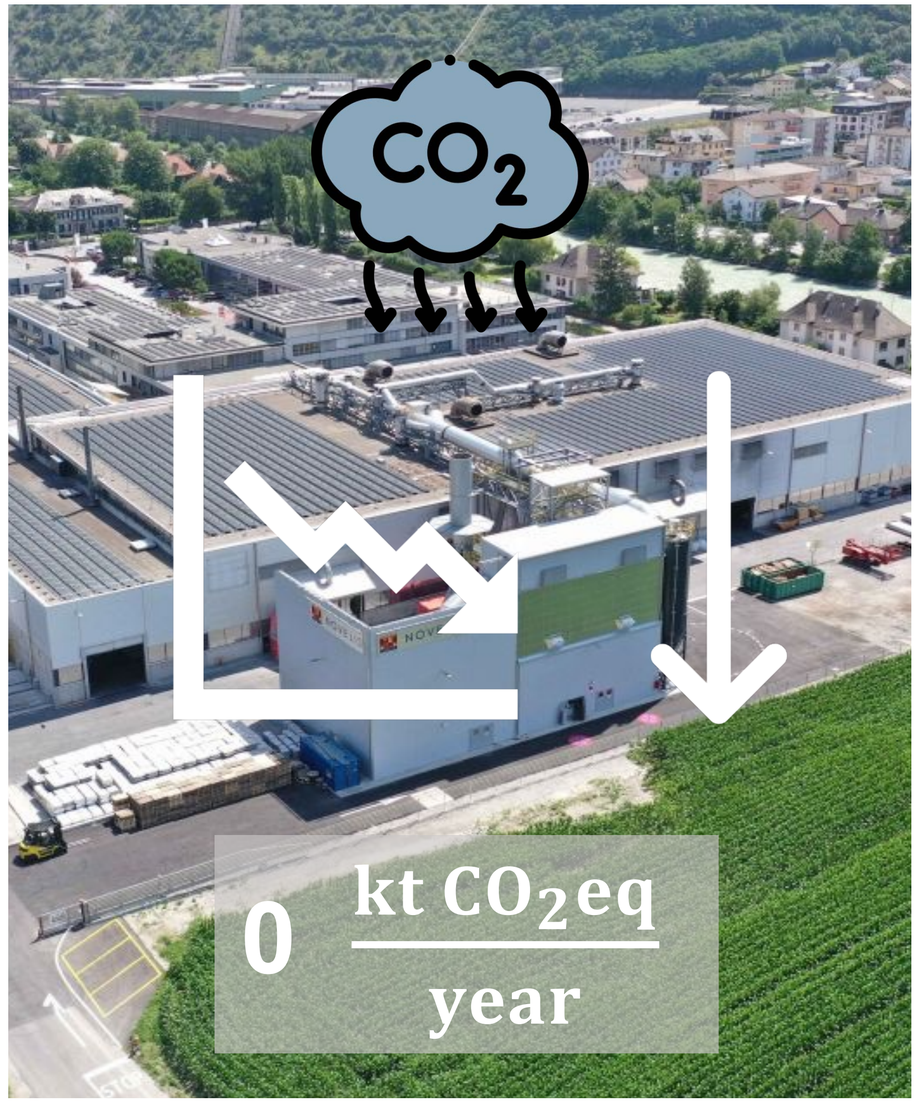
EPFL

OIKEN

Novelis

NET ZERO LAB valais

Hes·so VALAIS WALLIS



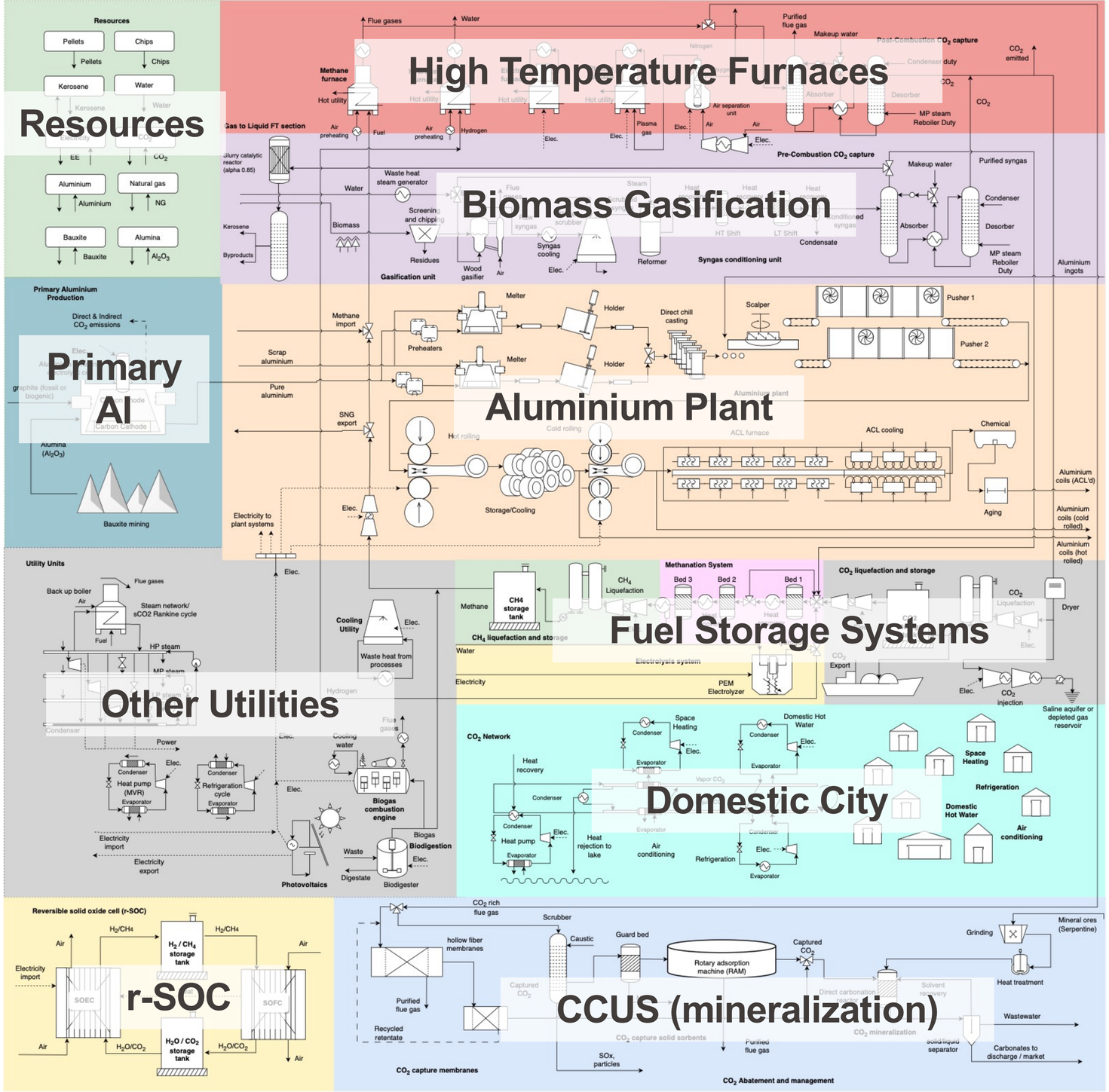
Aluminium Decarbonization Superstructure

[1] Flórez-Orrego D., Dardor D., Marèchal F. et al. 2023. "A Systemic Study for Enhanced Waste Heat Recovery and Renewable Energy Integration towards Decarbonizing the Aluminium Industry." ECOS 2023.

[2] Dardor D., Flórez-Orrego D., Marèchal F. et. al. "CO2 Capture and Management Strategies for Decarbonizing Secondary Aluminium Production". ESCAPE34, 2024.

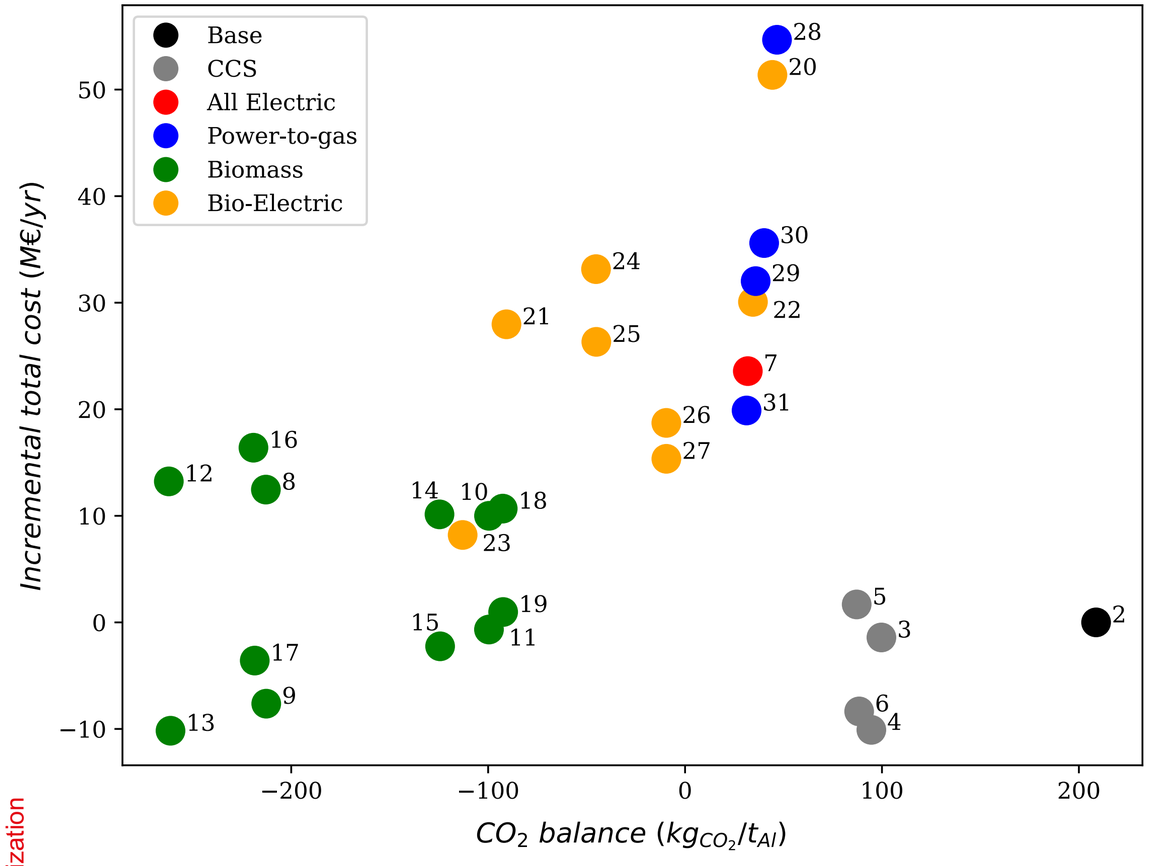
[3] Flórez-Orrego D., Dardor D., Marèchal F. et. al. "Renewable Energy Integration and Waste Heat Recovery for the Production of Sustainable Jet Fuel and Decarbonization of Industrial Heating Applications." AIChE 2023.

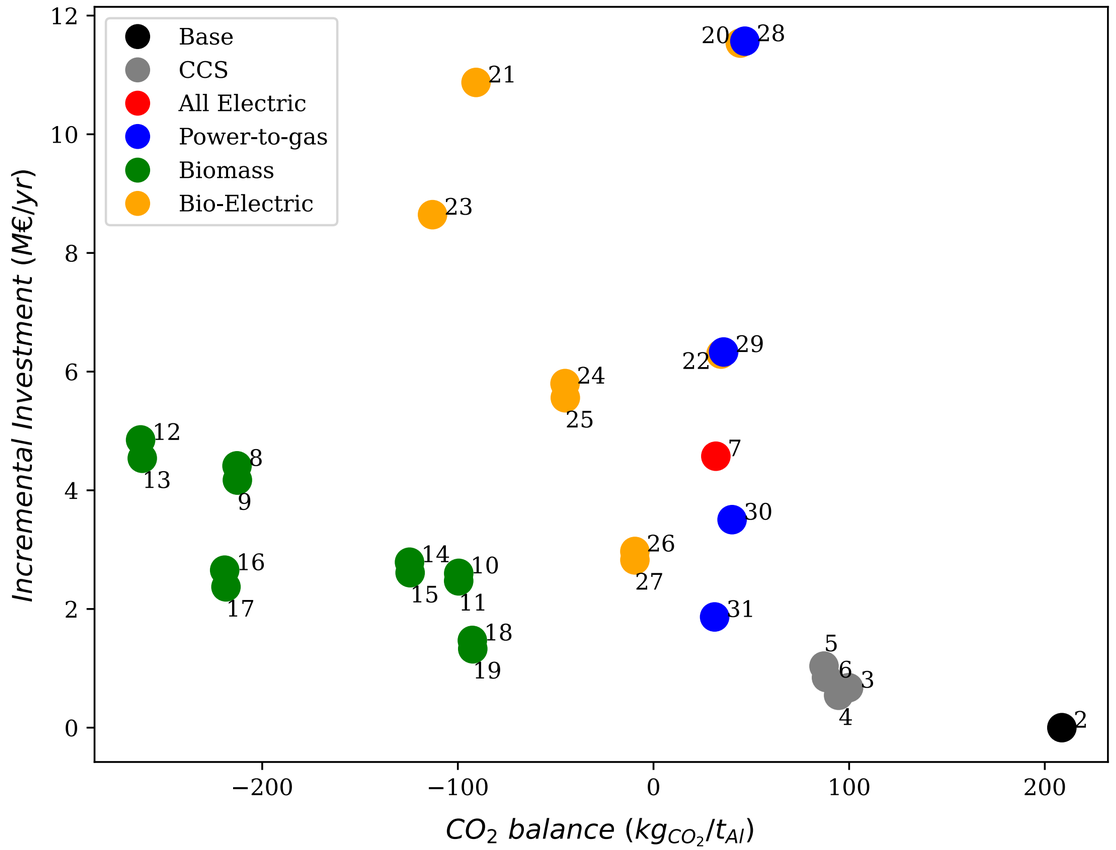
[4] Dardor, D., Flórez-Orrego D., Marèchal F. et. al. "Decarbonizing the Production of Primary Aluminium Using Renewable Resource." AIChE 2023.



Aluminium Decarbonization Options

List of decarbonization configurations (>30 options)





Economic performance vs. Net emissions

Note: Results at 100 €/tCO$_2$ tax, 0.15 €/kWh$_{EE}$, 0.045 €/kWh$_{NG}$, 0.06 €/kWh$_{Biom}$

Flórez-Orrego D., Dardor D., Maréchal F. et. al. 2024. "Pathways to Decarbonizing the Aluminium Industry: A Systemic Study of Waste Heat Recovery and Renewable Energy Integration." Journal. In preparation.

Conclusions

Integrating technology innovation in sustainable production processes & systems

- **Knowledge models**
  - Socio-Techno-Eco-spheres
- **Digital Twins : geo-localised goals, contraints & needs**
  - Generate the possible options from knowledge models
  - Process and System’s integration
  - Quantify the competition for the technology innovations
    - Socio-environo-techno-economic conditions of systemic integration
- **Sustainability metrics for decision support**
  - Life cycle approach
  - 3 pillars : economic - environmental - societal
- **Knowledge transfer**
  - Master of Advanced Studies : Sustainable Energy Systems Engineering