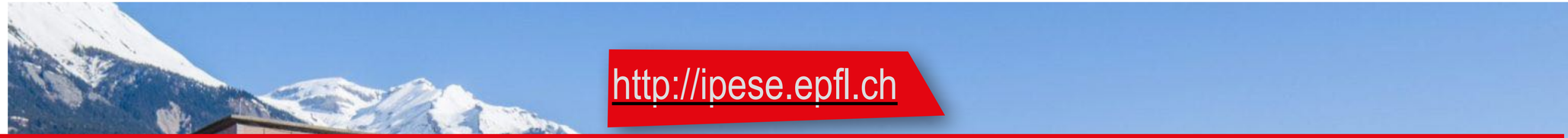


http://ipese.epfl.ch

Doctoral School in Energy
Course ME-602
Modelling, optimisation, design and analysis of integrated energy systems

April 2022

Prof François Marechal

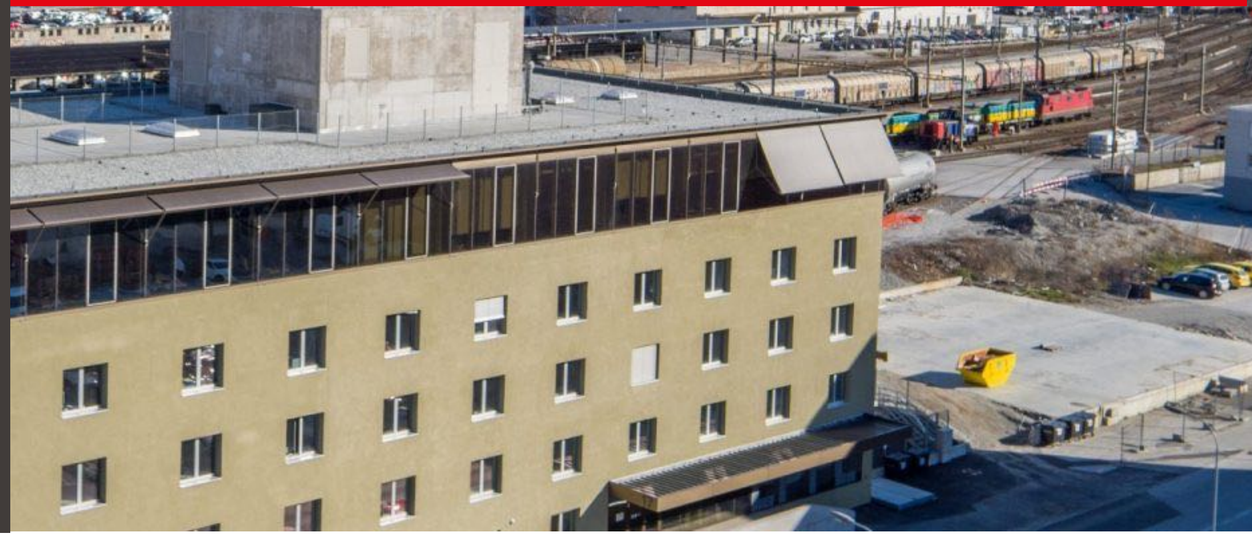
Industrial Process and Energy Systems Engineering

Institute of Mechanical Engineering

Faculty of Engineering

EPFL Valais Wallis

CH-1950 Sion



IPESE
Industrial Process and Energy Systems Engineering

Our chalenge : Engineering the Efficiency for a Net-Zero future

Investments

(**New**) Technologies
sizes : conversion and storage
Infrastructure => synergies & mutualisation

Renewable resources

Where-When-How much ?

Demand

Products
Services
Security of supply

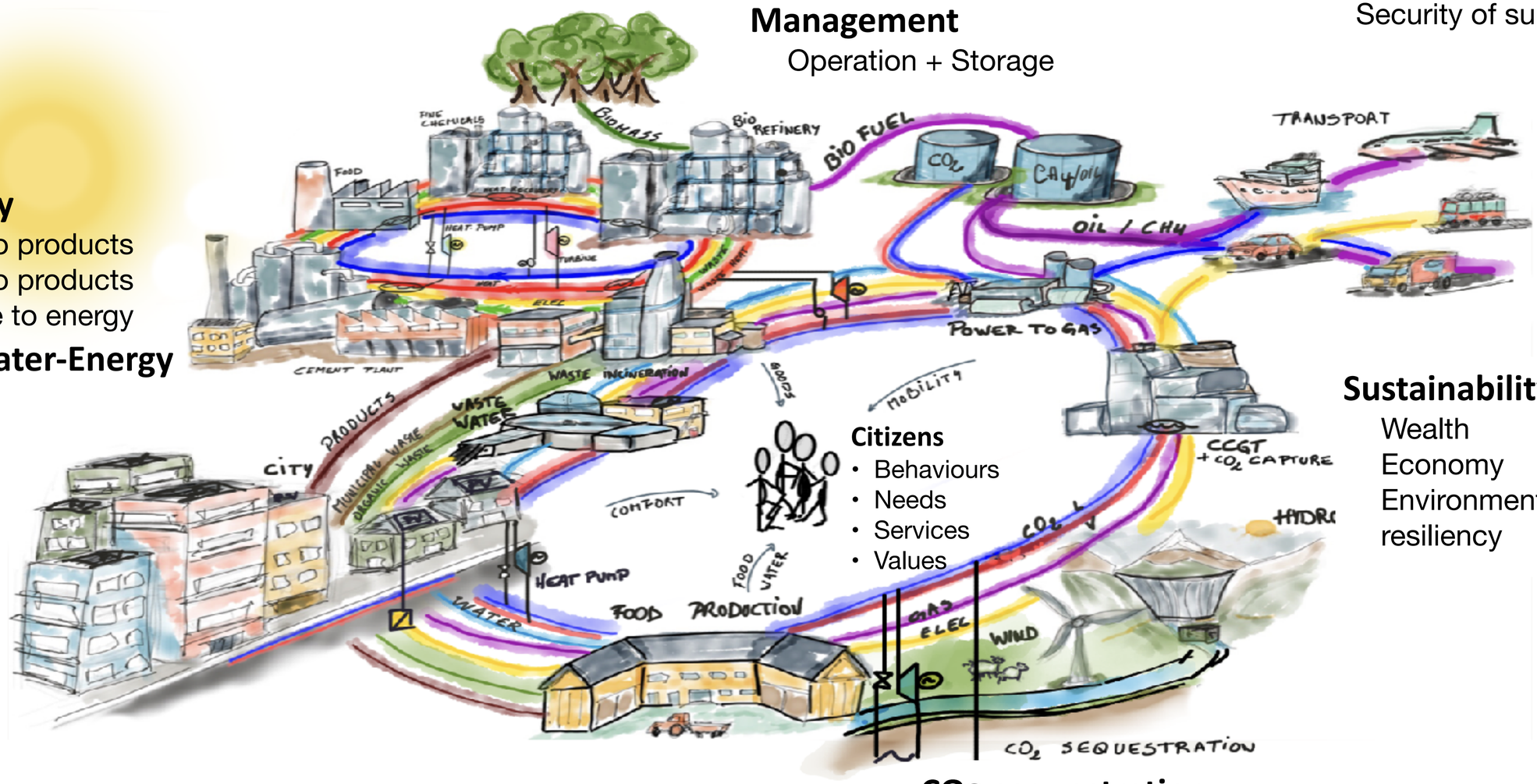
Management

Operation + Storage

Circularity

Waste to products
CO2 to products
Waste to energy

Waste-Water-Energy



CO2 sequestration

Sustainability metrics

Wealth
Economy
Environment
resiliency

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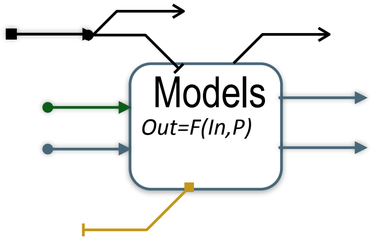
Decision support for system engineering

Context & Constraints
Resources
Product and services

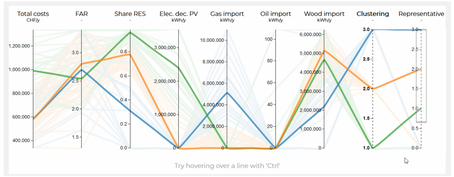
System Boundaries

Data base

Technology options



Connectivity

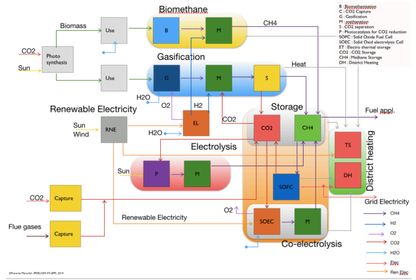


Results analysis

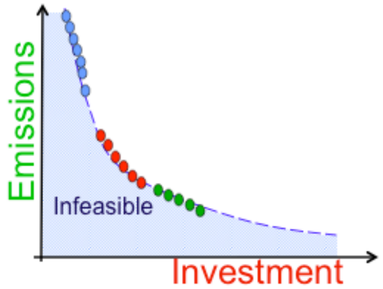
- Exergy analysis
- Sustainability assessment
- Sensitivity analysis
- Multi-criteria analysis
- Uncertainty

Decision

System superstructure

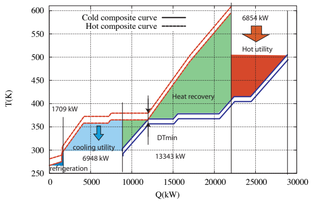


Configurations generation



Solving method

System integration



Decision variables

Performances

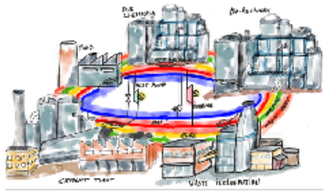
- Economic
- Thermodynamic
- Resilience
- Life cycle sustainability impact

AGIR : Analyse - Generate - Interpret - Report

OSMOSE : computer platform for decision support in integrated energy system design

EPFL Domains of applications

Process efficiency



Industrial processes

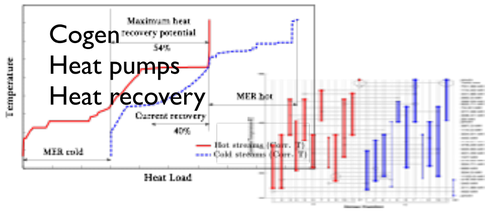
- From audits to implementation
- Symbiosis and circular economy
- Waste-Water-Energy integration
- Renewable energy integration
- CO2 & RES smart operation

Energy and resources Audits

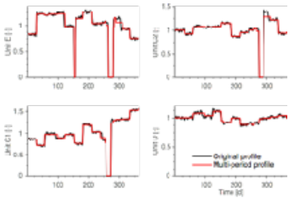
New technologies
Process Optimisation

Processes

Heat recovery and energy conversion

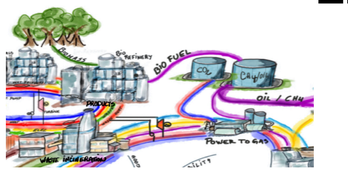


Operation



Scheduling
Storage management
Resilience

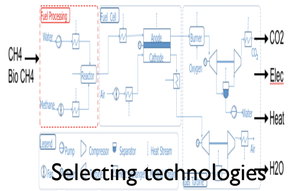
Renewable energy



Energy Conversion & Management

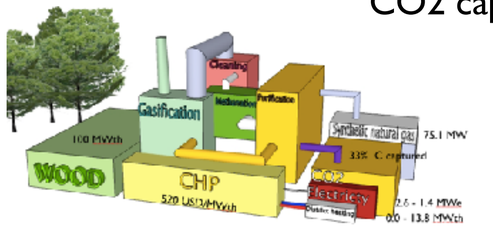
- Fuel cells based processes
- Power to Tanks to Power
- Biorefineries : C-energy + C-products
- CO2 capture, reuse, sequestration
- Energy storage

Fuel cell



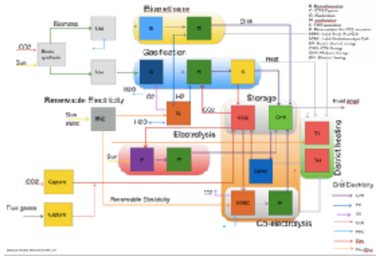
Selecting technologies
Configuration
Size
operation

Biofuel & Bio-refineries

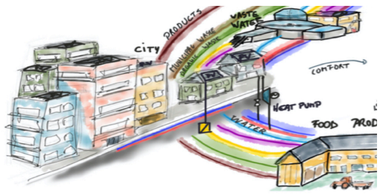


CO2 capture and reuse

Sun to fuel



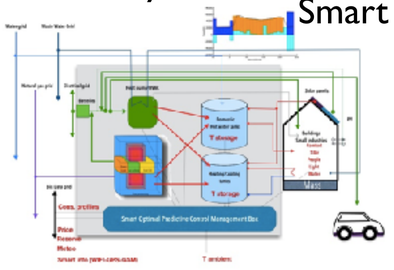
Energy system design



Urban and regional scales

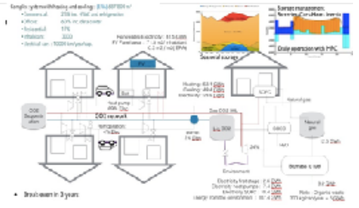
- PV - Heat pumps - Cogen
- Smart Energy Districts
- Waste - Water - Energy infrastructure
- District heating & cooling
- Energy System Transformation

Smart systems

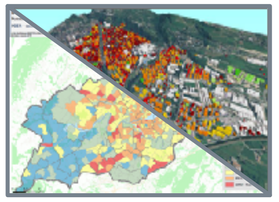


Smart grids/district networks

Industrial symbiosis



Energy System



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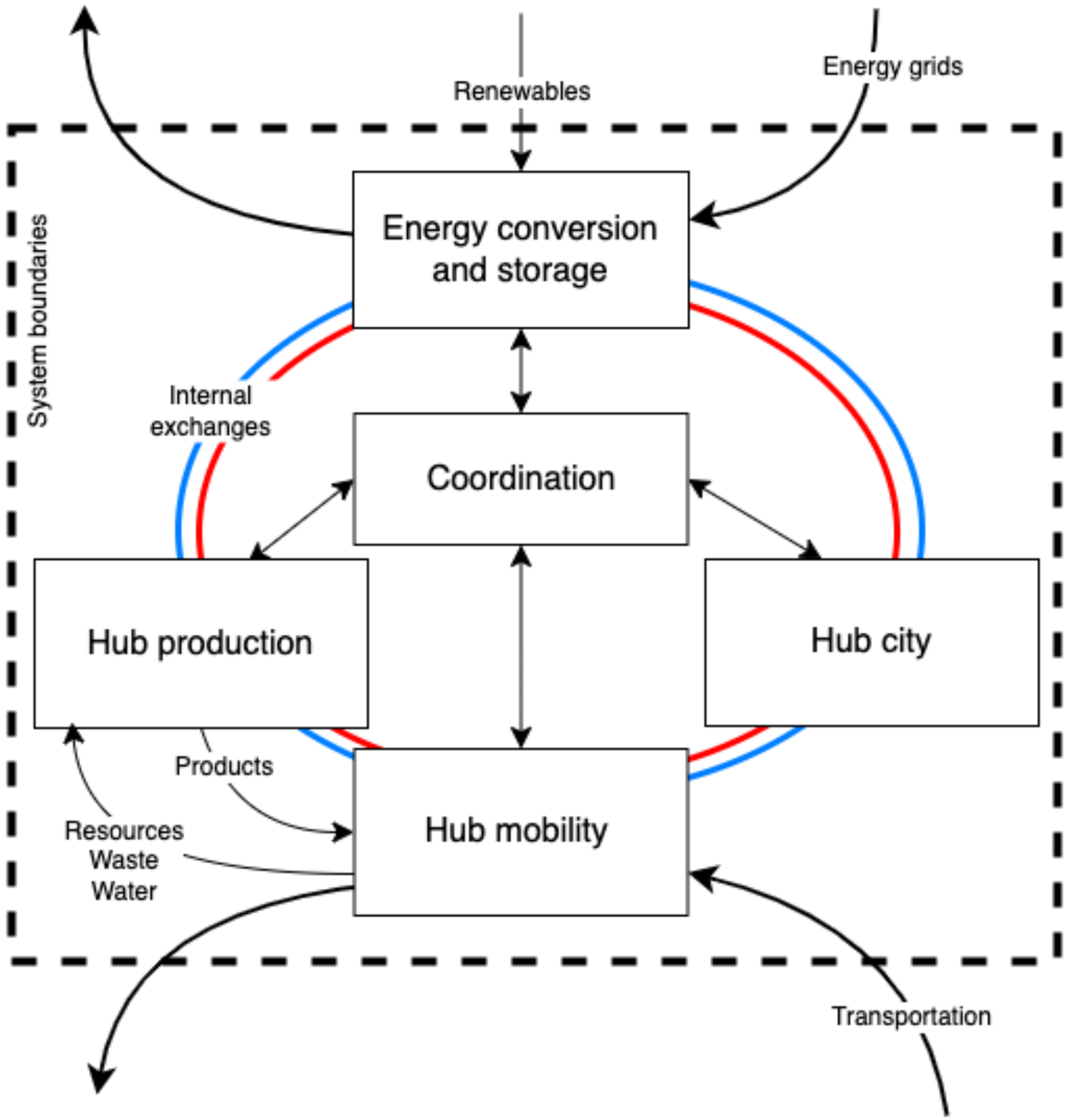
Renewable Energy Hub



Grids

Electricity
Gaz
Water
District Heating/cooling

Conversion & storage

PV - hydro - wind- geothermal
Biogas - gasification - electrolysis - fuel cells
storage : batteries, hydrogen, CO2, methane, biomass, heating, cooling, data , products

Internal exchanges and coordination

Heating - Cooling - Electricity - Gas
Water and waste water
Waste
Local production

Production

Industry
Recycling - up-cycling - preprocessing
Agriculture

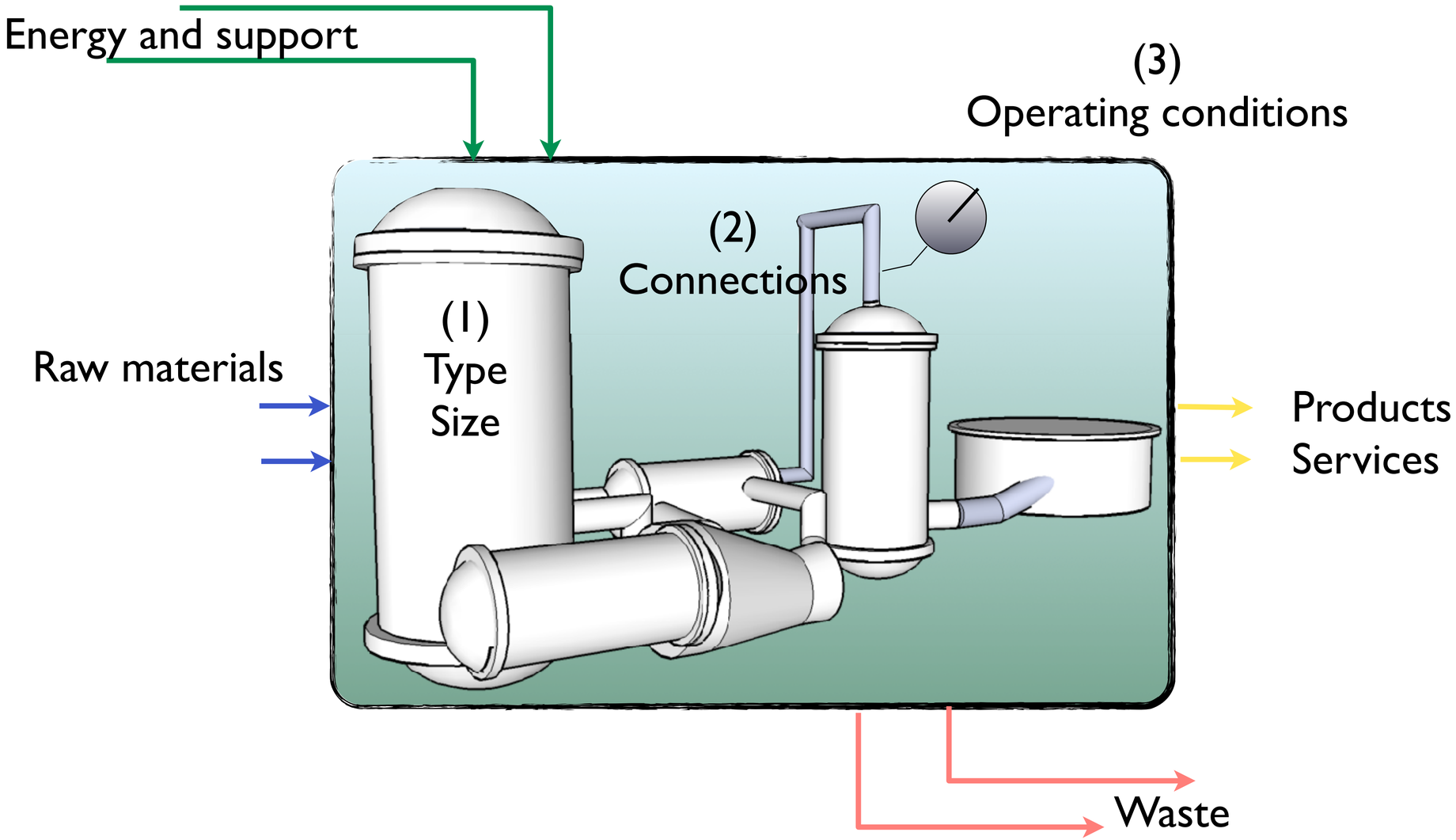
Vivre

Living - Leisure
Services to people
Consumers goods

Transport

Train
Highway
Supply chains : Raw materials - products - Waste - CO2

Integrated energy system design decisions



- Criterias
  - Economic
  - Sustainable development
  - Reliability

Planning

1. Day 1: 02/04/2024 : Non linear optimisation problem in integrated energy system design
    1. Energy system models
    2. Thermo-economic performance indicators
    3. Optimisation strategies and problem solving
    4. **Project** : optimising heat exchange recovery in a process using non linear programming techniques
2. Day 2 : 03/04/2024 : Process and energy system integration
    1. Efficiency and heat recovery by process integration techniques
    2. Combined heat and water integration
    3. Integrating energy conversion in industrial processes
    4. **Project** : Combined heat and water integration in a process using linear programming techniques
3. Day 3 : 04/04/2024 : Environmental impact assessment (will be given on line)
    1. Life Cycle Environmental impact assessment methodology for energy systems
    2. Environmental impact assessment performance indicators for decision making
    3. **Project** : Process options cost and environmental impact assessment using life cycle assessment techniques
4. Day 4 : 05/04/2024 : Renewable energy and large scale systems integration and decision support
    1. Multi-period problems formulation
    2. Integrating storage in process and energy systems
    3. Multi-criteria decision support and uncertainty
    4. **Project** : Integrating a process in a urban system and integrating renewable energy

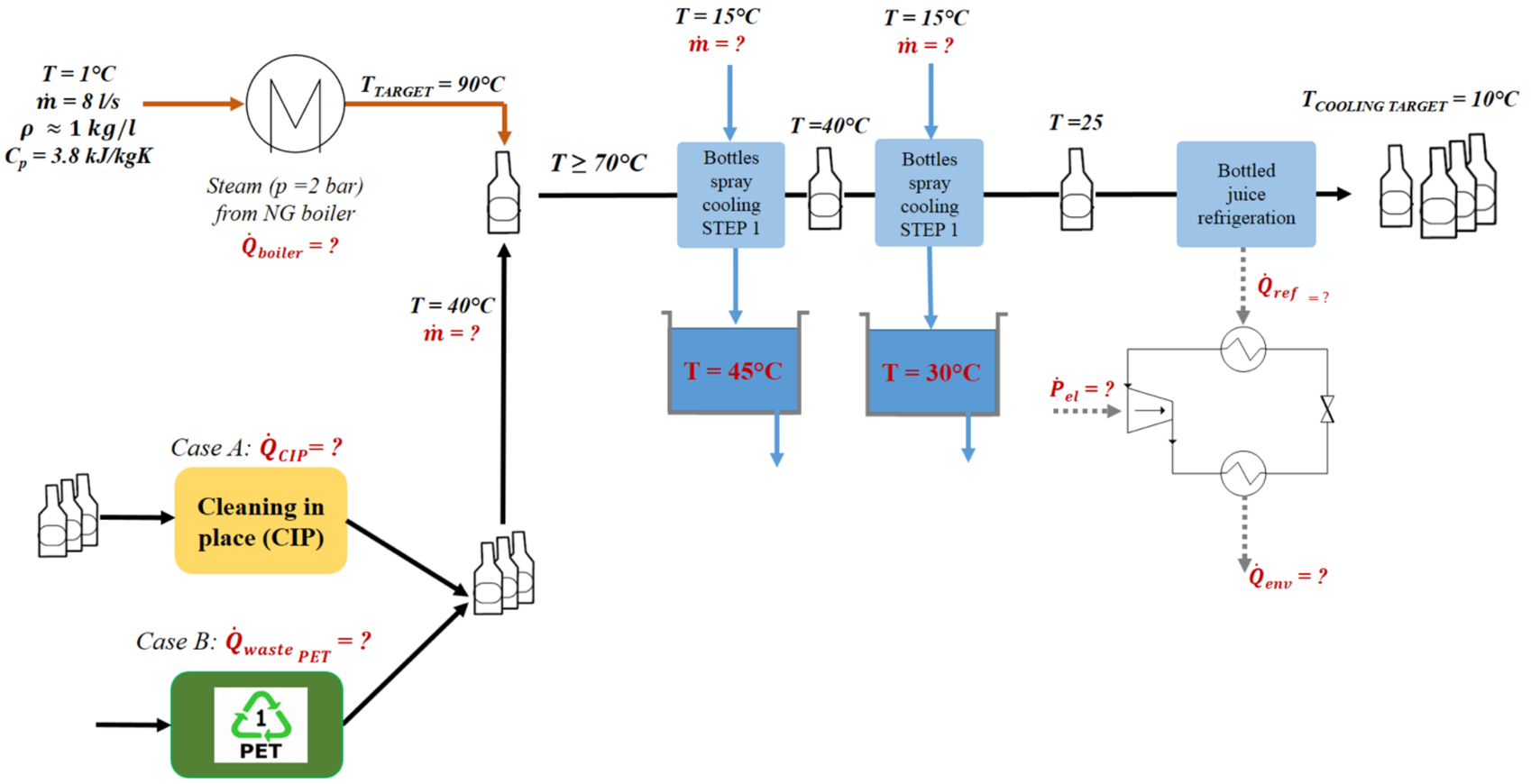
Case study

An investor wants to integrate a syrop production facility next to a city. In the cider production facility there is an existing bottling process which makes use of recycled glass bottles

The investor would like to investigate the following questions:

- How to mitigate the CO2 emissions and the energy and water usage related to the process?
- Is there a possibility of using renewable energy sources ?
- Are there possibilities of industrial symbiosis e.g. use of waste biomass, sharing the waste water treatment plant with the village or by developing a district heating?
- Is it better to recycle the glass bottles (case A) or should he consider investing in a PET bottle production facility from polyethylene pellets (case B)?
- Any possibility on-site production of the CO2 used in the factory

The process


T = 1°C
ṁ = 8 l/s
ρ ≈ 1 kg/l
C_p = 3.8 kJ/kgK
T_TARGET = 90°C
Steam (p =2 bar)
from NG boiler
Q̇_boiler = ?
T = 40°C
ṁ = ?
Case A: Q̇_CIP = ?
Cleaning in place (CIP)
Case B: Q̇_waste PET = ?
1
PET
T ≥ 70°C
T = 15°C
ṁ = ?
Bottles spray cooling STEP 1
T =40°C
T = 15°C
ṁ = ?
Bottles spray cooling STEP 1
T =25
Bottled juice refrigeration
T_COOLING TARGET = 10°C
T = 45°C
T = 30°C
Q̇_ref = ?
Ṗ_el = ?
Q̇_env = ?

Organisation

- Grading of the lecture
  - Write a report on the application
- Slides are available on moodle
- Big thank to the team
  - Eduardo Pina
  - Wen du