The potential of digitalisation
Energy and Sustainability

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EPFL Valais-Wallis
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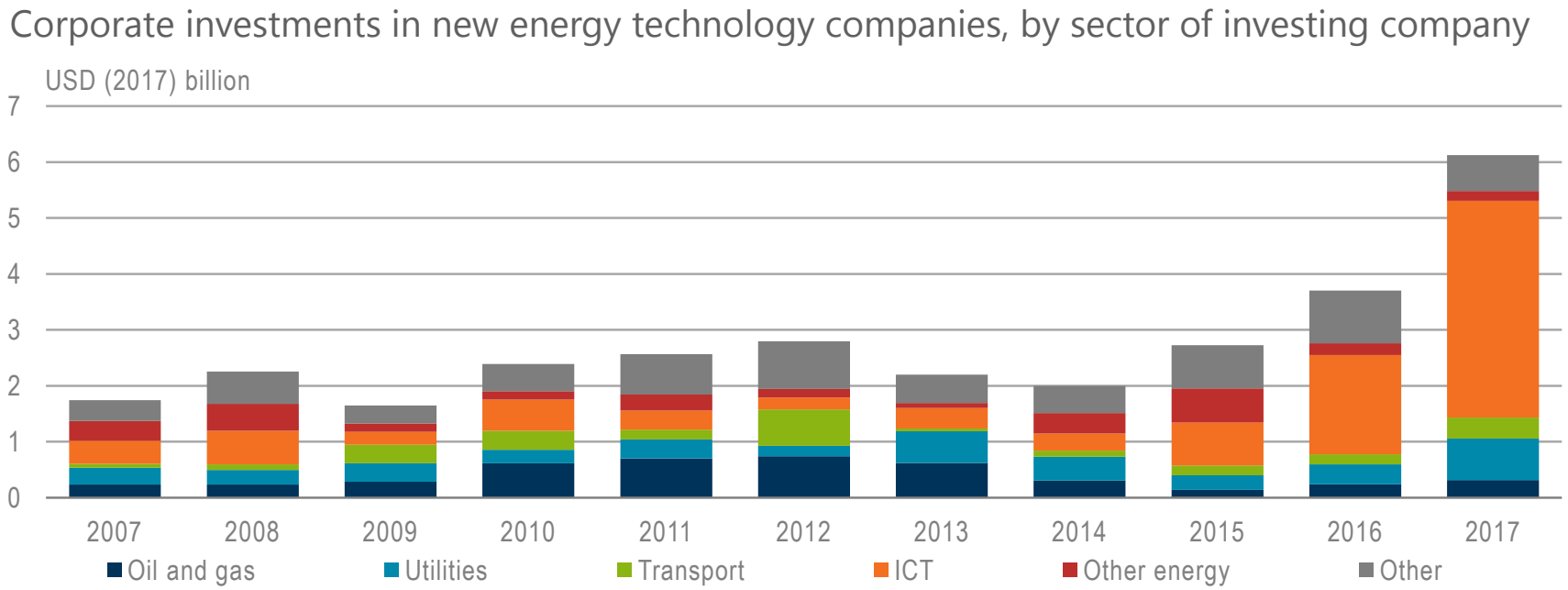
Importance of digitalisation in the energy sector

Companies invest more in energy tech startups, led by ICT sector



Corporate venture capital and growth equity for energy tech startups reached USD 6 billion in 2017; companies are taking strategic positions in a changing energy system, digital firms above all others.

world energy investment 2018, IEA.org

Energy efficiency and digitalisation

$$[kJe_{saved} / kJe_{used\ in\ ICT}] = 5$$

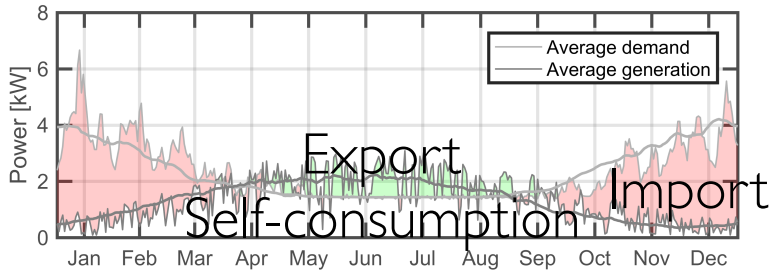
Market = 400 b$

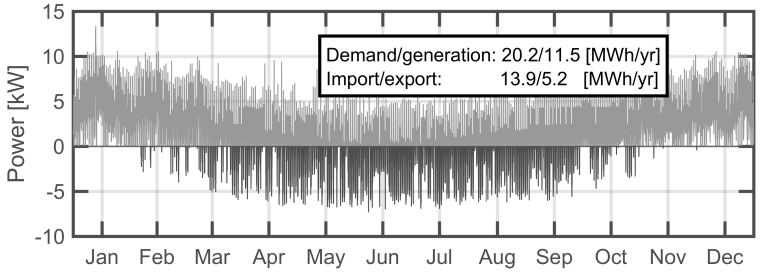
15.2 PWh

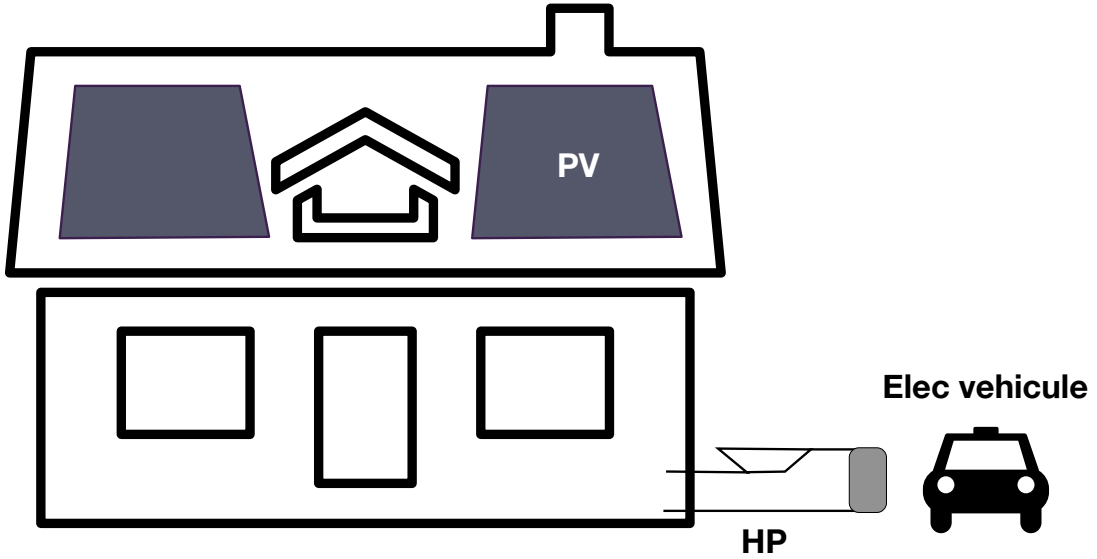
around 10 % of total

Change levers	Power	Transportation	Manufacturing	Service & consumer	Agriculture & land use	Buildings
Digitalization & dematerialization		• Videoconferencing • Telecommuting		• E-commerce • E-paper • Online media		
Data collection & communication	• Demand management • Time-of-day pricing	• Eco-driving • Real-time traffic alerts • Apps for intermodal transportation • Asset sharing/crowd sourcing		• Public safety/ disaster management • Smart water	• Soil monitoring/ Weather forecasting • Smart water • Livestock management	
System integration	• Integration of renewables • Virtual power plant • Integration of off-grid renewables & storage	• Integration of EVs • Intelligent traffic management • Fleet management & telematics				• Integration of renewables • Building management system
Process, activity & functional optimization	• Power-load balancing • Power grid optimization	• Optimization of truck route planning • Optimization of logistics network	• Optimization of variable-speed motor systems • Automation of industrial processes	• Minimization of packaging • Reduction in inventory	• Smart farming	• Building design • Voltage optimization

Adapted from GESI Smater report 2020, 2014





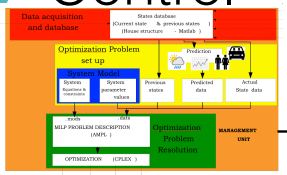


Prediction

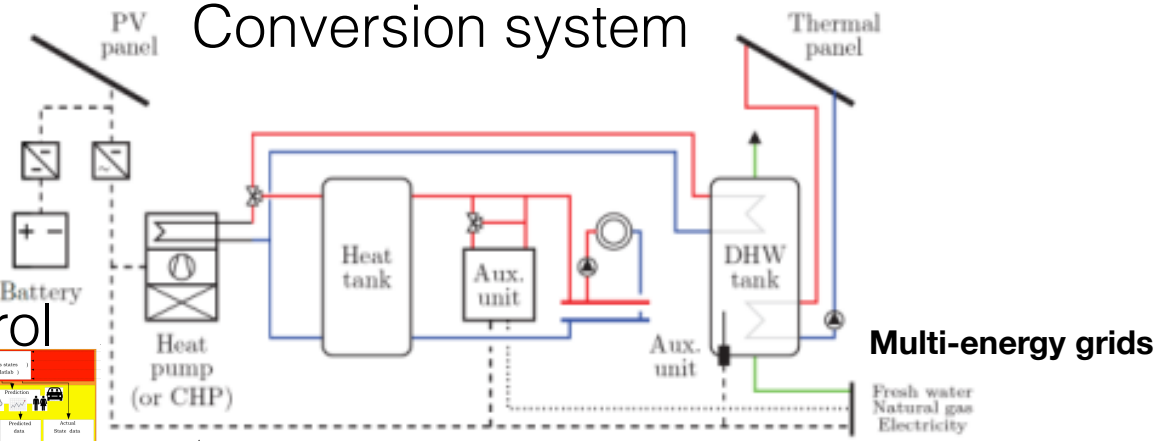
Pooling

Grid Market

Control



Conversion system



Multi-energy grids

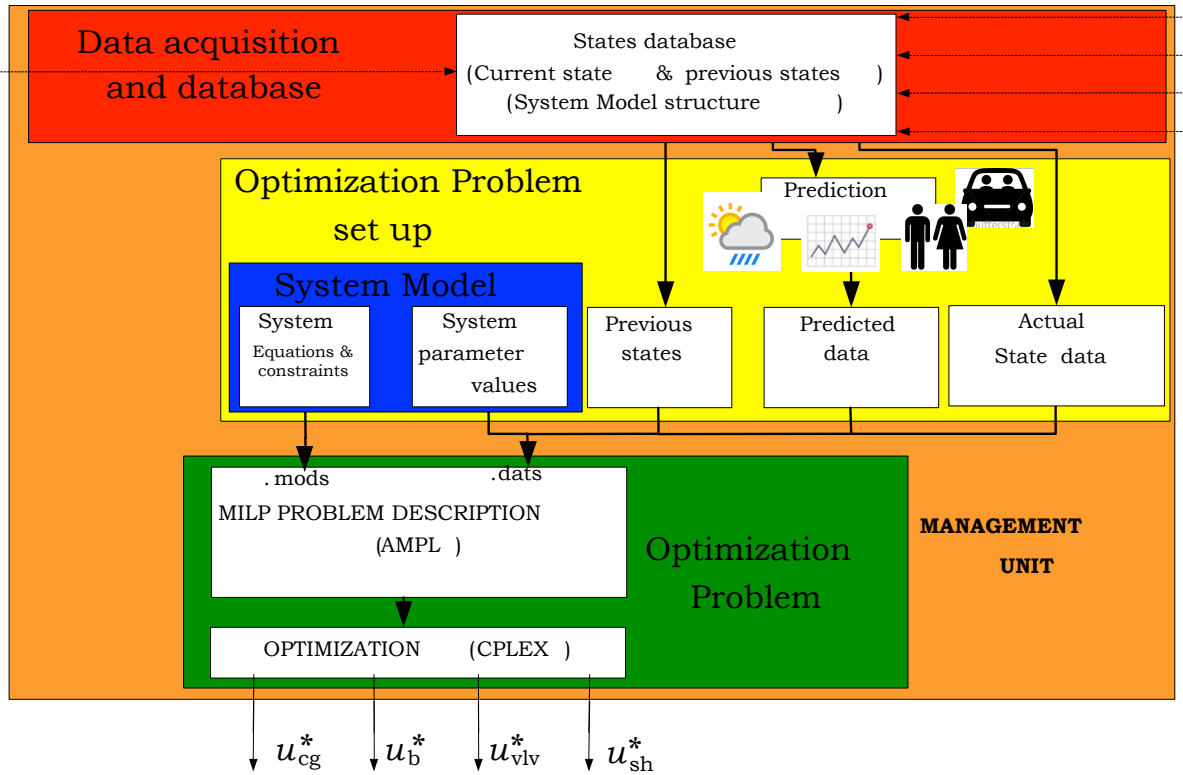
Investment

Model predictive strategic control

Real time Market

Tariff info

Grid connexions



Sensors

T_{in}
T_{ext}
T_{sh}
T_{dhw}

System state

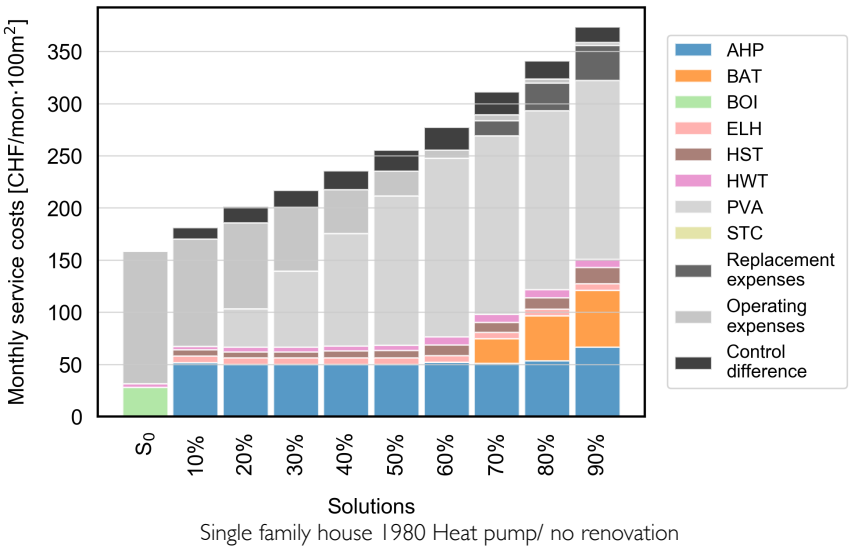
Prediction

Optimisation

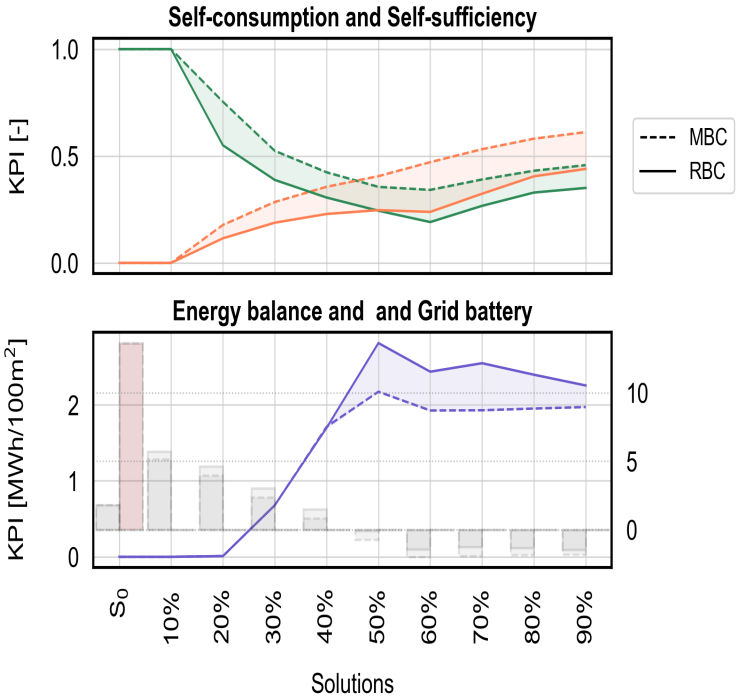
Operation set-points

Collazos et al., Computers and Chemical Eng. 2009

Integrative design : operation and investment



Single family house 1980 Heat pump/ no renovation



Multi stakeholders : Users - Investors - Utilities

- CAPEX : +180 CHF/month/100 m2 (i.e. + 4% real estate value (geneva, CH))
- OPEX : -100 CHF/month of Oil avoided (50 $/bbl)
- Grid : 45% of electricity exported but Zero-Energy

System flexibility : smart houses/ processes are free battery

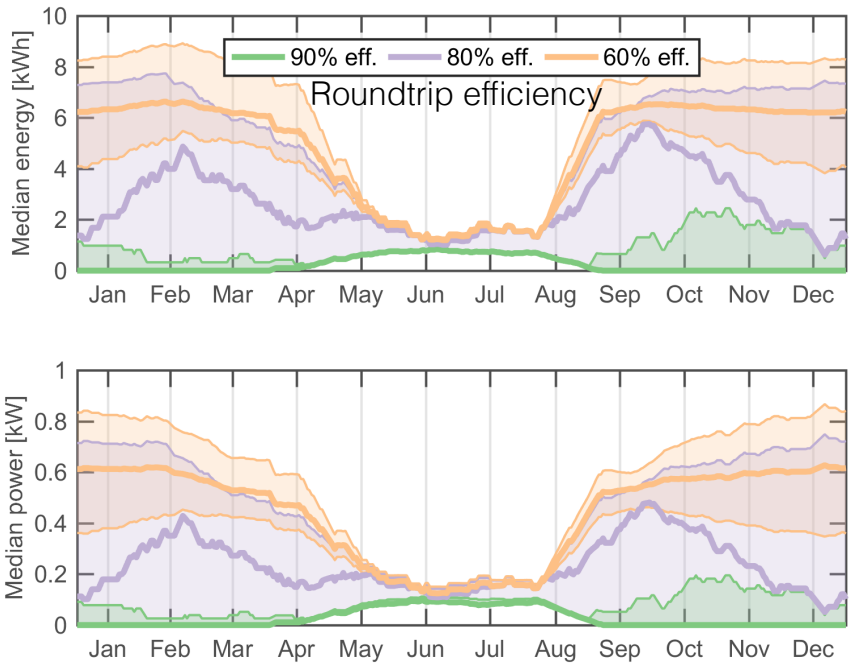
Building performance (solution I)

Ind.	Value (imp/exp/gen)
E [MWh]	34.8 / 00.0 / 00.0
H [MWh]	00.0 / 00.0 / 00.0
COP [-]	3.00

Building energy system design (solution I)

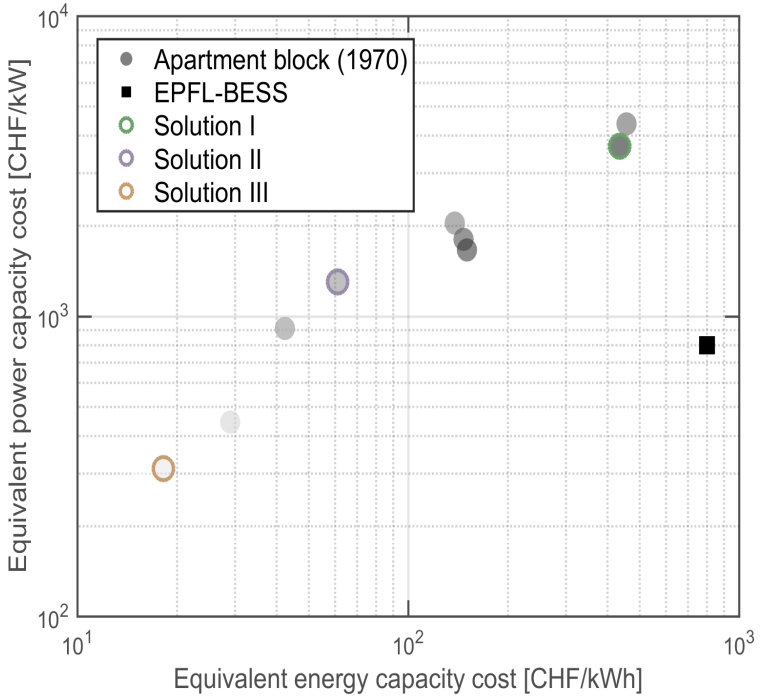
Unit	Size	
Heat pump	**7.0**	kW_e
Battery	0	kWh_e
Boiler	0	kW_{th}
Water tank	**0.22**	m^3
Electric heater	**14**	kW_e
Heat tank	**1.0**	m^3
Photovoltaics	0	kW_p
Solar thermal	0	m^2
SOFC-CHP	0	kW_e

Offered stored energy and power by the system



Annual equivalent battery performance

Equivalent Battery

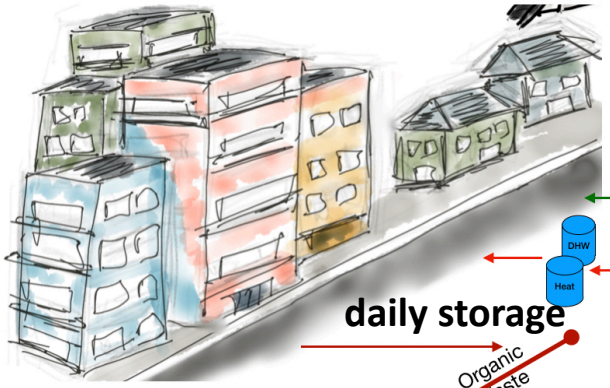


Equiv. Battery : cost 0
Power max = 1 hour
Energy = 30% Mean cons
Roundtrip = 1.0 - 0.95

The system can deviate on demand from forecasted operation

- Installed power is an asset for the grid
- Real time Exchange is the key => Blockchain

System level integration : micro grids



Decentralised systems

PV

Infrastructure

DHW

Heat

HP

daily storage

Electricity

Gas

Organic Waste

Cogen

Waste management

Power2Gas

SOEC

Electricity

Supply chain

Organic Waste

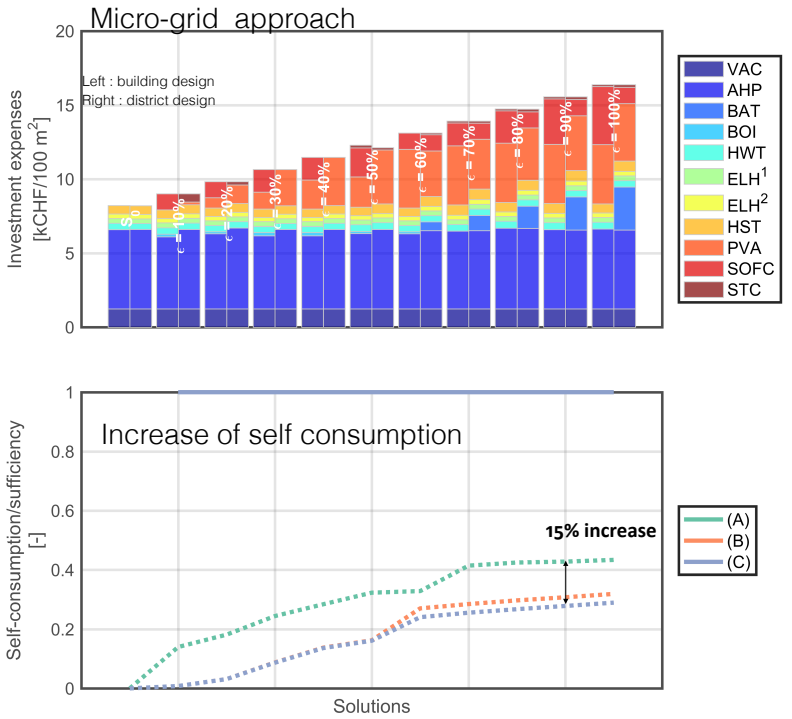
SNG

Gas

Gas

Seasonal storage

Centralised systems



Stochastic users

Equipment pool

Operators

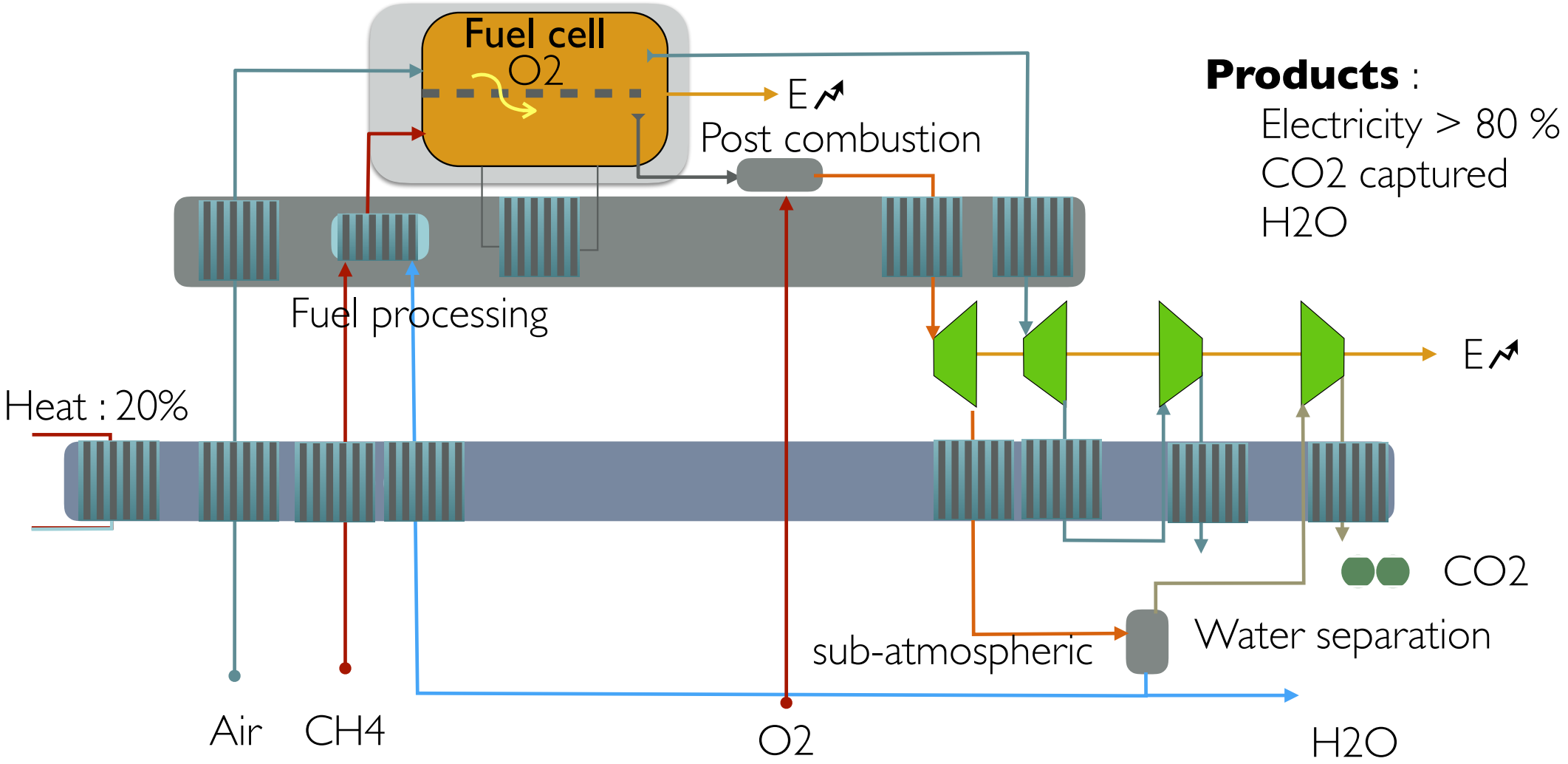
Remote monitoring

Remote control

Intermittent resources

Storage

Decentralised electricity with advanced Fuel Cell System



Facchinetti, M, Daniel Favrat, and Francois Marechal. "Sub-atmospheric Hybrid Cycle SOFC-Gas Turbine with CO2 Separation." *PCT/IB2010/052558, 2011.*

Challenges : process development

Right size - Right place - Right time

- Process manufacturing
  - 3D printing of processes
  - Pipeless systems
  - Supply chains integration
  - Factories of factories :
    - scaling by numbers vs by volume

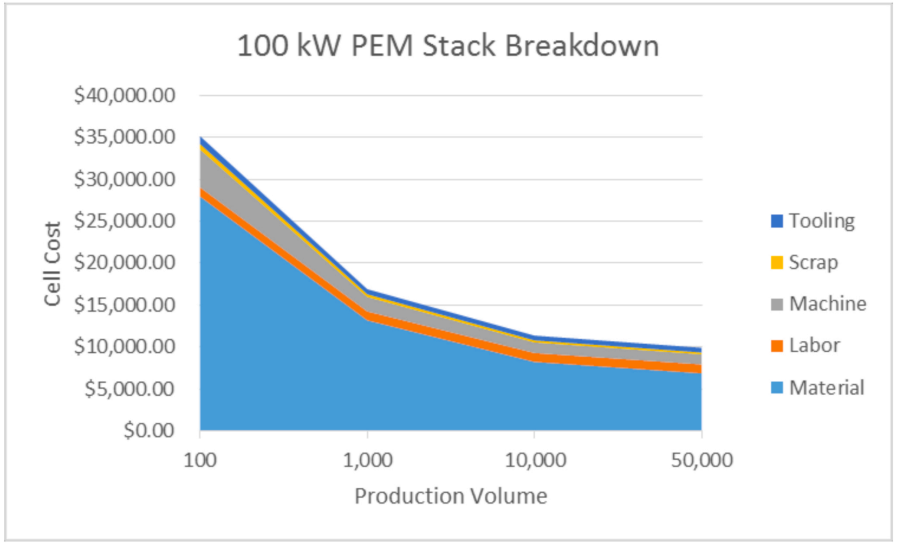


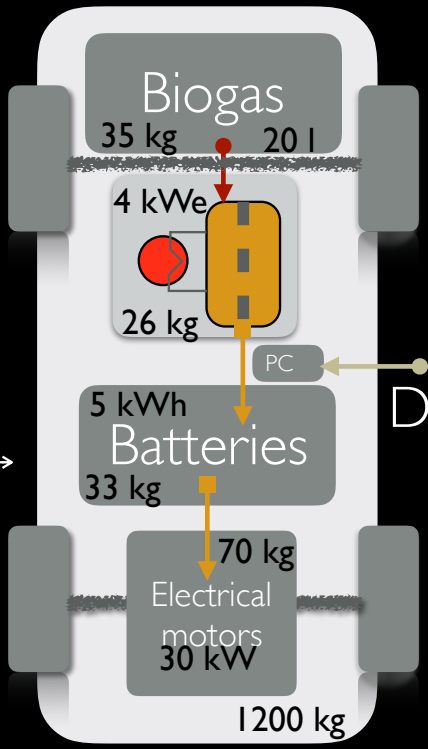
Figure 5-4. Breakdown of 100 kW system – 60 kW fuel cell costs and production volume trends.

Battelle Memorial Institute, 2016

AUTONOMOUS SYSTEMS ?

Driving mode

Autonomy : 950 km
Cons : 1.1l/100 km

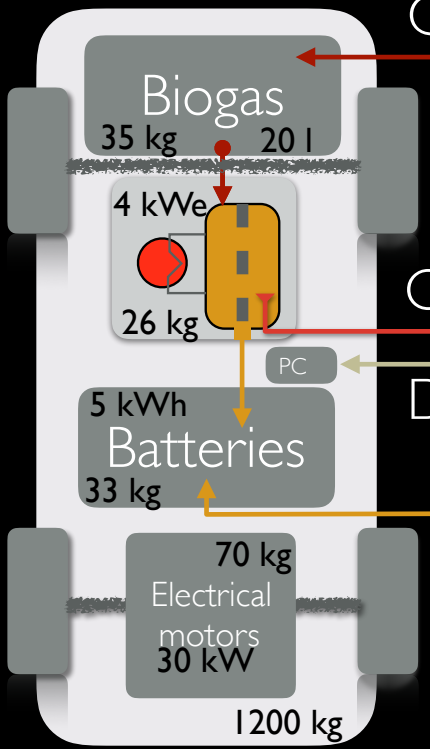


Data Grid

SOFC-GT
Hybrid car

Parking mode

Power plant : 3.5 kWe (eff. >70%)
Battery : 5 kWh

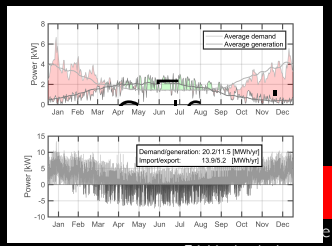


Gas Grid

CO2 Grid

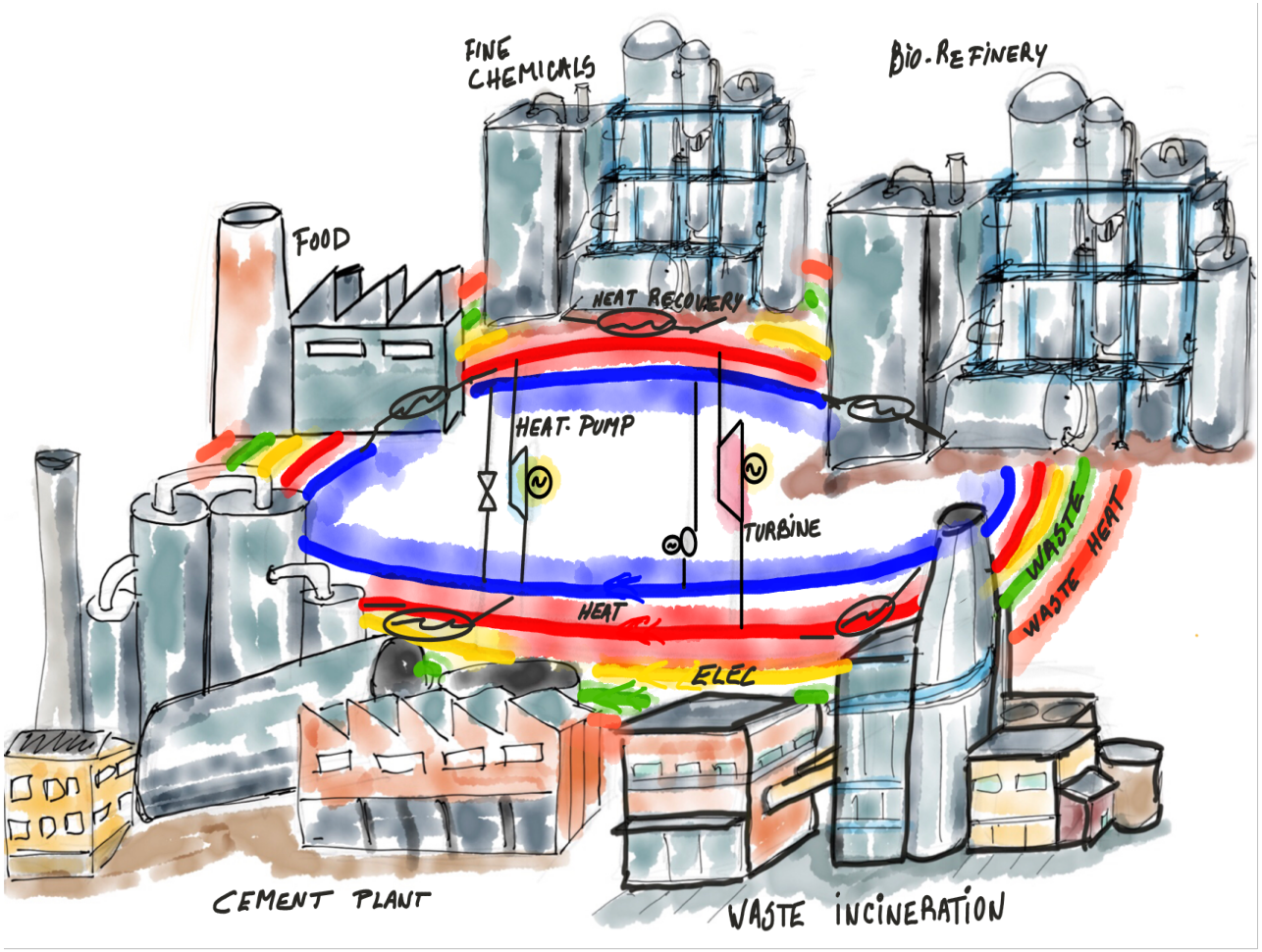
Data Grid

Micro
El. Grid



Dimitrova, Zlatina, and François Maréchal. "Environomic design for electric vehicles with an integrated solid oxide fuel cell (SOFC) unit as a range extender." *Renewable Energy* 112 (2017): 124-142

Industrial system integration : circular economy



Heat and mass (waste) exchanges

- Heat recovery
- Heat pumping
- ORC and steam Rankine cycle
- Energy and water integration
- Waste management
- Resource efficiency
- Industrial Symbiosis
- Combined fuel and heat

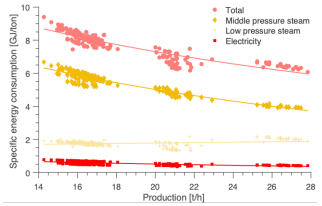
What can I share ?

Digitalisation

Reference: Siemens magazine, 2018

analyse energy consumption

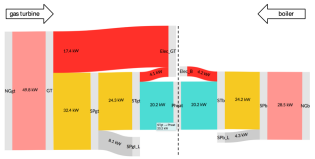
→ energy sources
energy consumption trend
+energy baseline



- Process data management
- Data reconciliation
- Performance models (AI)

Define the main energy drivers

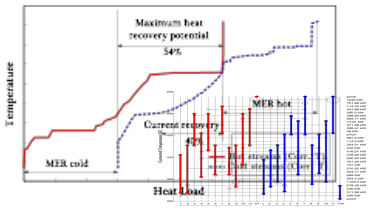
→ energy consumption breakdown
influencing factors



- Benchmarking
- Visualisation
- Reporting

Target the energy savings options

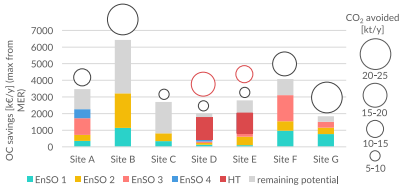
→ optimal energy needs
optimal operation



- Optimisation
- Process modeling
- Virtual reality
- Process control
- Cost Estimation

characterize & prioritise energy savings options

→ Portfolio of energy savings options



- Uncertainty
- Business models
- Key performance indicators
- Targeting-monitoring
- Life cycle impact

Optimal strategic operation of process

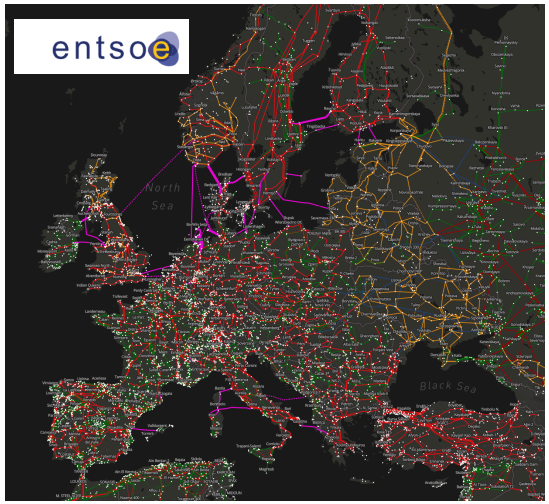
Application example: **batch process** in Switzerland

- 5 production lines
- 2 final products (A and B)
- 2 raw materials and 5 intermediates

Subject to constraints of final products delivery quantities and dates

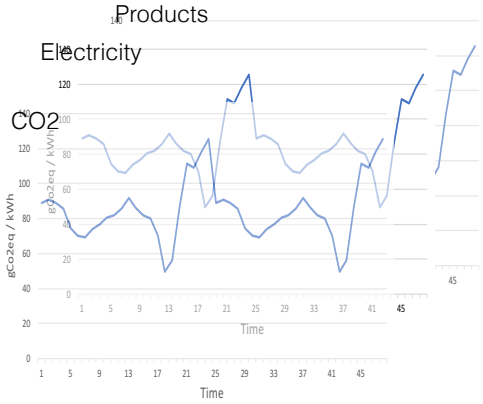
CO2 emission forecast for next two days based on the ENTSOE data base

Transparent data base

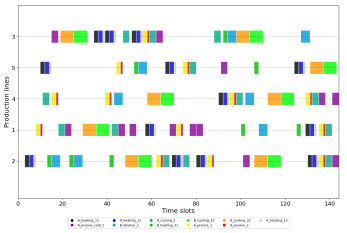


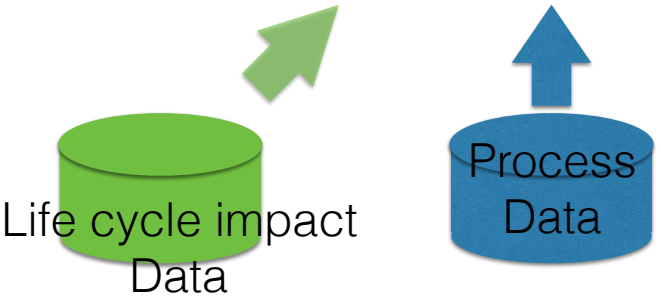
https://www.entsoe.eu/data/map/

Predictions



Model based Optimal scheduling



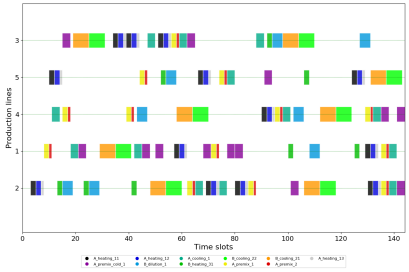


optimal predictive strategic operation

Status of inventory+ equipment

Market predictions

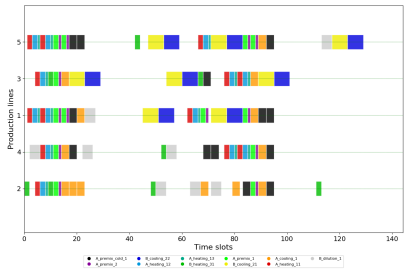
50 hours ahead prediction



Minimisation of the energy consumption

Utility market

Electricity consumption [MWh]	Operating cost [EUR]	CO2 emissions [kgCO2eq]
32.3	745.5	958.5

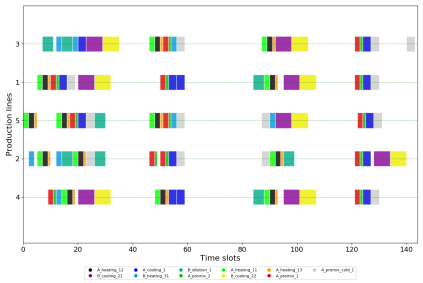


Minimisation of the operating cost

Electricity market

Electricity consumption [MWh]	Operating cost [EUR]	CO2 emissions [kgCO2eq]
32.3	640.1	870.2

-14.2 %



Minimisation of CO2 equivalent emissions

CO2 market

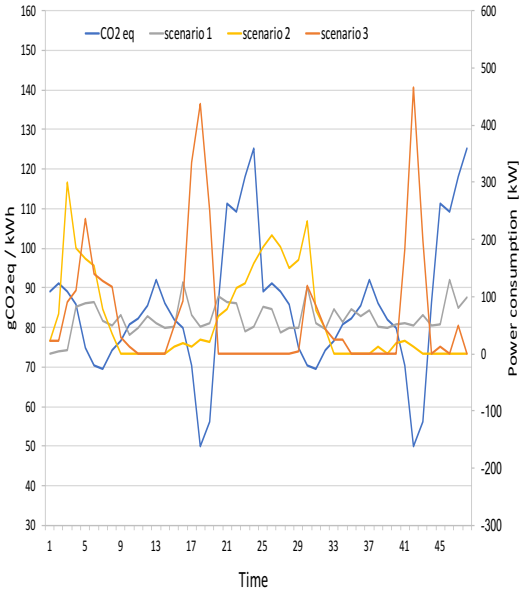
Electricity consumption [kWh]	Operating cost [EUR]	CO2 emissions [gCO2eq]
32.3	747.5	690.0

-27.9 %

Blockchain

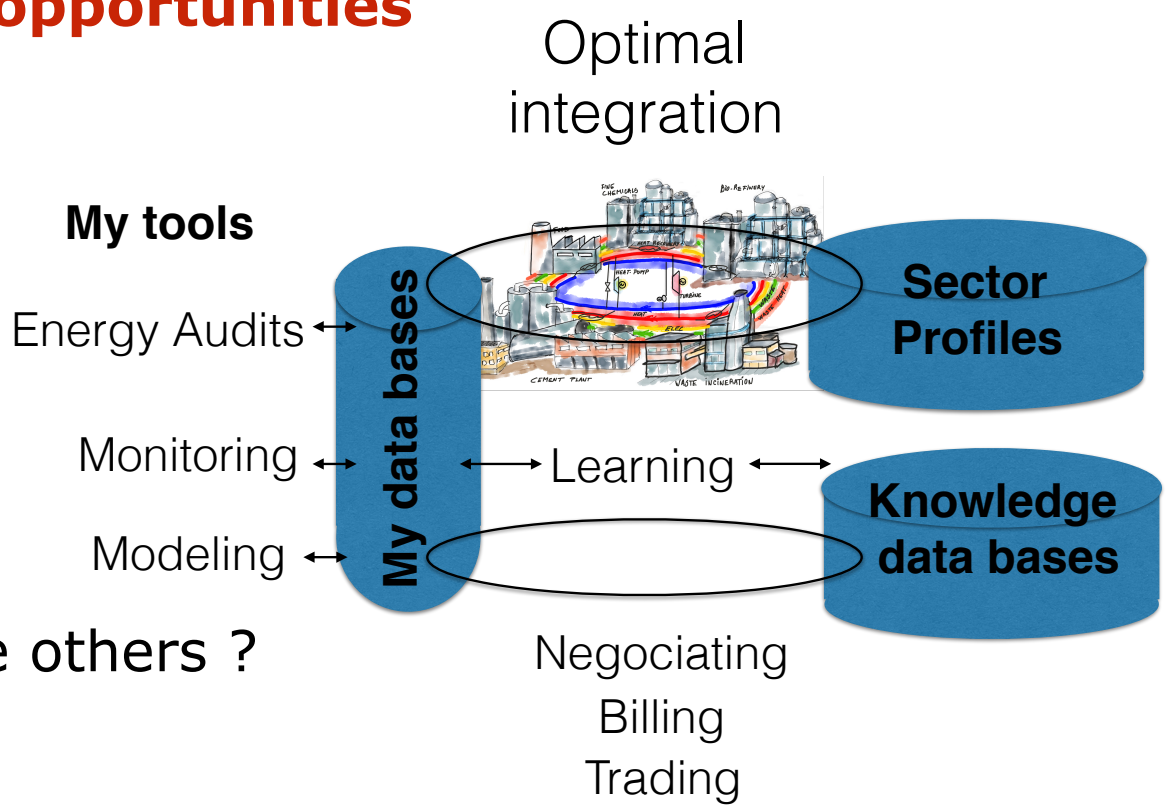
Strategic planning

different presence on the grid



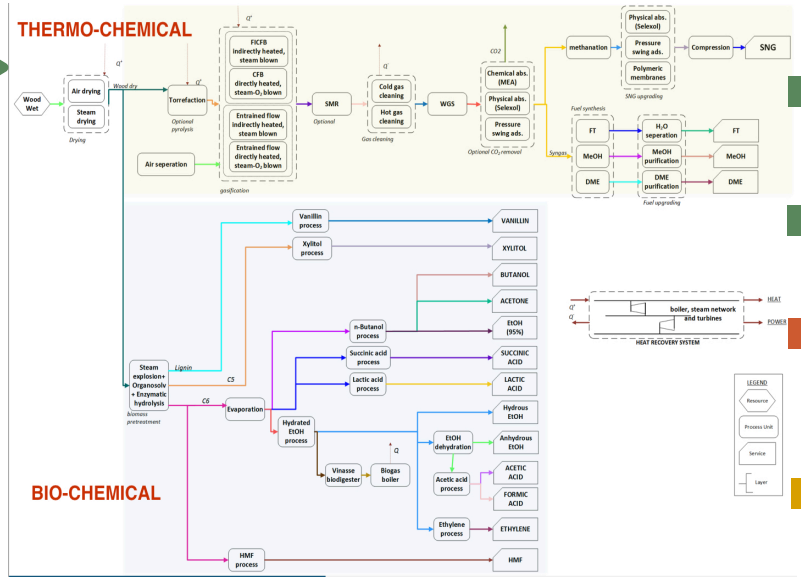
Industrial symbiosis digitization challenges

- **System integration : identify opportunities**
  - What can I share ?
  - With whom ?
  - For which profit ?
- **System operation**
  - What is my status ?
  - What are my predictions ?
  - What are the predictions of the others ?
- **Billing**
  - What have been the flows exchanged ?
  - Blockchain technologies ?



Biorefineries : digitalisation challenges

Biomass

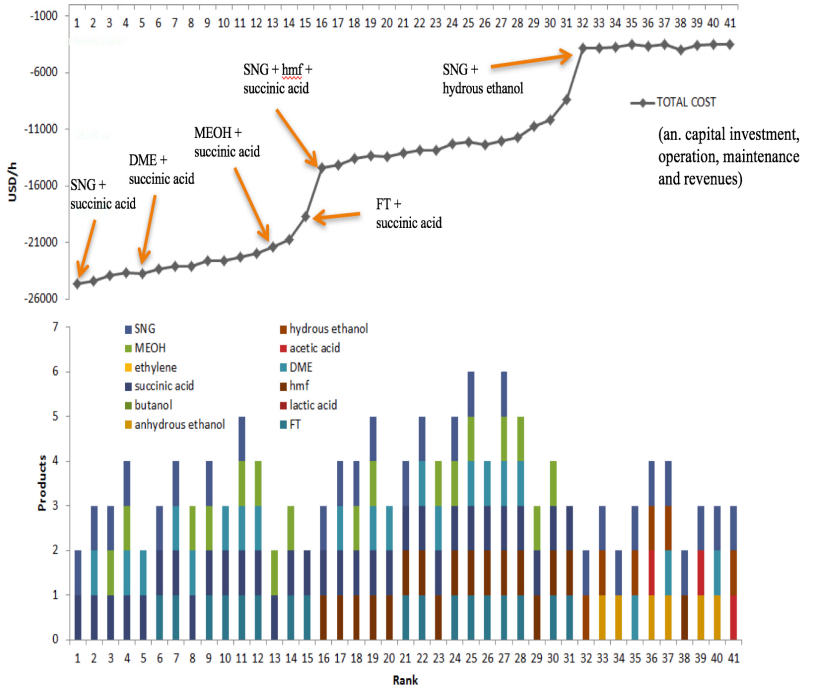


Bioenergy

CO2

Bioproducts

Electricity



Process design

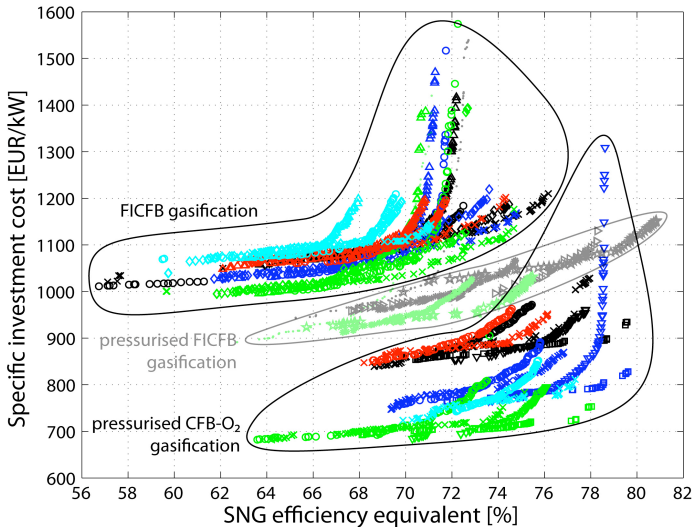
- Process / technology model data bases
- Screening techniques
- Knowledge based design techniques
  - Group contribution methods
  - Artificial intelligence

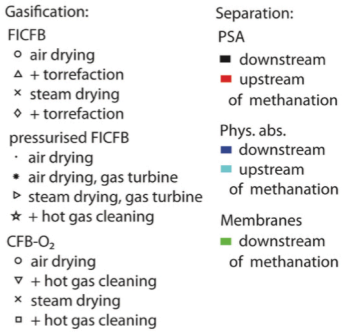
Supply chain integration

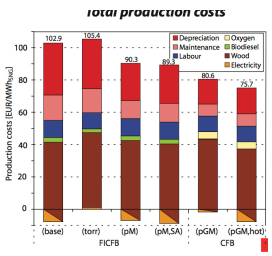
- Availability of ressources
- Needs of products
- Size of integrated production
- Flexible processes
- Remote control and automation

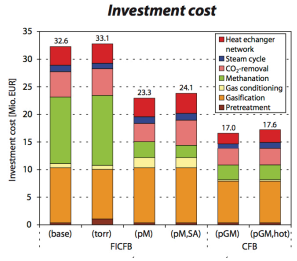
Systematic method for process system design options

Wasting 1.5 years of computation time stored in one paper ?









Digitalisation

Open Data

Shared data base

Shared models

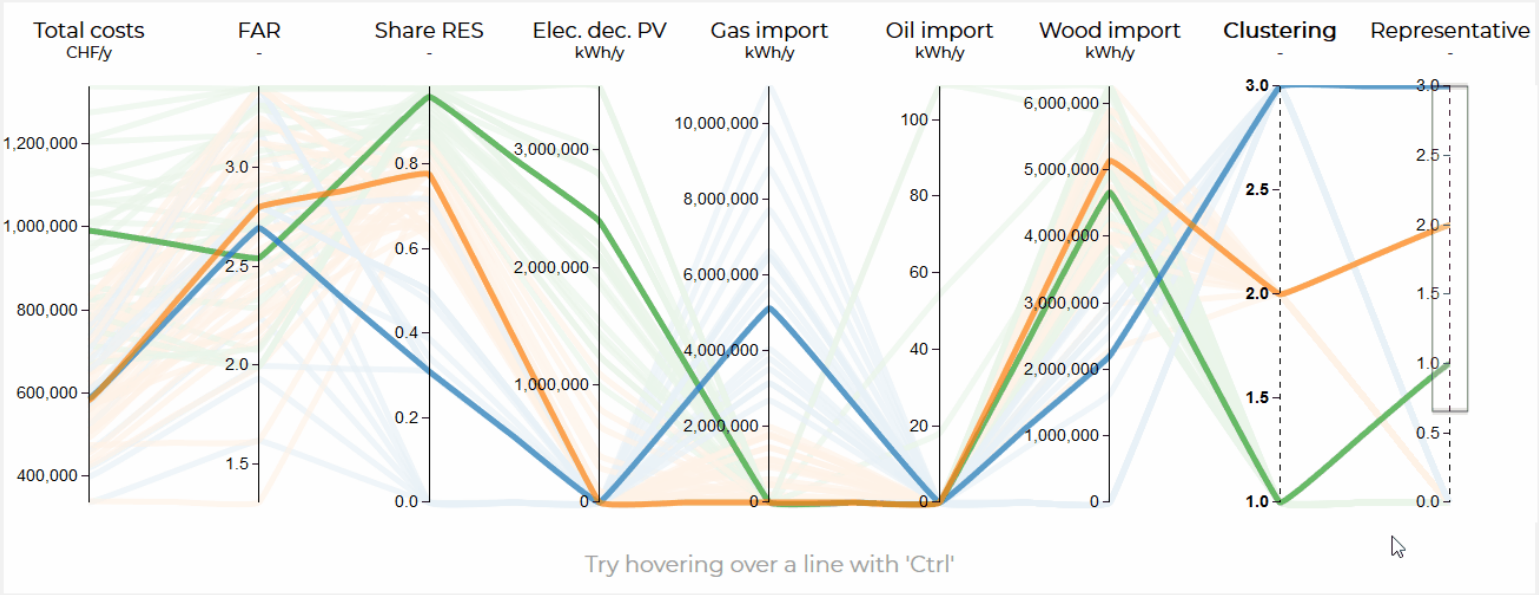
Artificial Intelligence

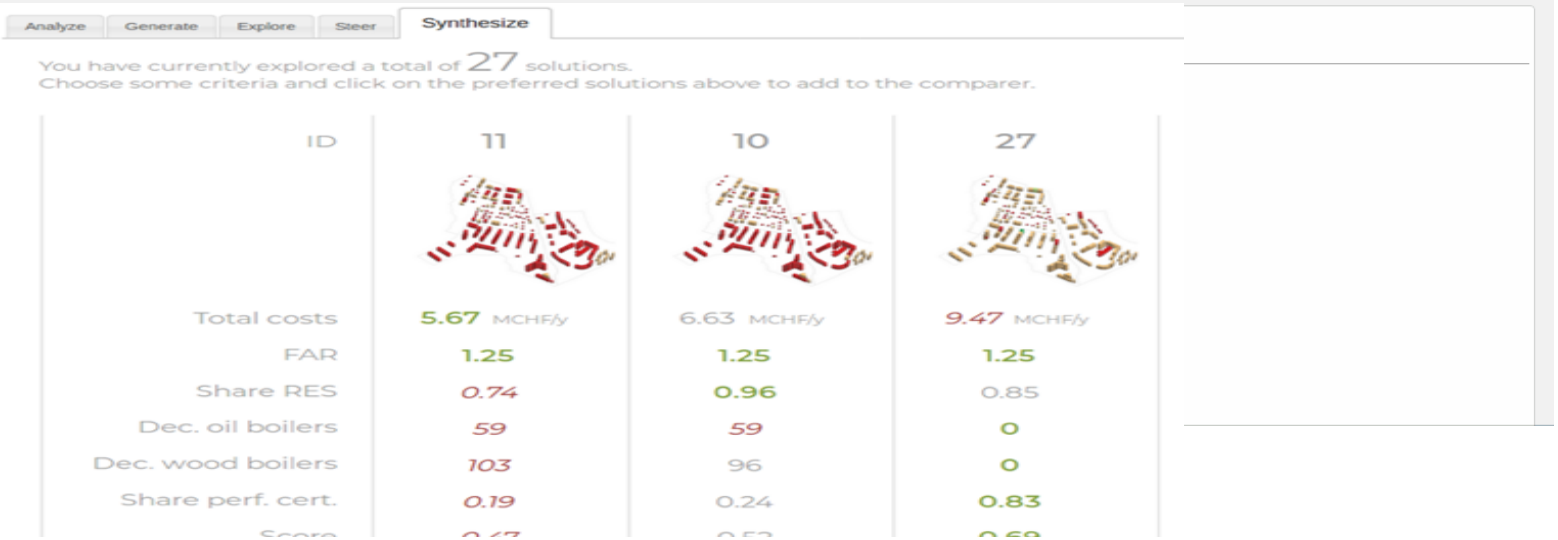
- Knowledge (open & transparent) data bases of processes (process models)

  Develop surrogate models (e.g. Pareto sector profiles)

Gassner, Martin, and François Maréchal. *Energy & Environmental Science* 5, no. 2 (2012): 5768 – 5789.

Digitalisation for decision support





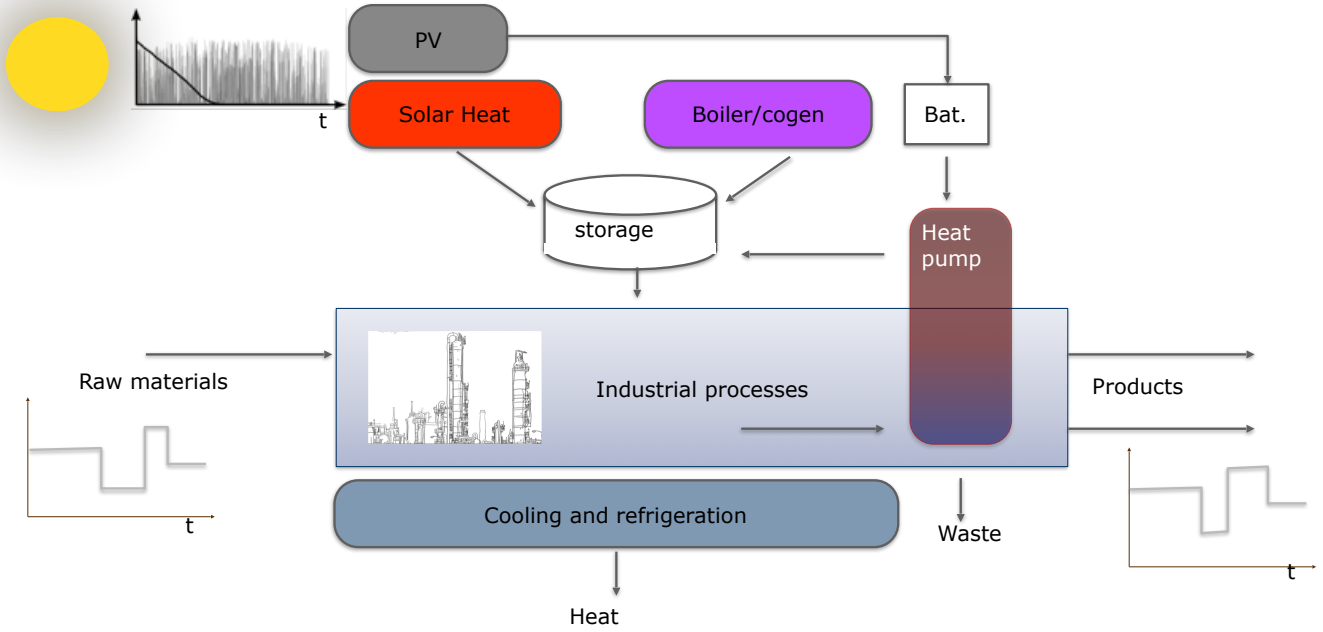
Solutions generator using optimisation techniques

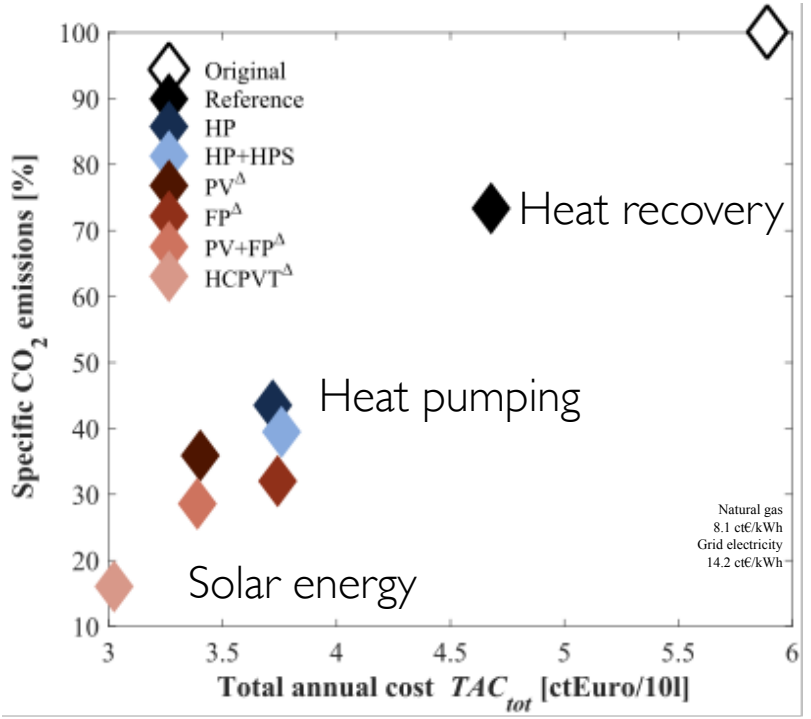
Solutions Browser
KPI modeling
Artificial Intelligence

Solutions Report
Multi-criteria
Multi-stakeholders

urbio.ch

Integrating solar energy in industrial processes





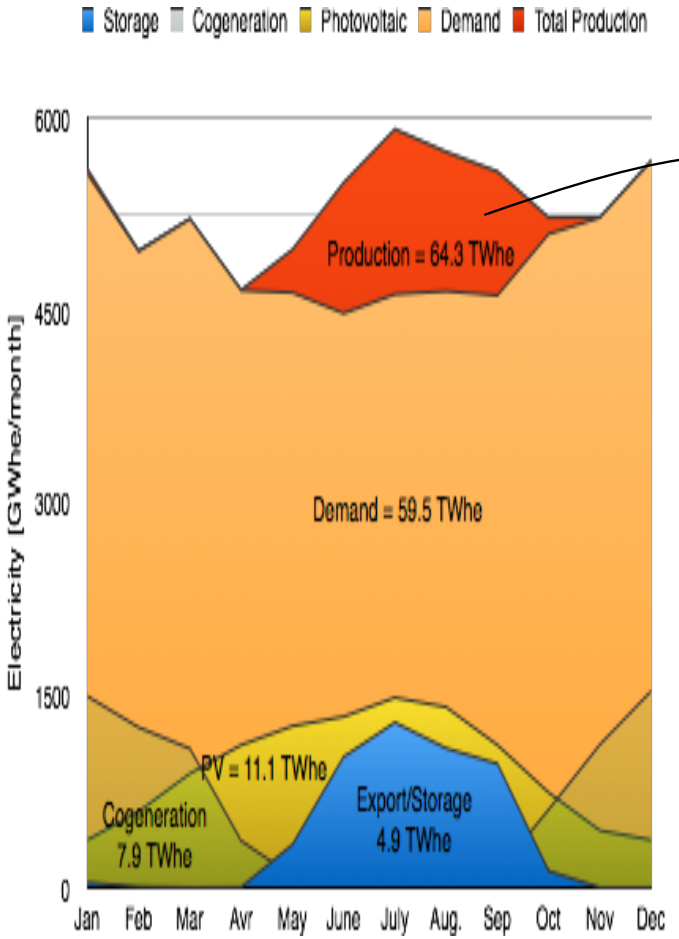
Multi-energy system
=> flexibility assets
=> MPC

Wallerand, Anna S., et al. "Optimal design of solar-assisted industrial processes considering heat pumping: Case study of a dairy." *Renewable Energy* (2017).

Industry is part of the renewable energy system !

Combined heat, fuel and storage

SNG : Synthetic Natural Gas



Summer

WOOD
100 $MW_{th, dry}$

Production SNG

170 MW SNG

38 MW Useful heat

37 MW Waste heat

Fuel

Industry

City

Electricity
145 $MW_{th, dry}$

H2
123 $MW_{th, dry}$

CO_2 (108 kg CO_2 avoided / MWh wood)

Winter

WOOD
100 $MW_{th, dry}$

SNG production

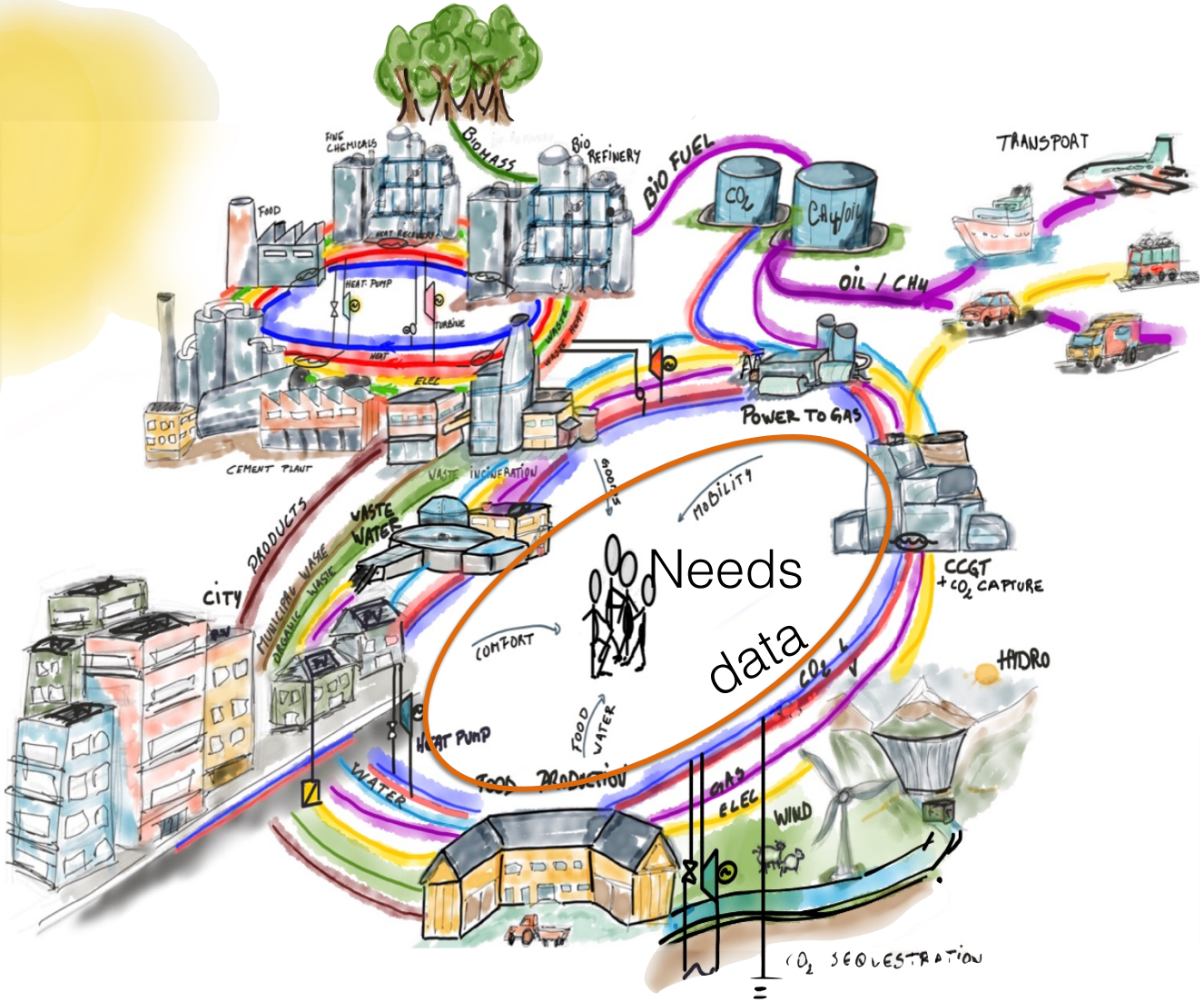
67.5 MW SNG

15.7 MW Useful heat (200 °C)

16.8 MW Waste heat

1.4 MW net electricity

Integrated Circular Systems



Needs

- Big data

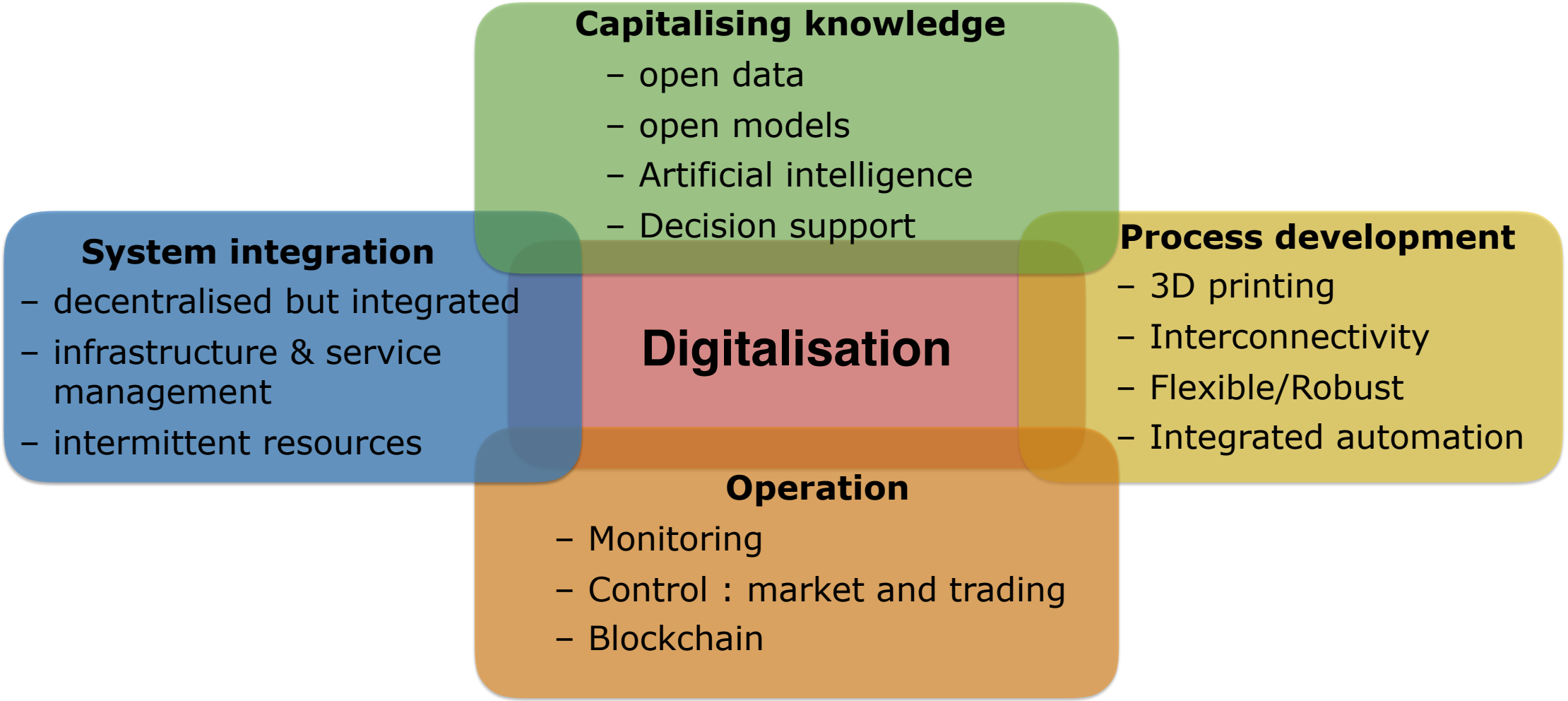
Multi-Energy infrastructure :

- operation
- planning

Business

- Resources
- Energy
- Water
- Waste

Challenges of Digitalisation for energy and environment



iets
Industrial Energy-Related Technologies and Systems
An Implementing Agreement established under the auspices of the International Energy Agency

For those interested :

IETS Annex XVIII
Digitalization, Artificial Intelligence and Related Technologies for Energy Efficiency and GHG Emissions Reduction in Industry

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