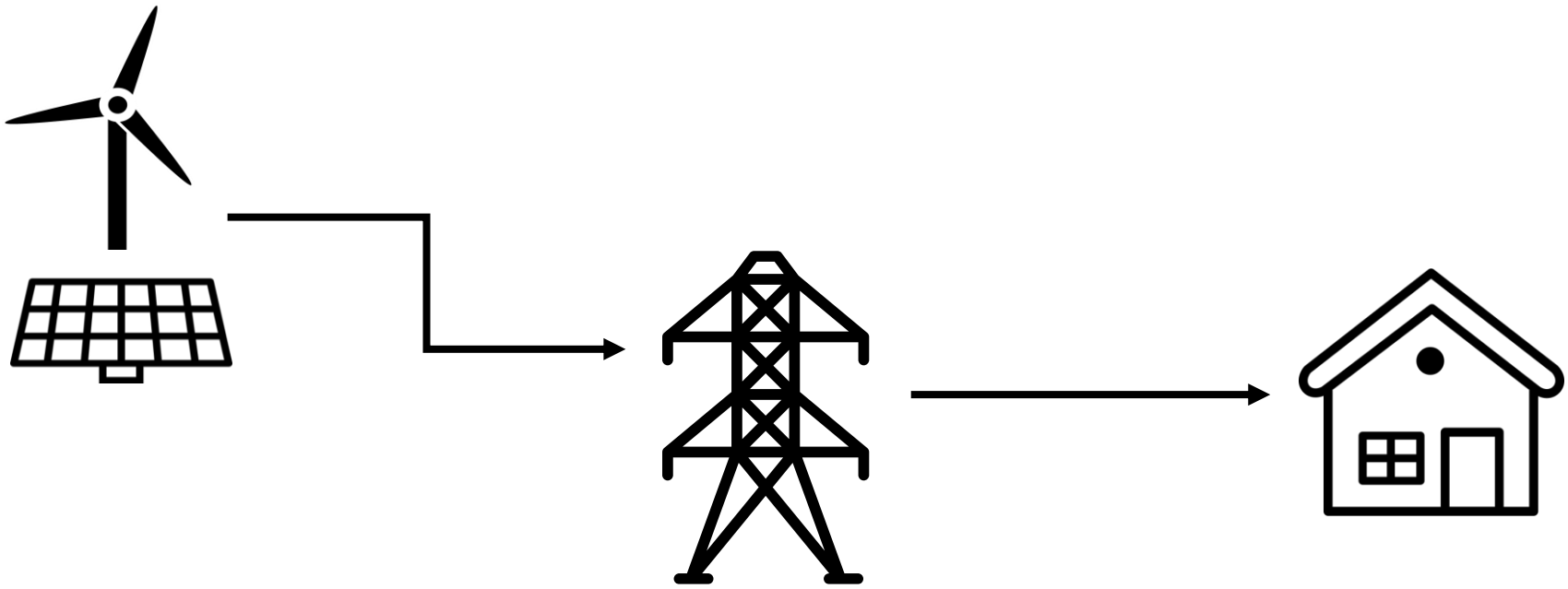
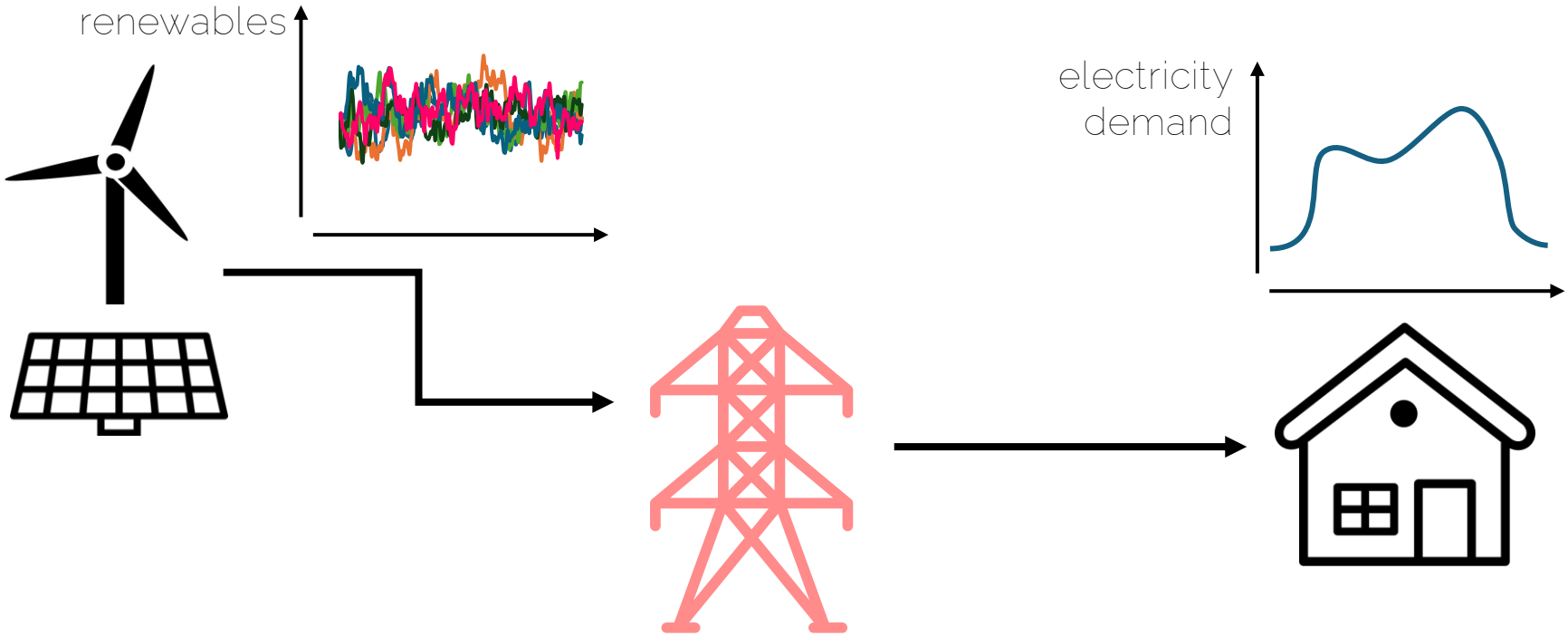
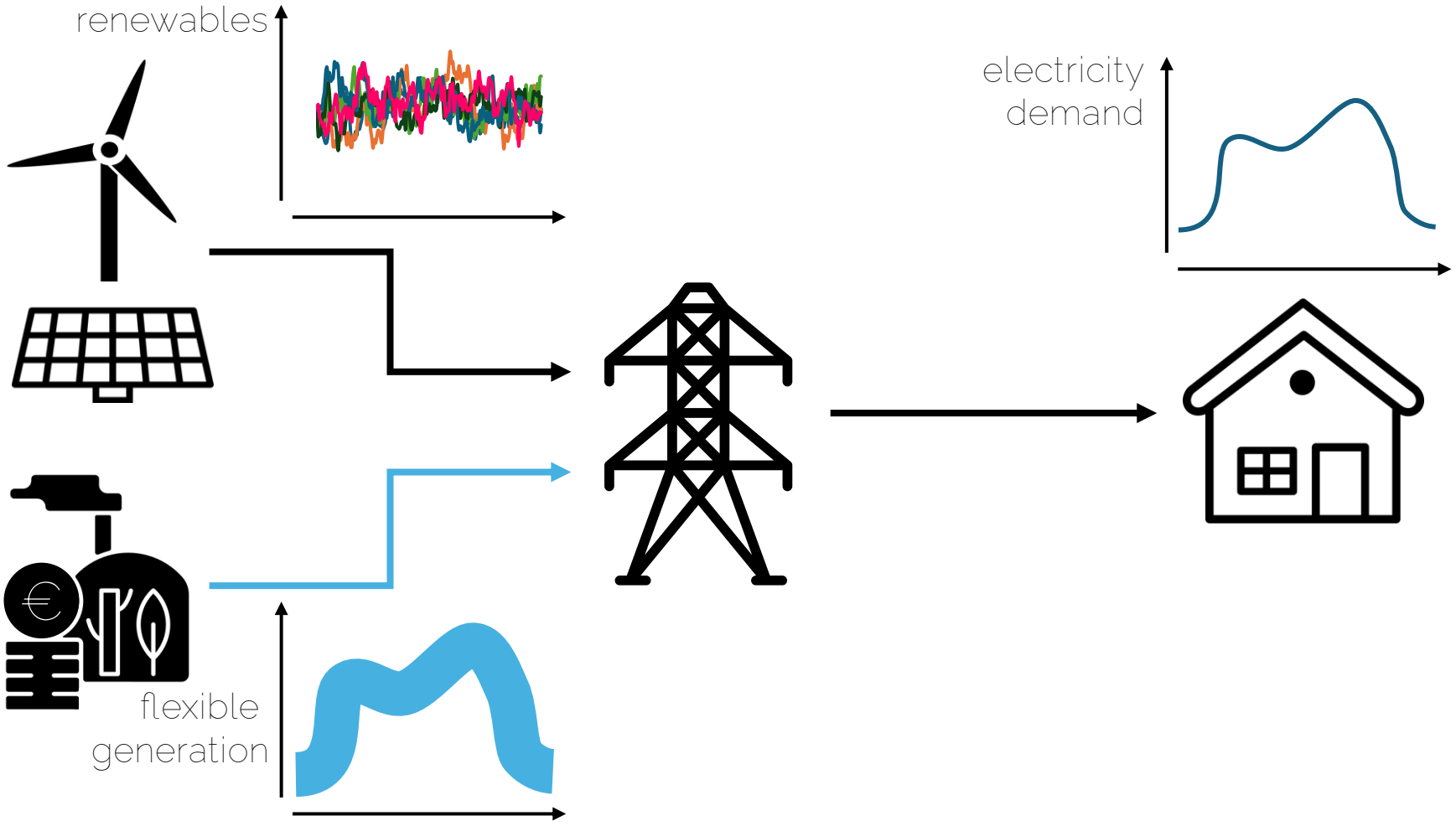
Renewables help us to reach net zero emissions



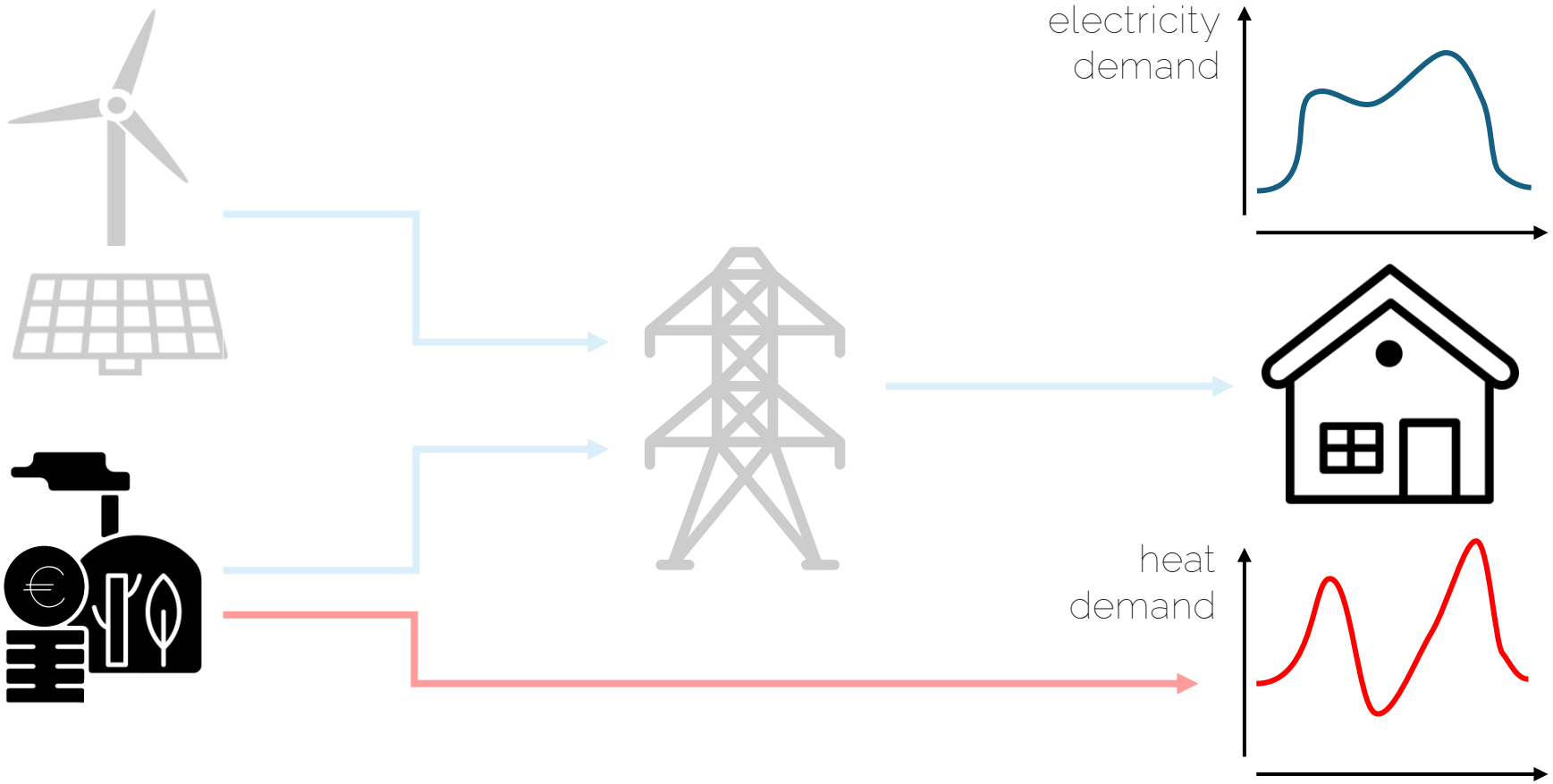
Transition towards net zero emissions is hindered by uncertainties



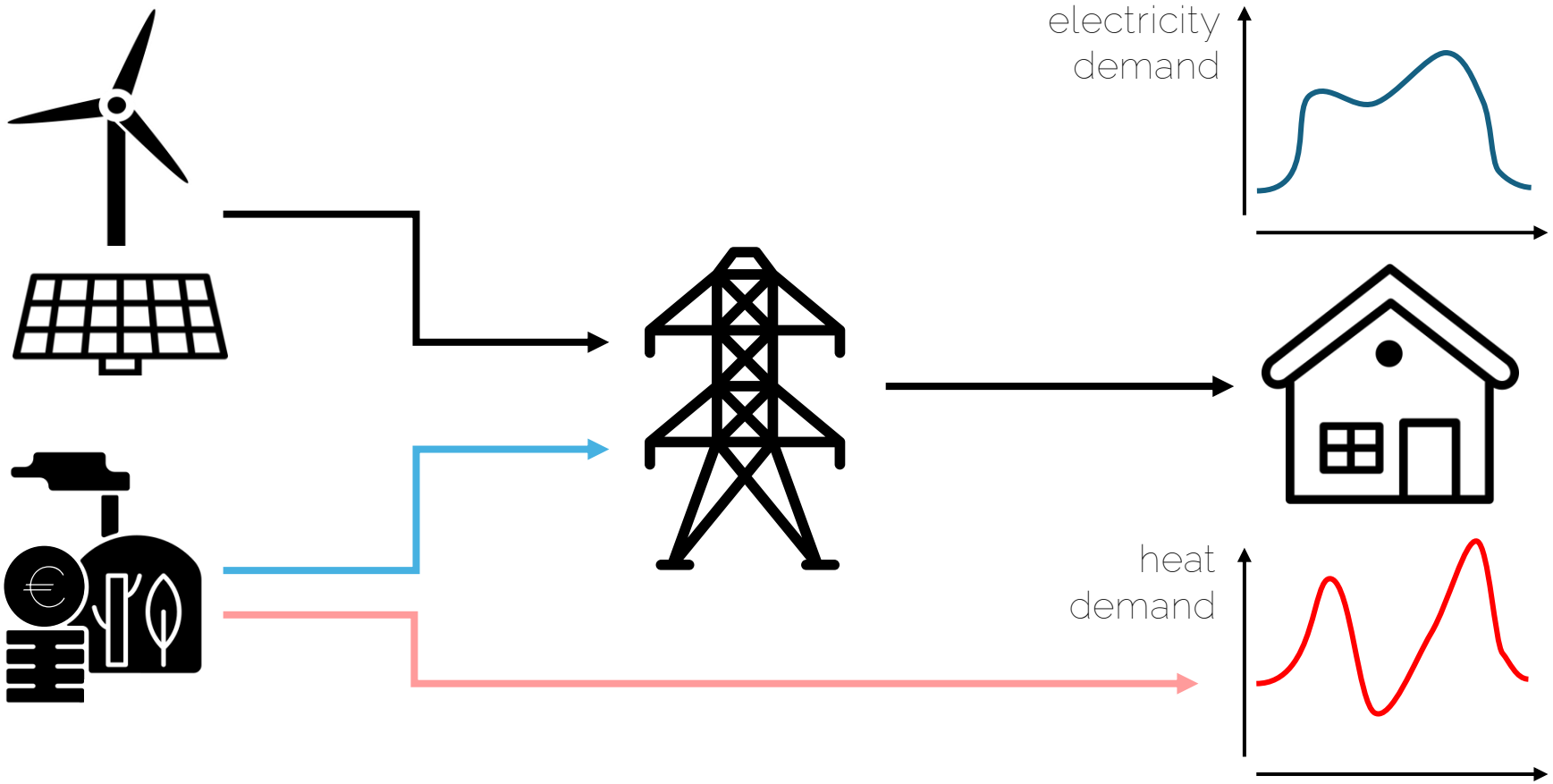
Transition towards net zero emissions induces the need for flexible power generation



Combined heat and power plants can satisfy the heat demand of local buyers



Combined heat and power plant provide flexibility in electric and heat networks



FLEX-CHP

The contribution of biomass- and waste-fired CHP's
to the security of supply and the stability
of the electrical grid in Belgium

VUB VRIJE UNIVERSITEIT BRUSSEL

2VALORISE

ENTRAS

The contribution of biomass- and waste-fired CHP's to the security of supply and the stability of the electrical grid in Belgium

The contribution of biomass- and waste-fired CHP's to the security of supply and the stability of the electrical grid in Belgium

From 2Valorise

From Wikipedia

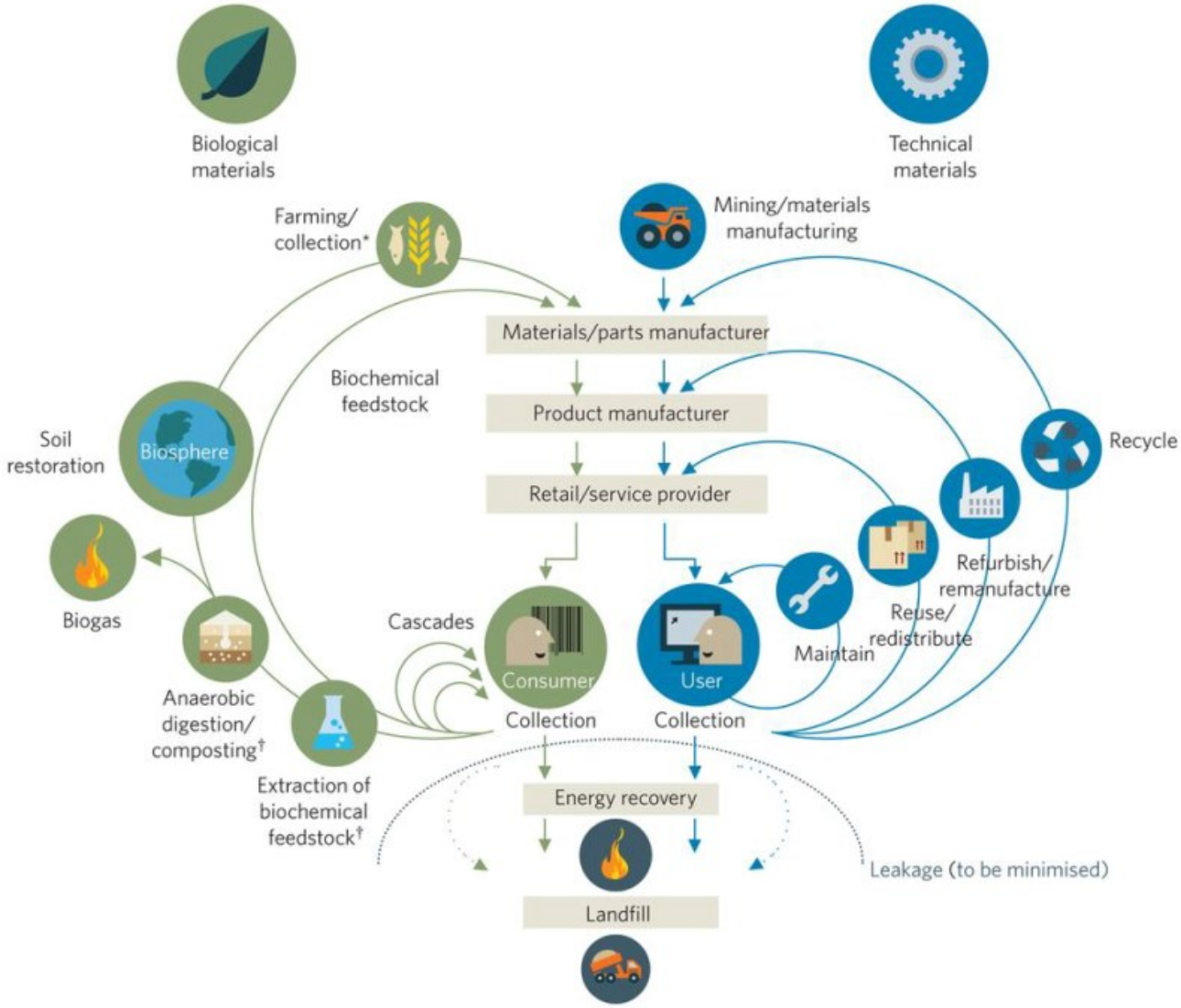
The contribution of biomass- and waste-fired CHP's to the security of supply and the stability of the electrical grid in Belgium

" One man's trash is another man's treasure"

From 2Valorise

From Wikipedia

General philosophy: "we need to use less and recycle more, as the best waste is no waste"



How much biomass and waste will there be available in the future in Belgium?

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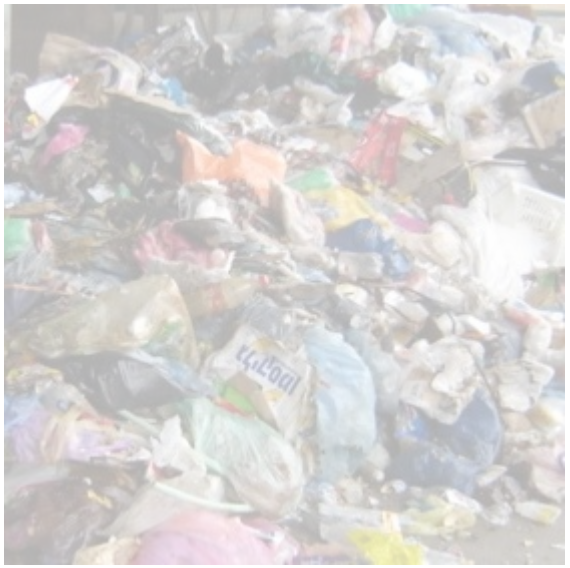
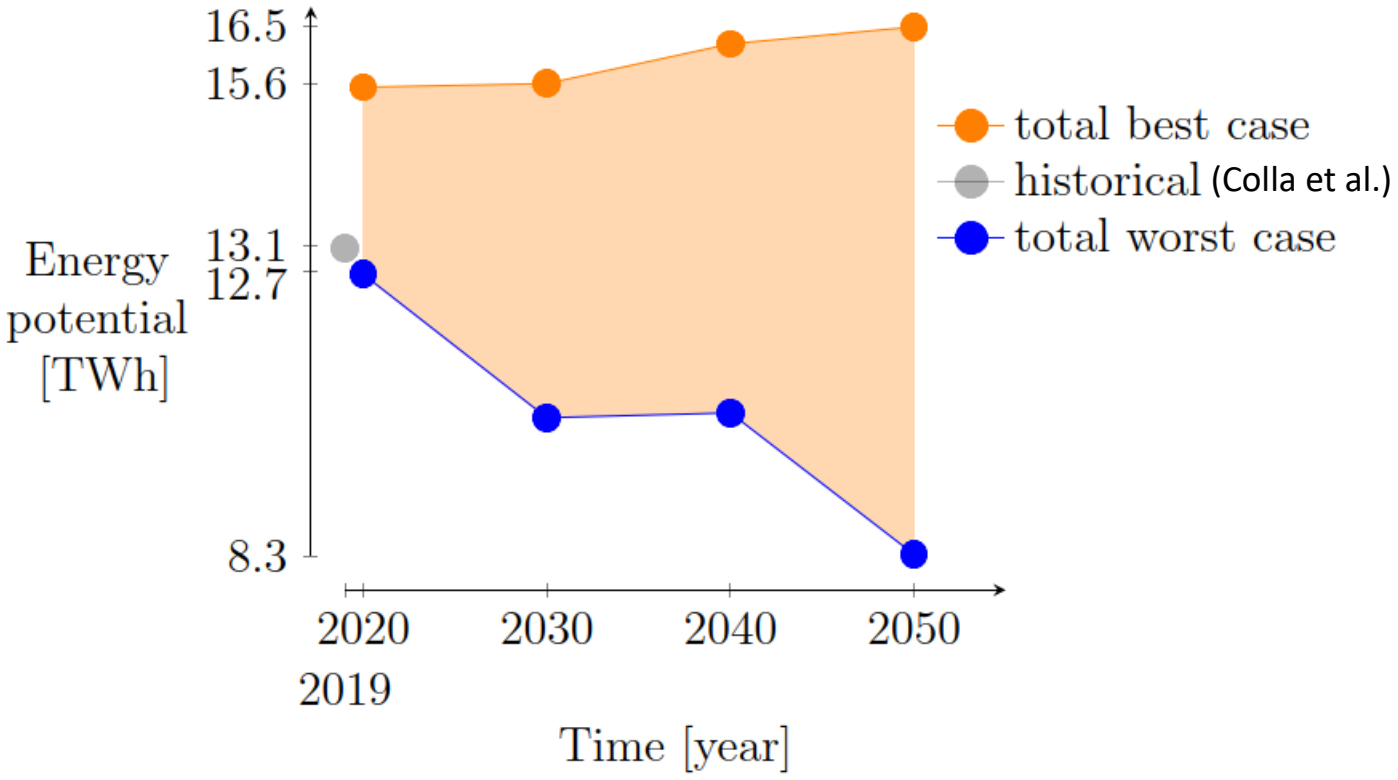
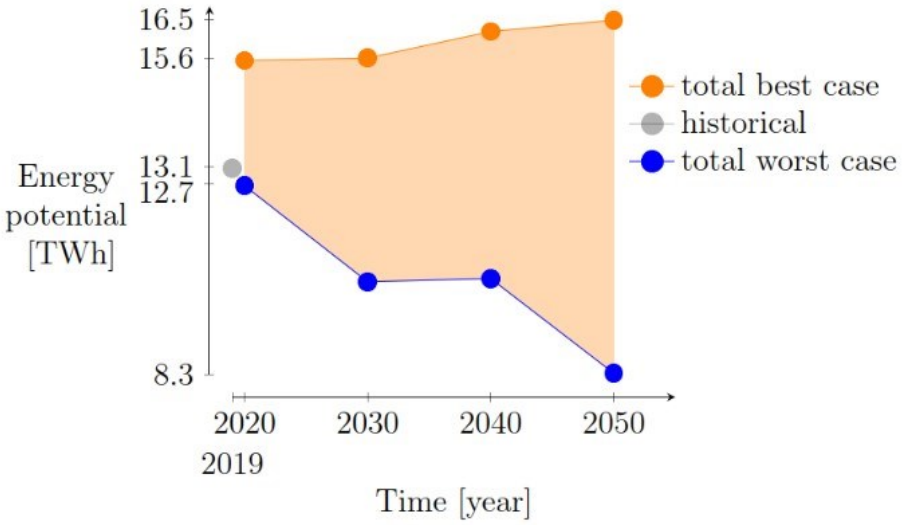
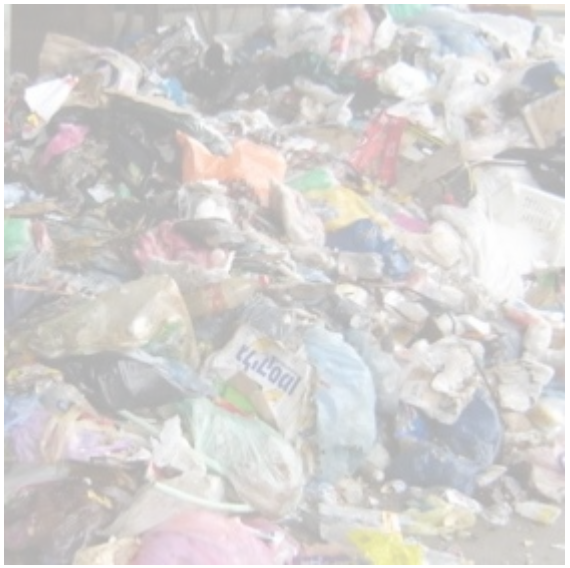


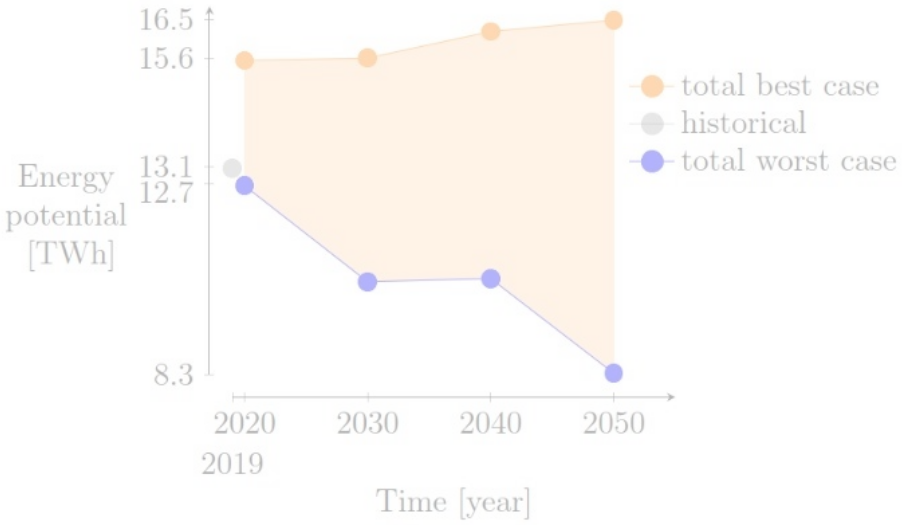

16.5
15.6
13.1
12.7
8.3
Energy potential [TWh]
2019
2020
2030
2040
2050
Time [year]
total best case
historical (Colla et al.)
total worst case

How much biomass and waste will there be available in the future in Belgium?

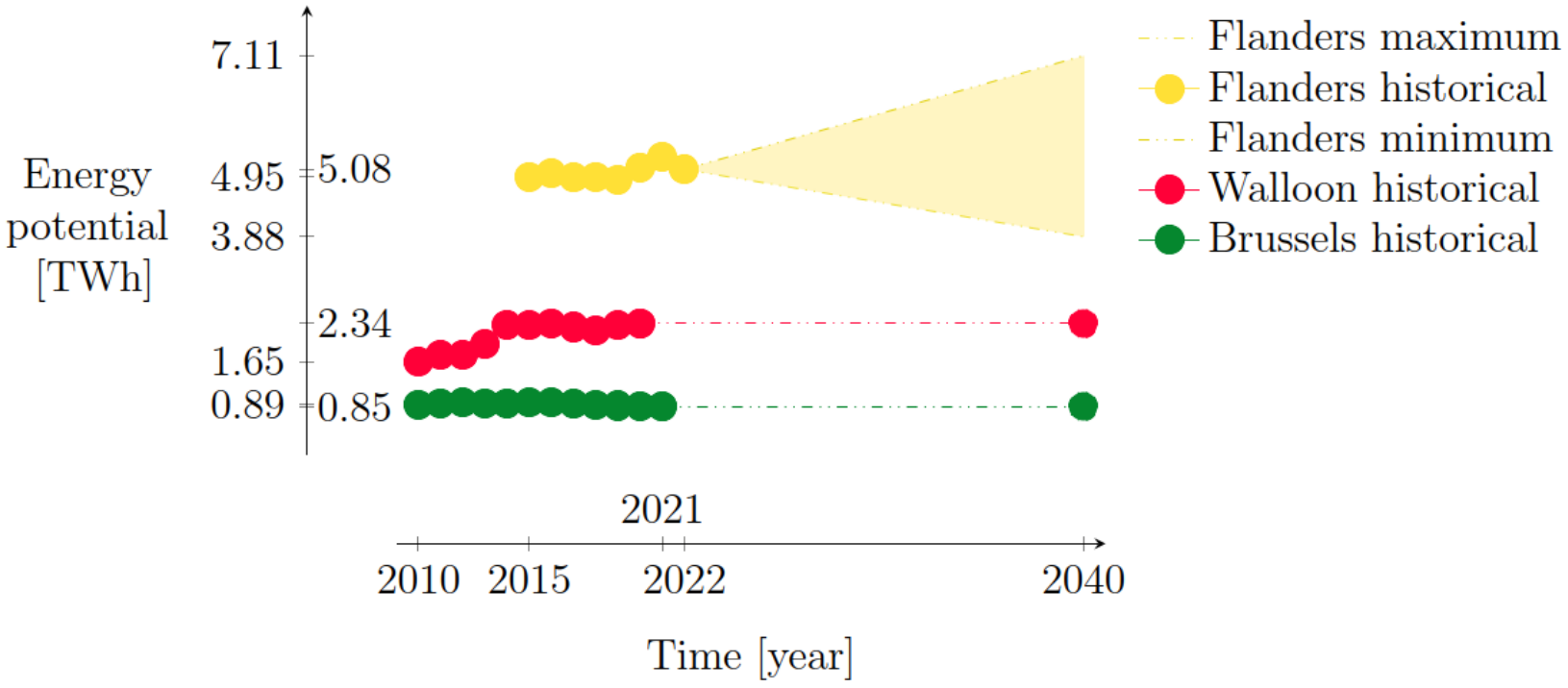




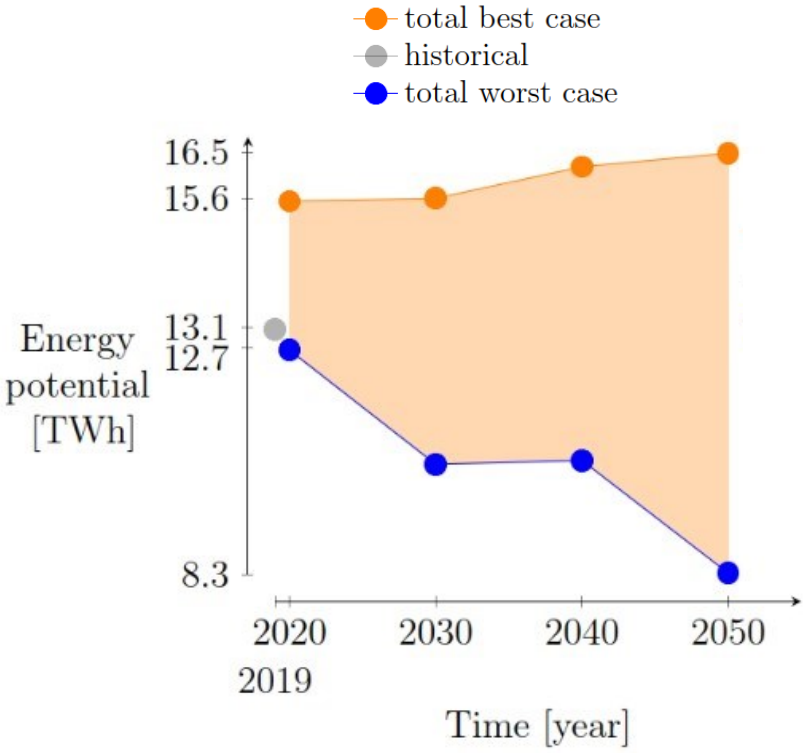
How much biomass and waste will there be available in the future in Belgium?

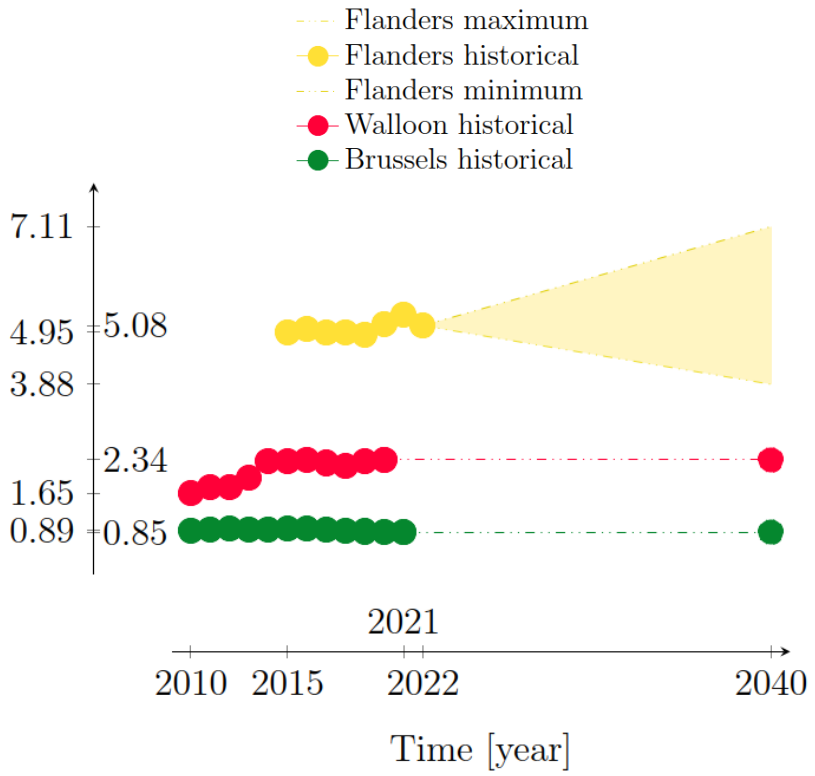


BWtE created two scenarios for Flanders, while for Wallonia and Brussels this is not possible now



An uncertain biomass and waste potential in the future in Belgium

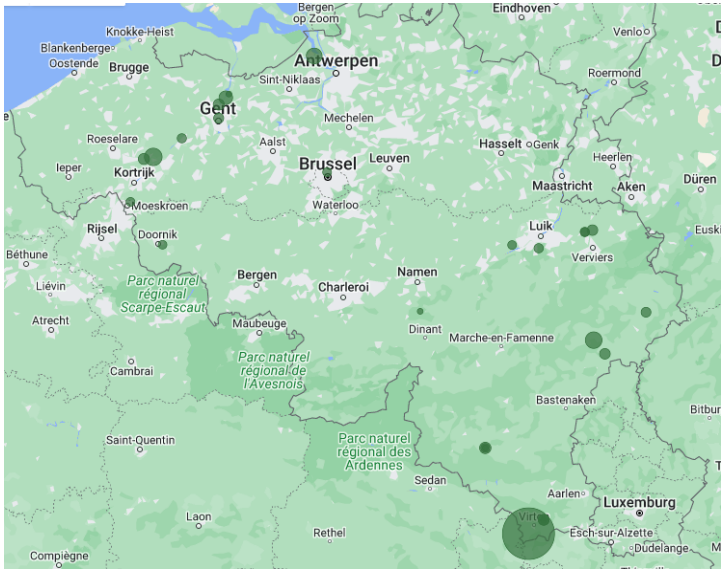




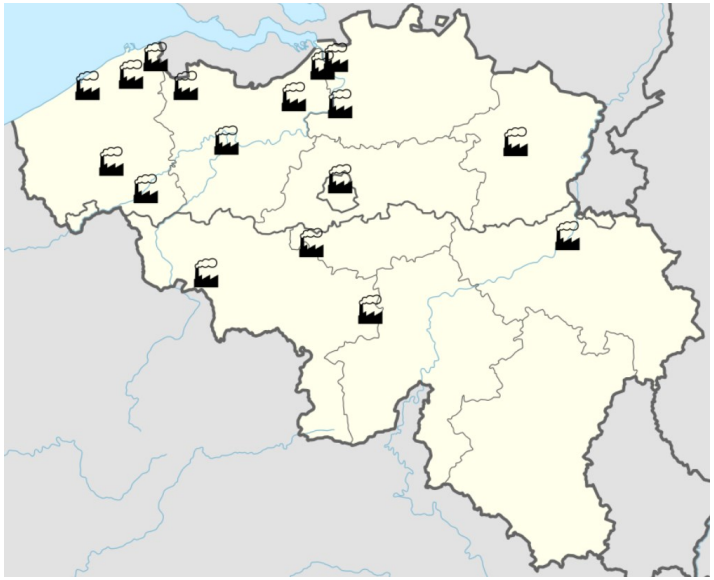
What if there is a decrease in energy potential?

What if there is a decrease in energy potential?

Biomass-fueled cogeneration

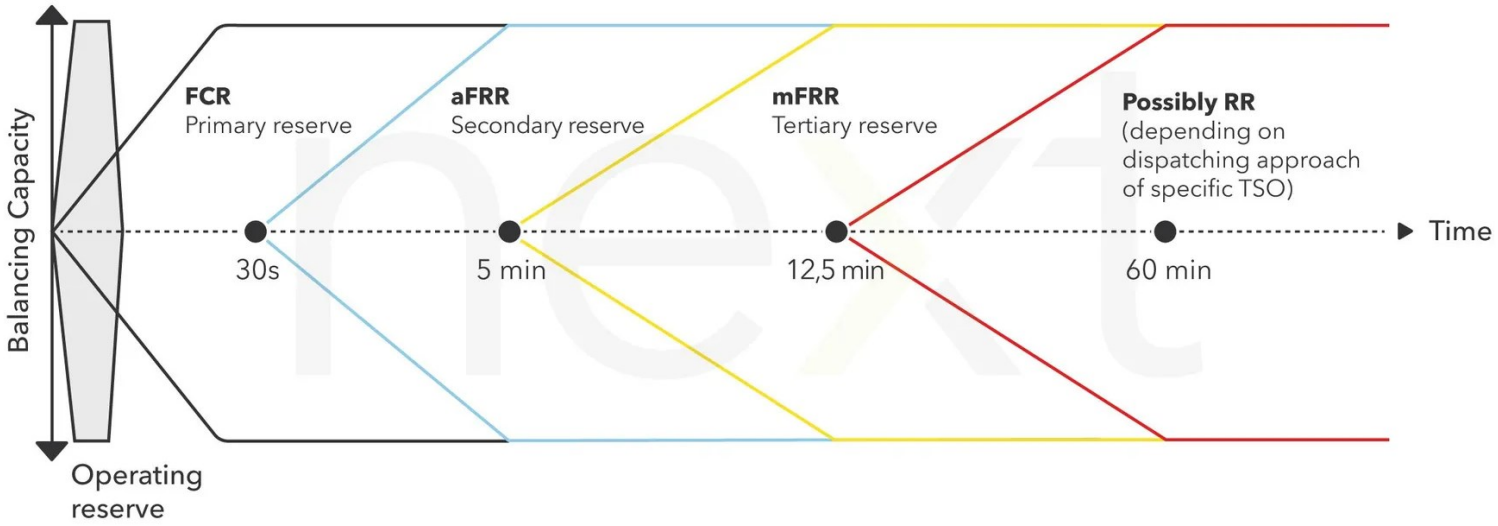


Municipal waste-fueled cogeneration

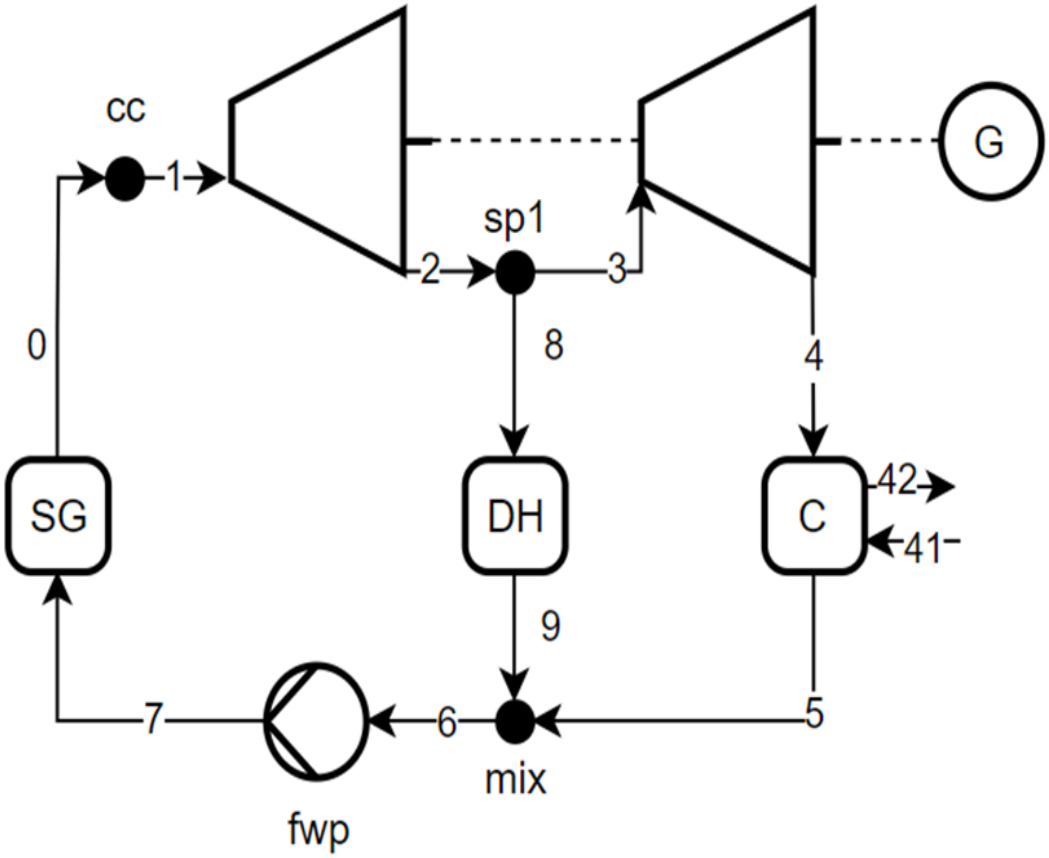


Most likely scenario is the shutdown of some plants

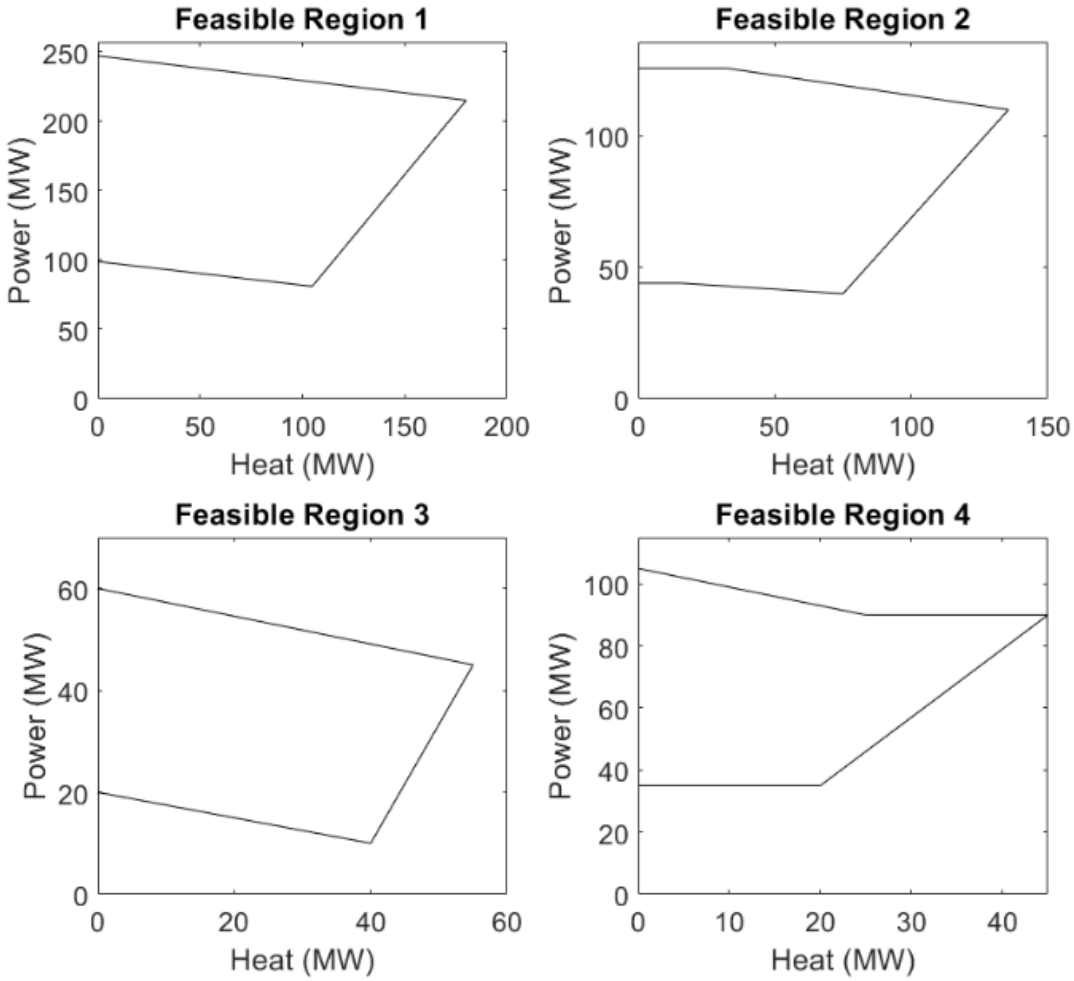
With a reduction in fuel availability, there is room for flexibility



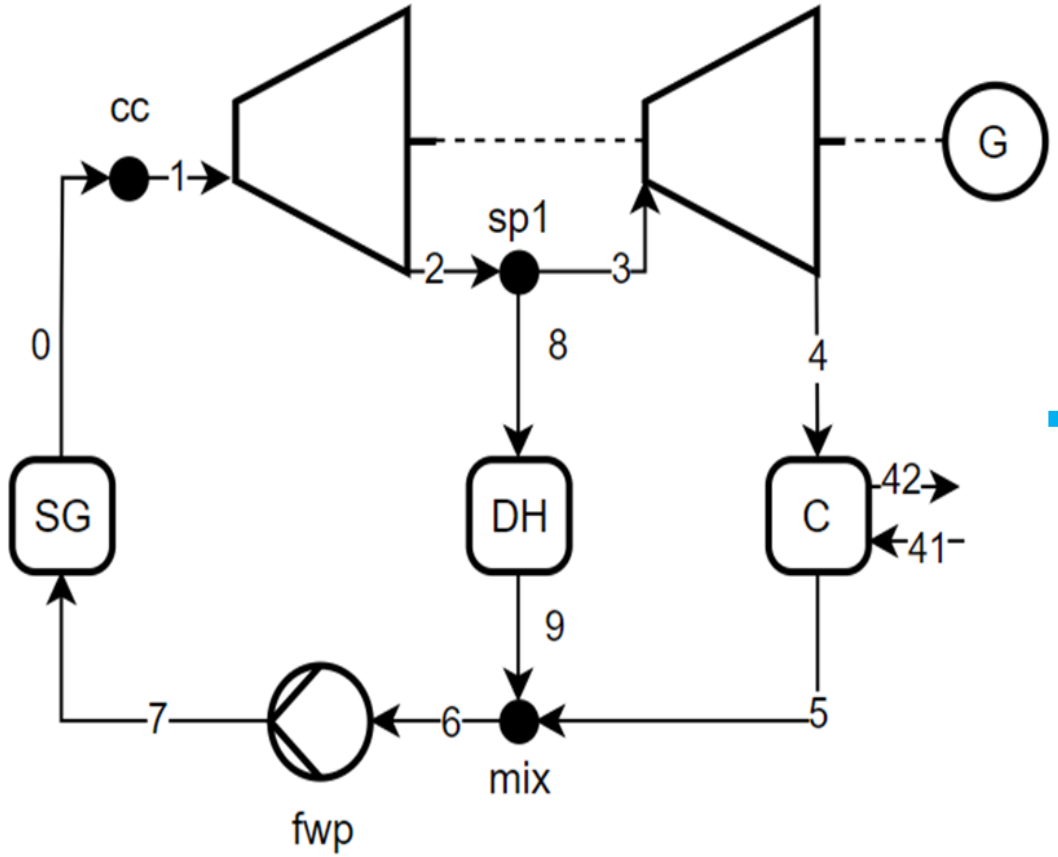
From next-kraftwerke


cc
1
sp1
2
3
G
0
8
4
SG
DH
C
42
41
9
7
6
5
mix
fwp

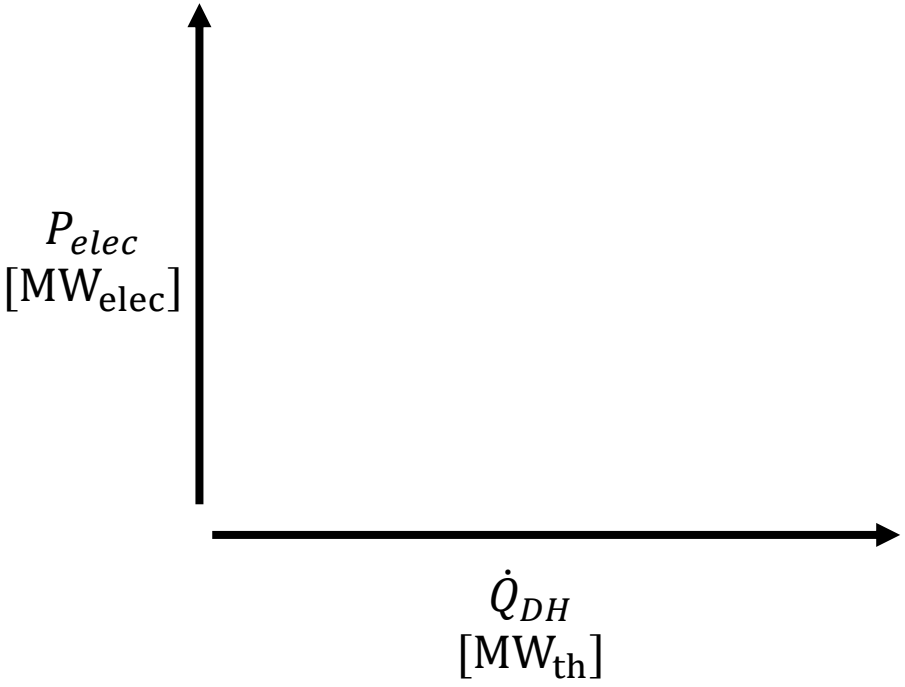
Every cogeneration plant has a unique feasible region

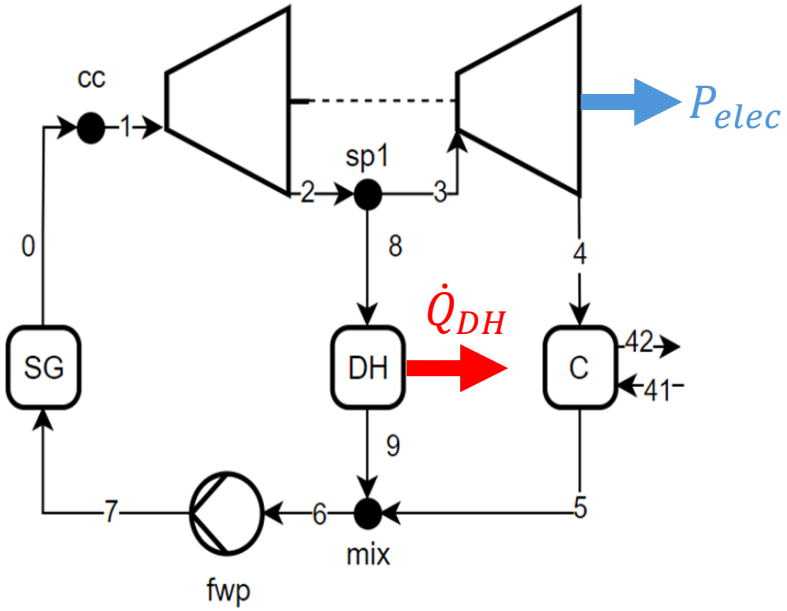


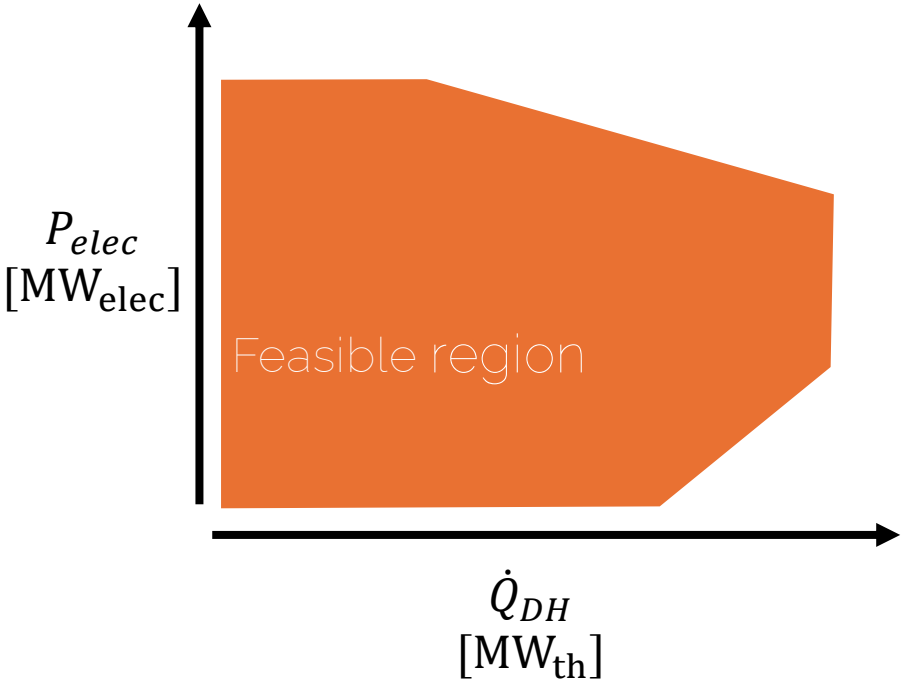
cost

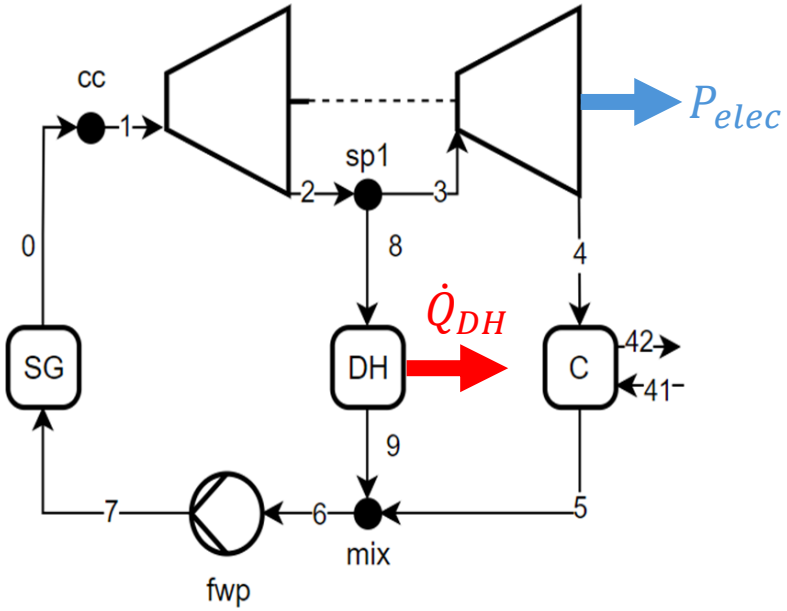


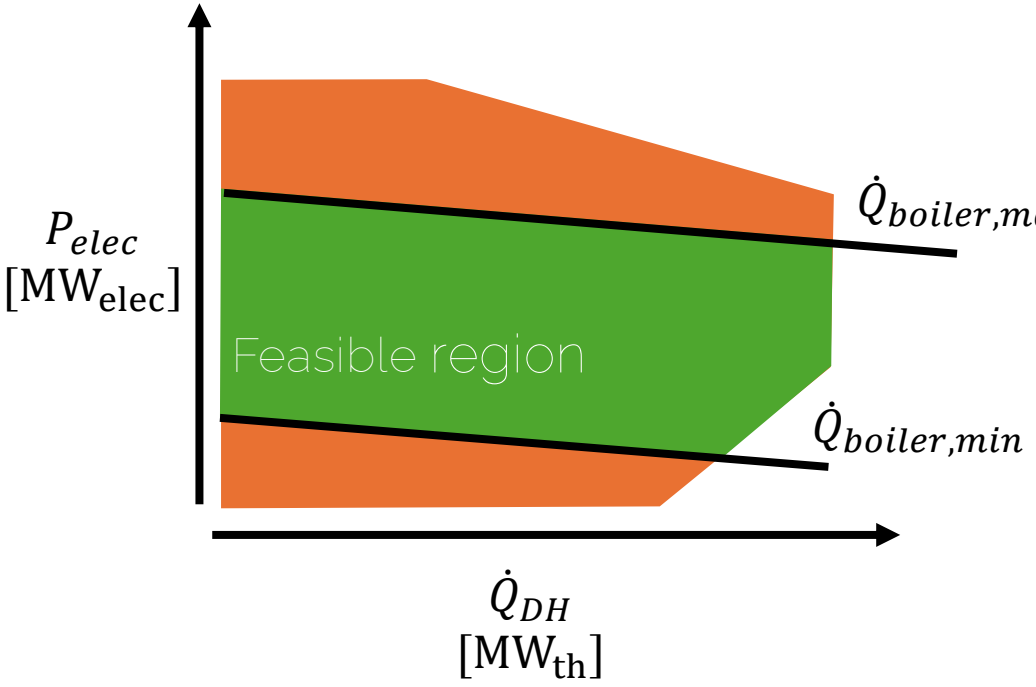
revenue

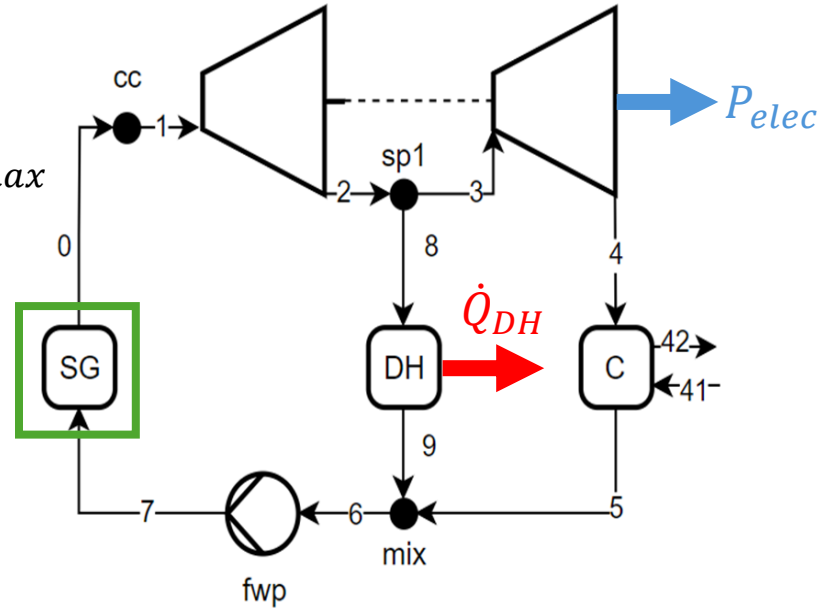

P_{elec}
[MW_{elec}]
$\dot{Q}_{DH}$
[MW_{th}]

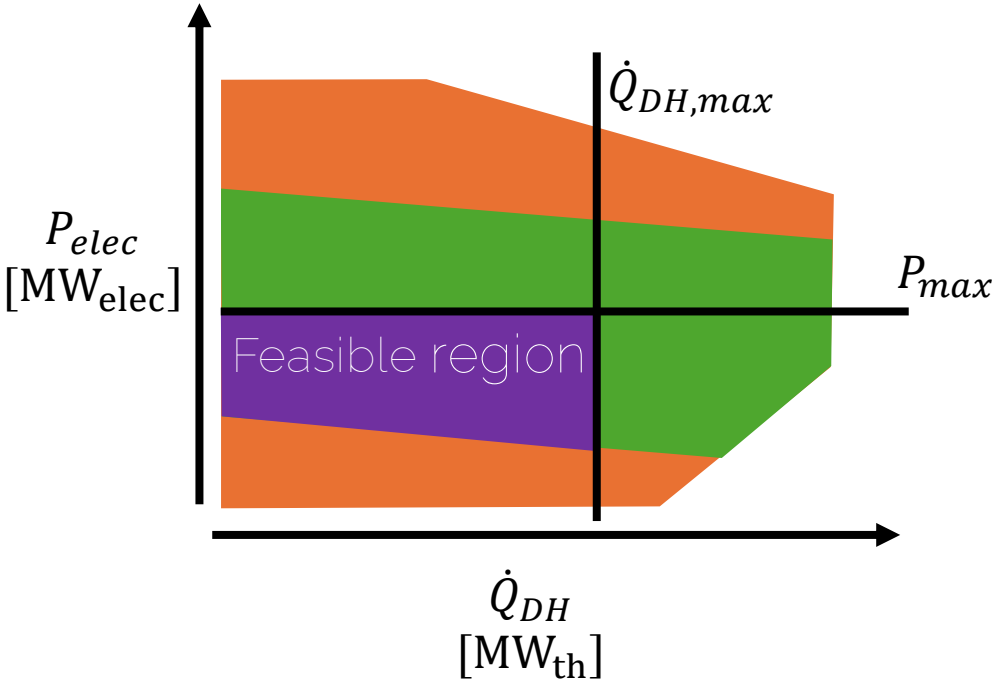

cc
1
sp1
2
3
P_{elec}
0
8
4
$\dot{Q}_{DH}$
SG
DH
C
42
41
9
7
6
5
mix
fwp

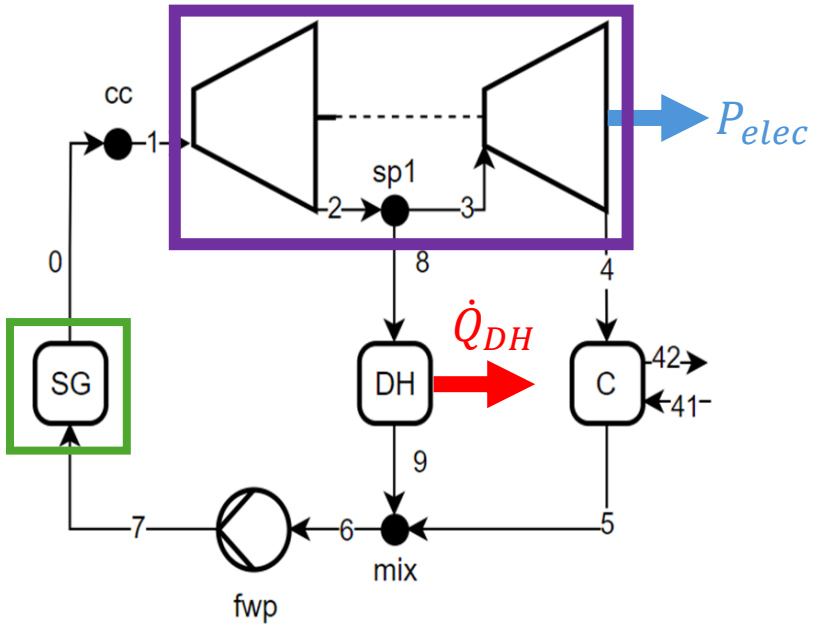

P_{elec}
$[\mathrm{MW_{elec}}]$
Feasible region
$\dot{Q}_{DH}$
$[\mathrm{MW_{th}}]$

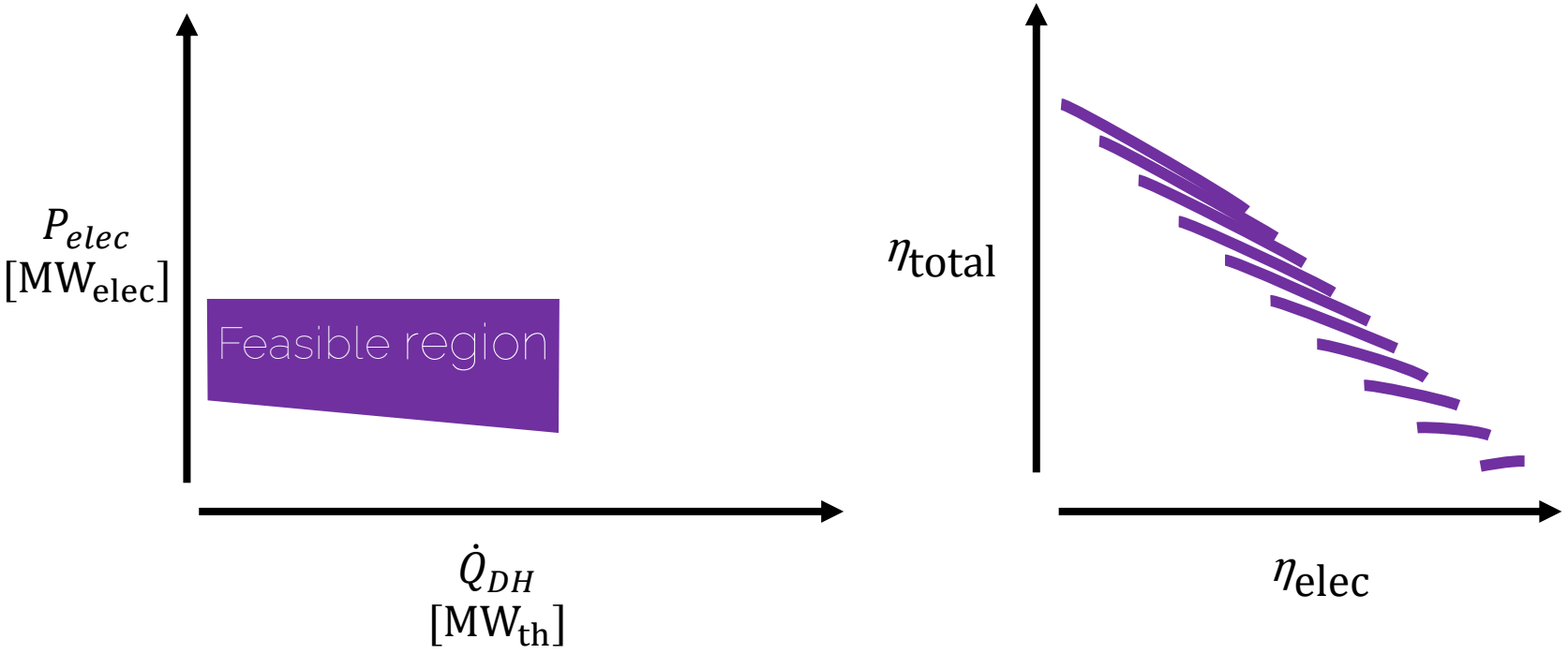

cc
1
sp1
2
3
P_{elec}
0
8
4
$\dot{Q}_{DH}$
SG
DH
C
42
41
9
7
6
5
mix
fwp

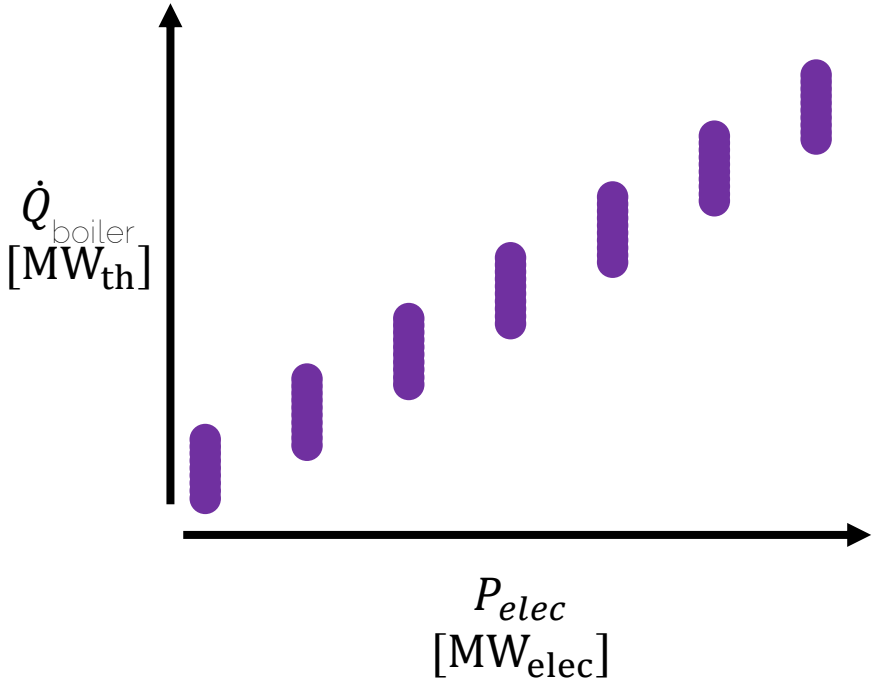

P_{elec}
[MW_{elec}]
Feasible region
$\dot{Q}_{boiler,max}$
$\dot{Q}_{boiler,min}$
$\dot{Q}_{DH}$
[MW_{th}]

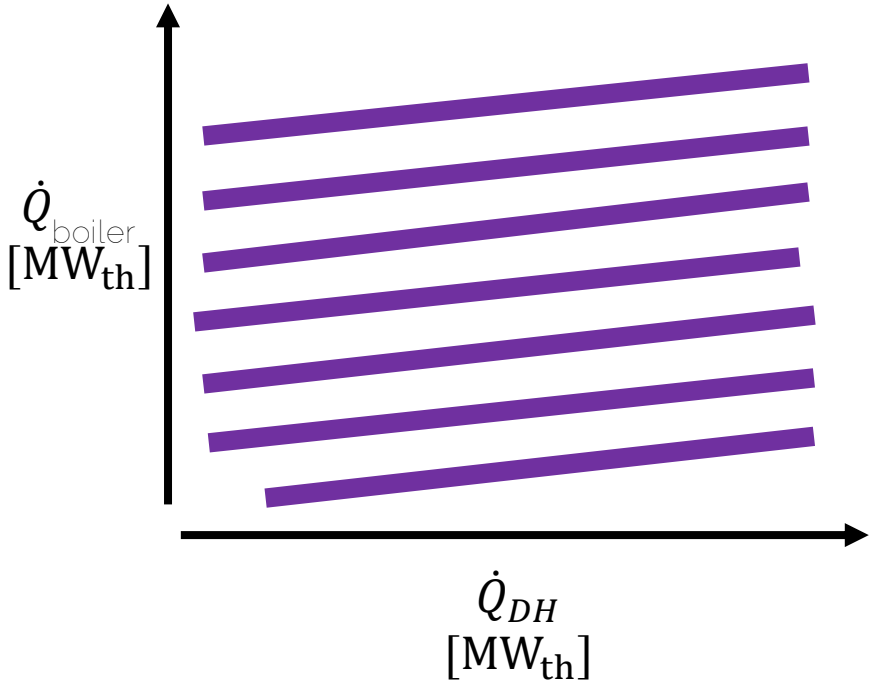

cc
1
sp1
2
3
P_{elec}
0
8
4
$\dot{Q}_{DH}$
SG
DH
C
42
41
9
7
6
5
mix
fwp


P_{elec}
[MW_{elec}]
$\dot{Q}_{DH,max}$
P_{max}
Feasible region
$\dot{Q}_{DH}$
[MW_{th}]

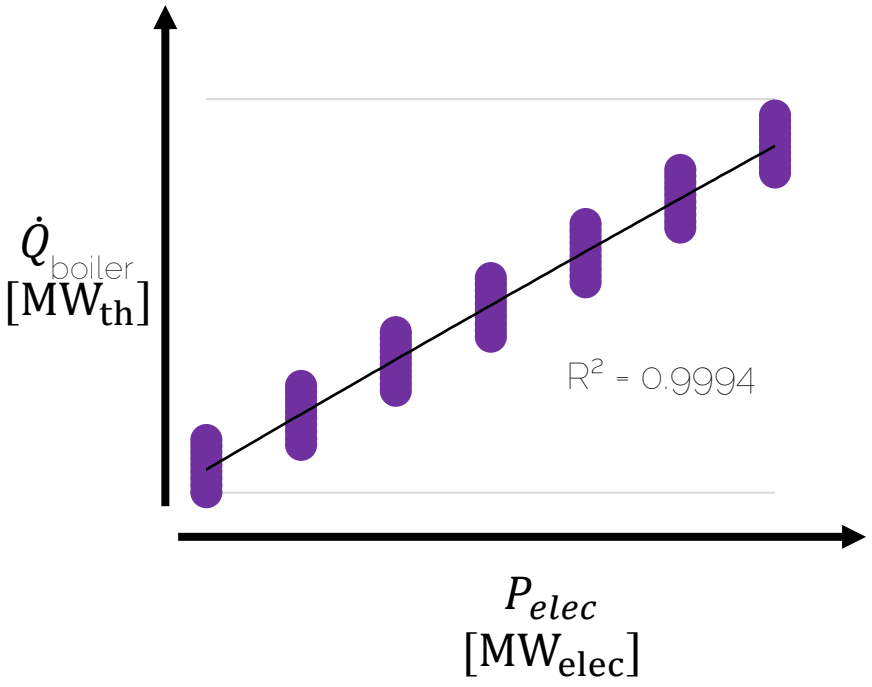

cc
1
sp1
2
3
P_{elec}
0
8
4
$\dot{Q}_{DH}$
SG
DH
C
42
41
9
7
6
5
mix
fwp

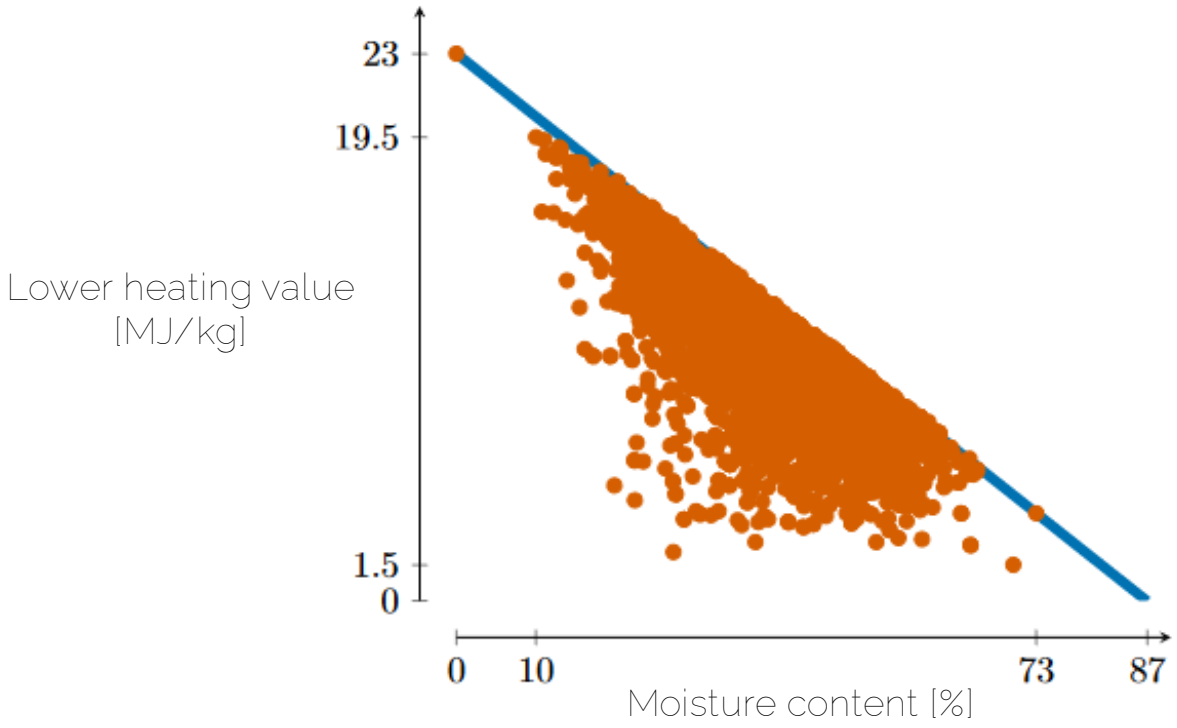

P_{elec}
$[\mathrm{MW_{elec}}]$
Feasible region
$\dot{Q}_{DH}$
$[\mathrm{MW_{th}}]$
η_{total}
η_{elec}

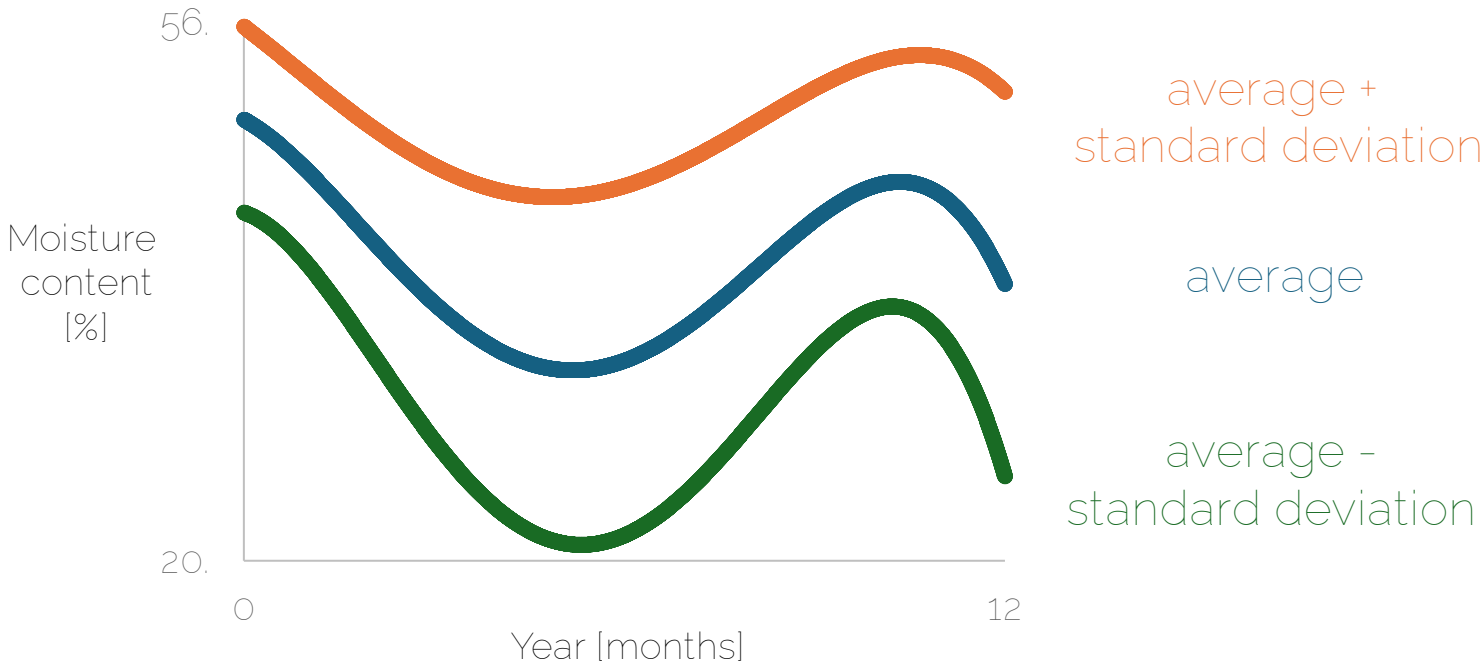

$\dot{Q}_{\text{boiler}}$
$[\text{MW}_{\text{th}}]$
P_{elec}
$[\text{MW}_{\text{elec}}]$


$\dot{Q}_{\text{boiler}}$
$[\text{MW}_{\text{th}}]$
$\dot{Q}_{DH}$
$[\text{MW}_{\text{th}}]$

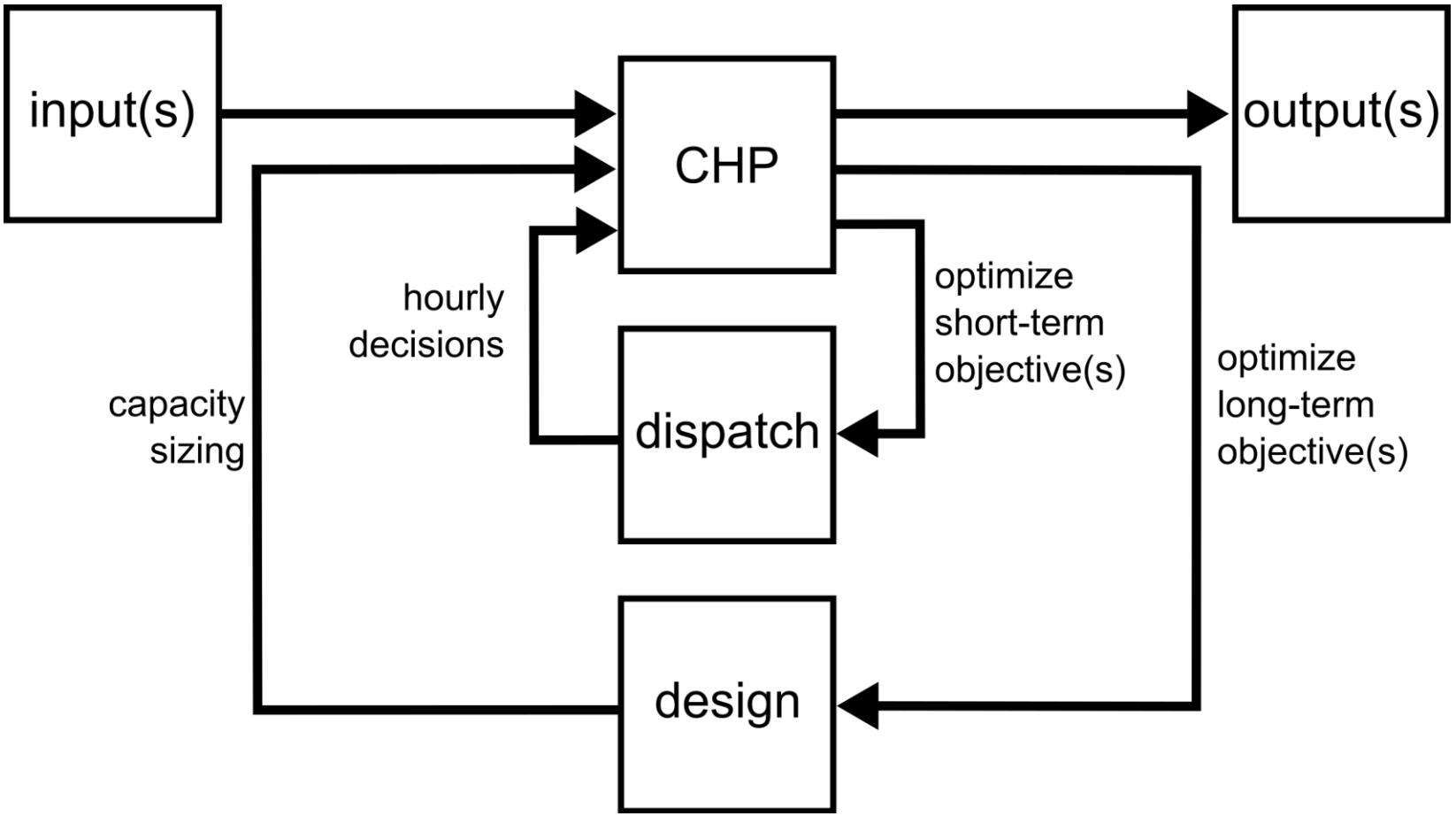
$$\dot{Q}_{boiler} = a\,P^2 + b\,P + c\,H^2 + d\,{}^*H + e\,{}^*\,P\,{}^*\,H$$



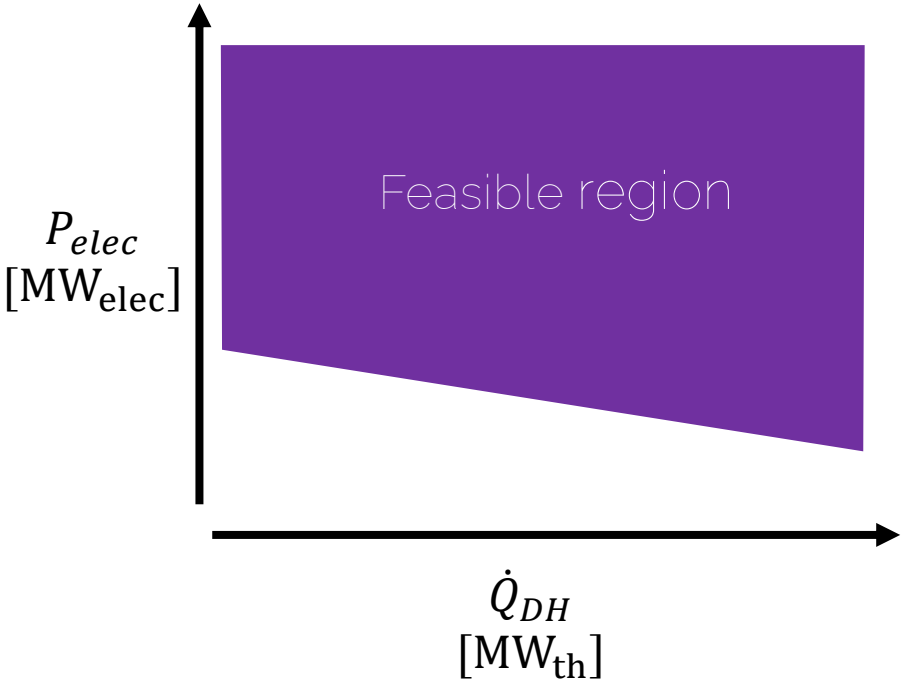

Lower heating value
[MJ/kg]
23
19.5
1.5
0
0
10
73
87
Moisture content [%]


56.
20.
Moisture content [%]
0
12
Year [months]
average + standard deviation
average
average - standard deviation

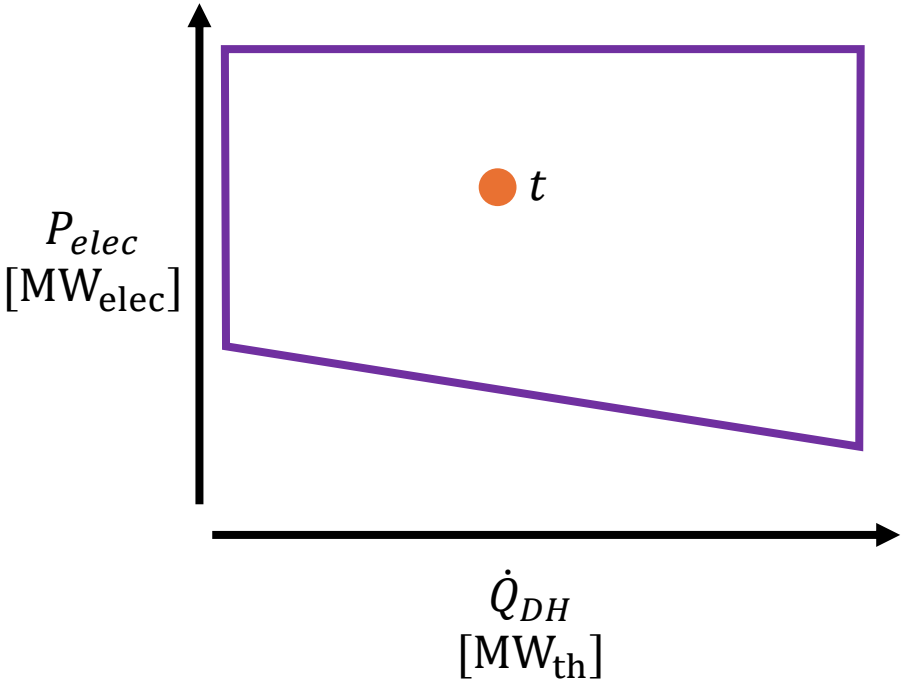
A two-step optimization approach optimizes daily optimization while minimizing investment



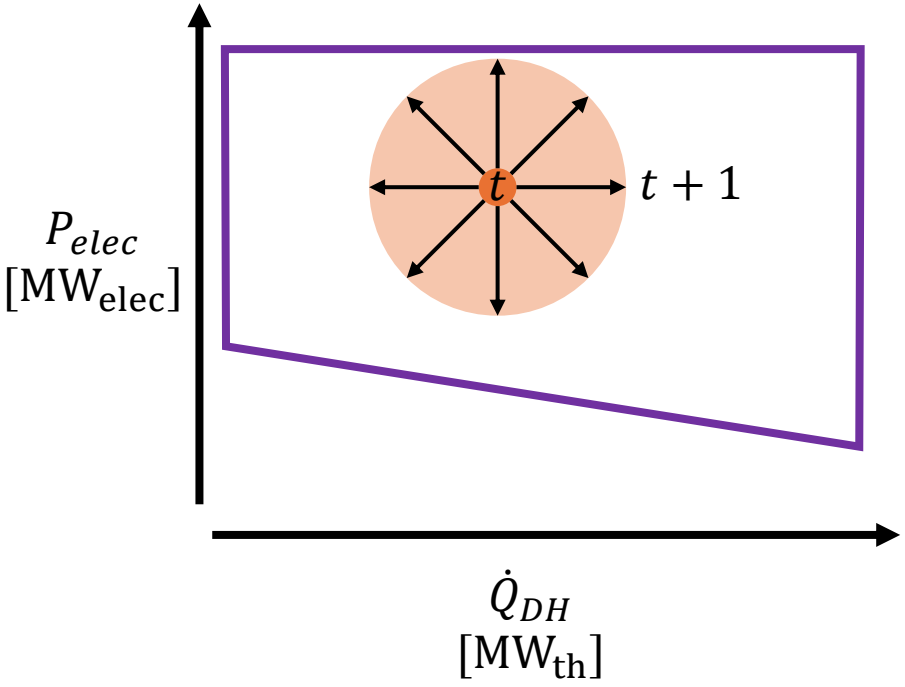
Searching for key performance indicators for measuring flexibility



Searching for key performance indicators for measuring flexibility

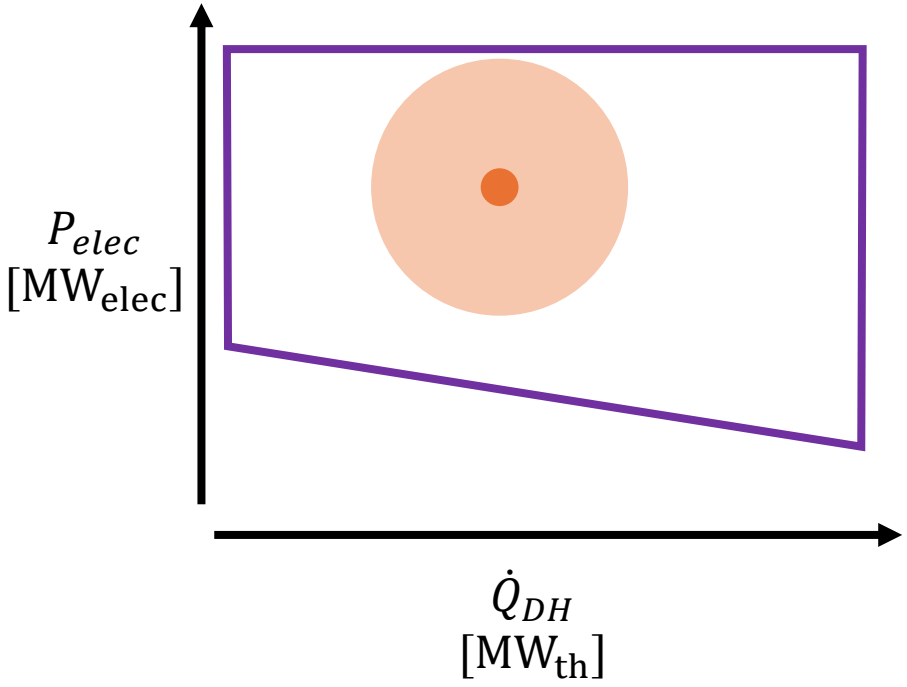


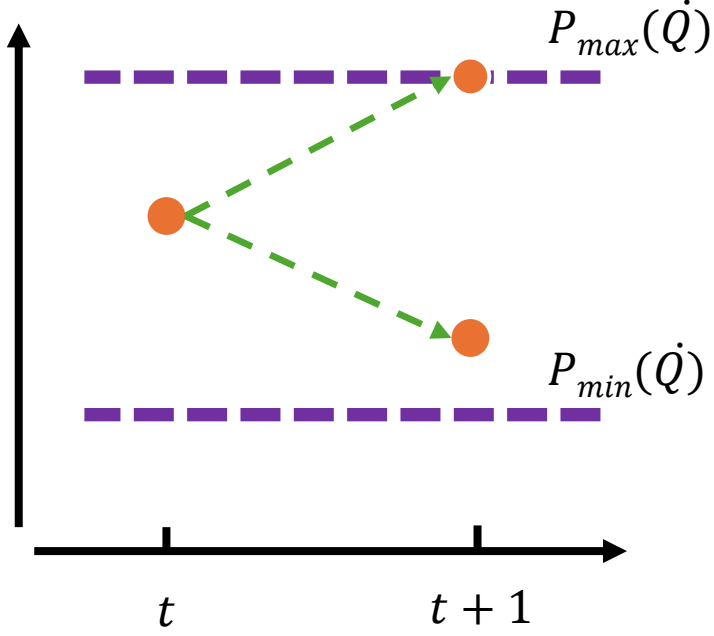
Searching for key performance indicators for measuring flexibility



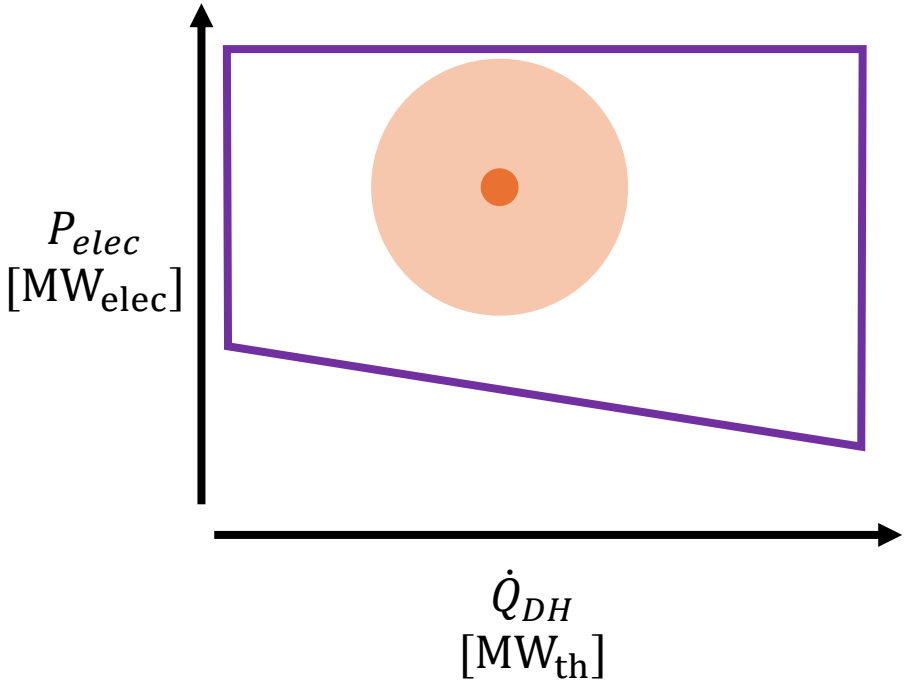
Flexibility index (FI) provides this measure

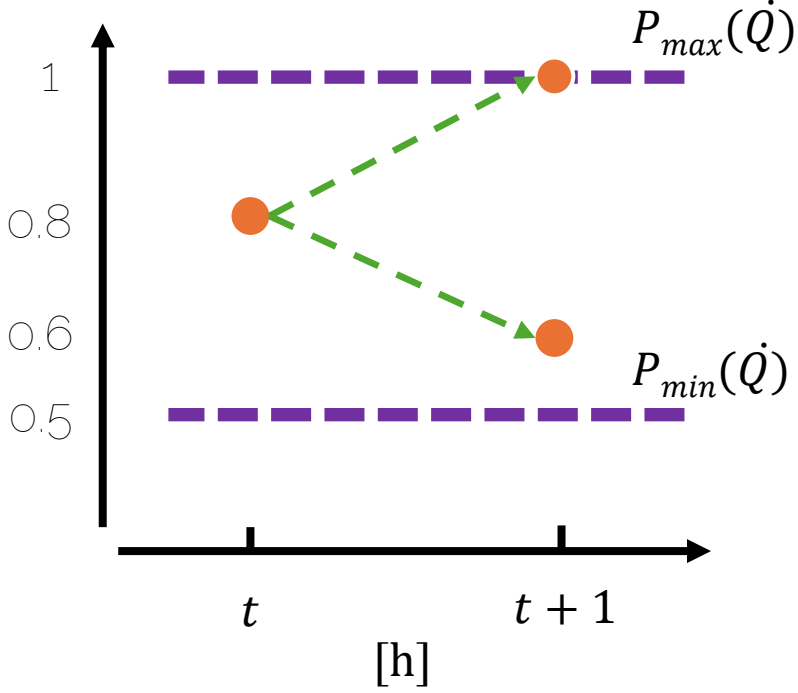
$$FI(t) = \frac{P_{up,max}(t+1) - P_{down,max}(t+1)}{P_{max}(\dot{Q}) - P_{min}(\dot{Q})}$$





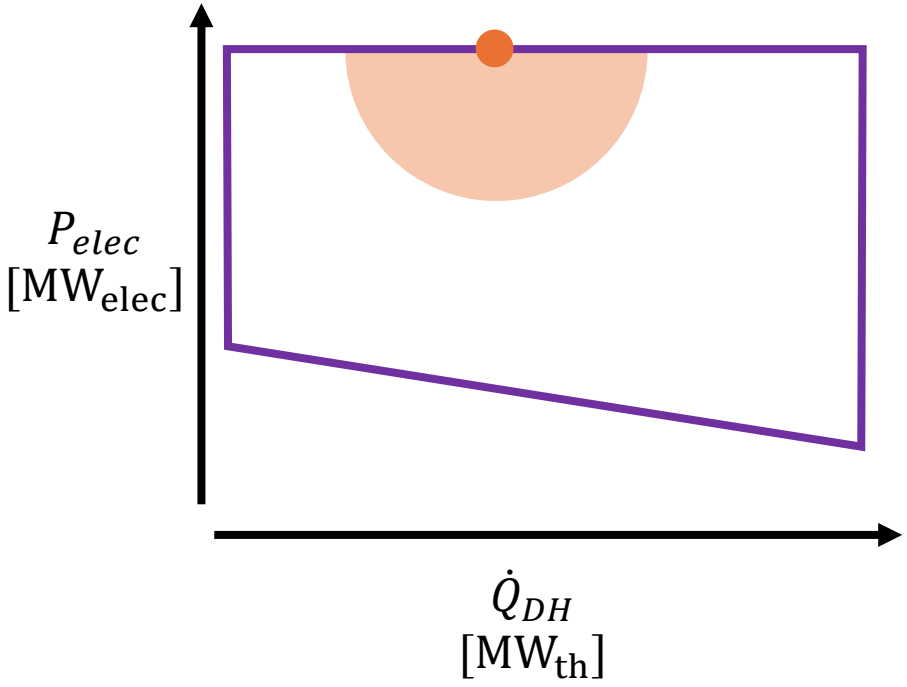
$$FI(t) = \frac{P_{up,max}(t+1) - P_{down,max}(t+1)}{P_{max}(\dot{Q}) - P_{min}(\dot{Q})}$$

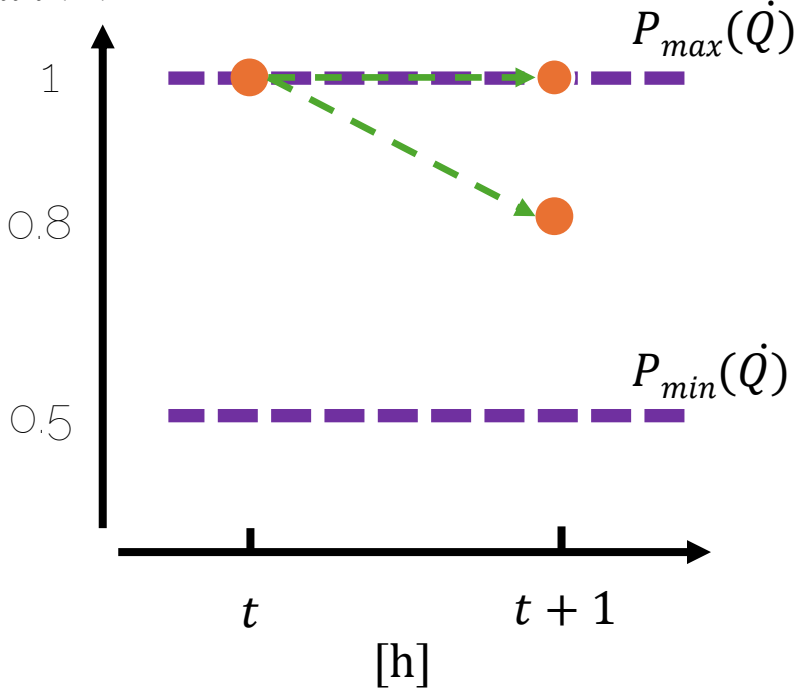




$$FI(t) = \frac{1 - 0.6}{1 - 0.5} = 0.8$$

$$FI(t) = \frac{P_{up,max}(t+1) - P_{down,max}(t+1)}{P_{max}(\dot{Q}) - P_{min}(\dot{Q})}$$

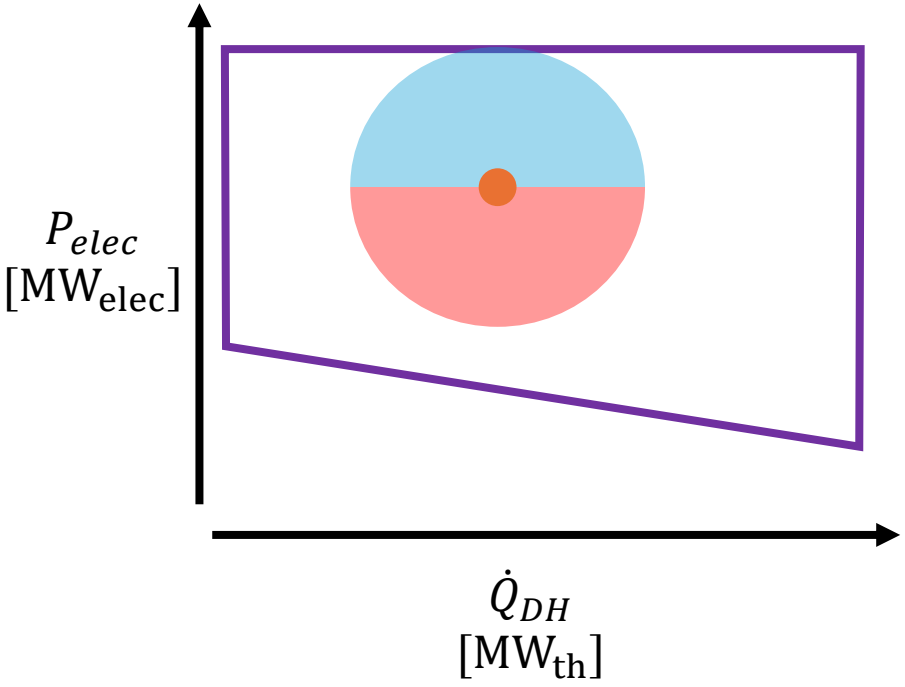




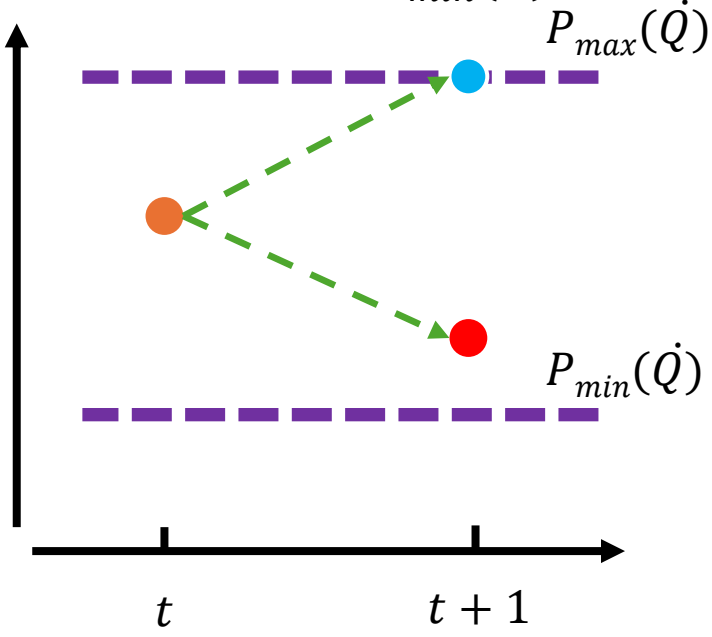
$$FI(t) = \frac{1 - 0.8}{1 - 0.5} = 0.4$$

Other option is splitting the flexibility index

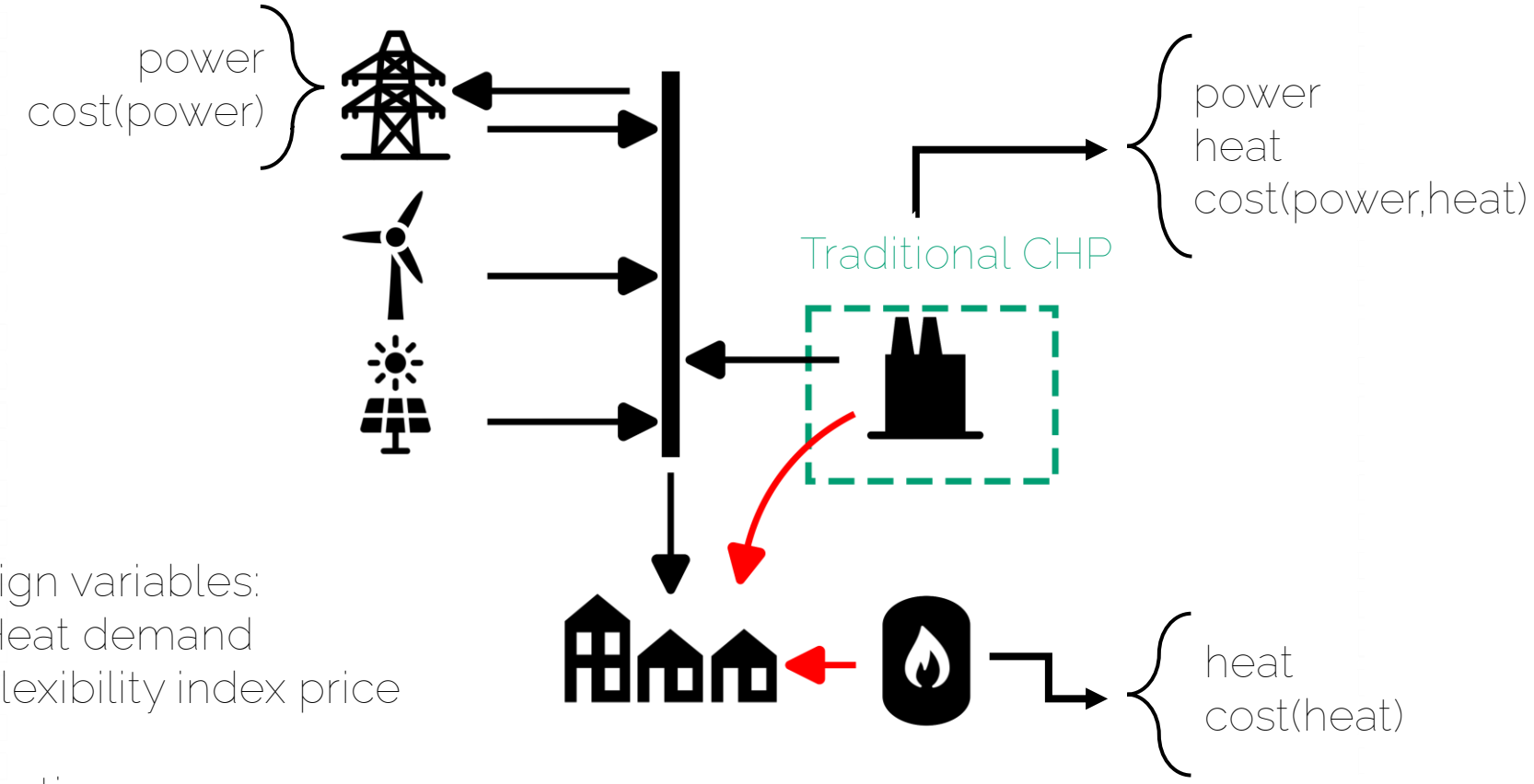
$$FI_{up}(t) = \frac{P_{up,max}(t+1) - P(t)}{P_{max}(\dot{Q}) - P(t)}$$



$$FI_{down}(t) = \frac{P(t) - P_{down,max}(t+1)}{P(t) - P_{min}(\dot{Q})}$$

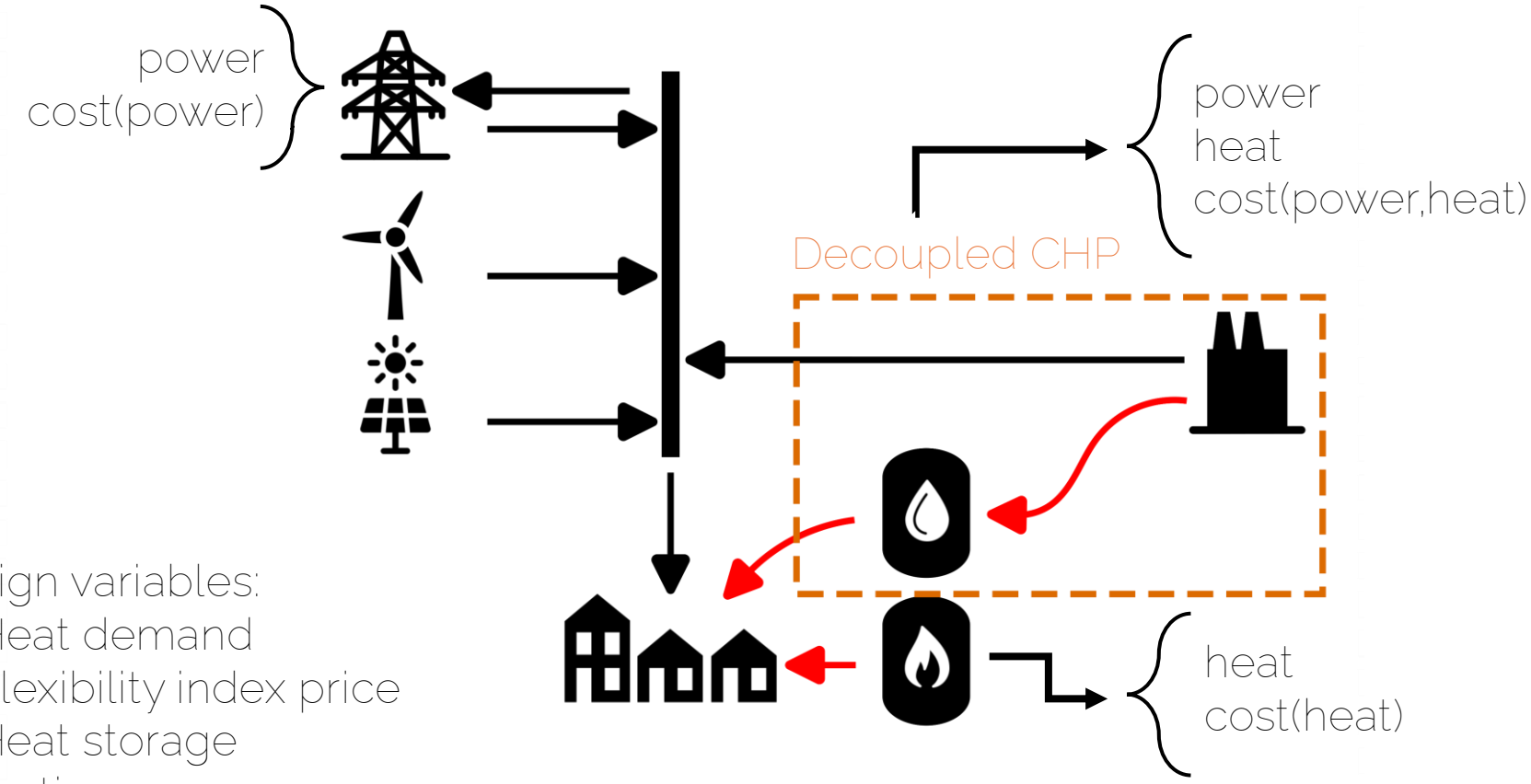


The genetic algorithm adapts the capacities to find a design which optimizes the objectives



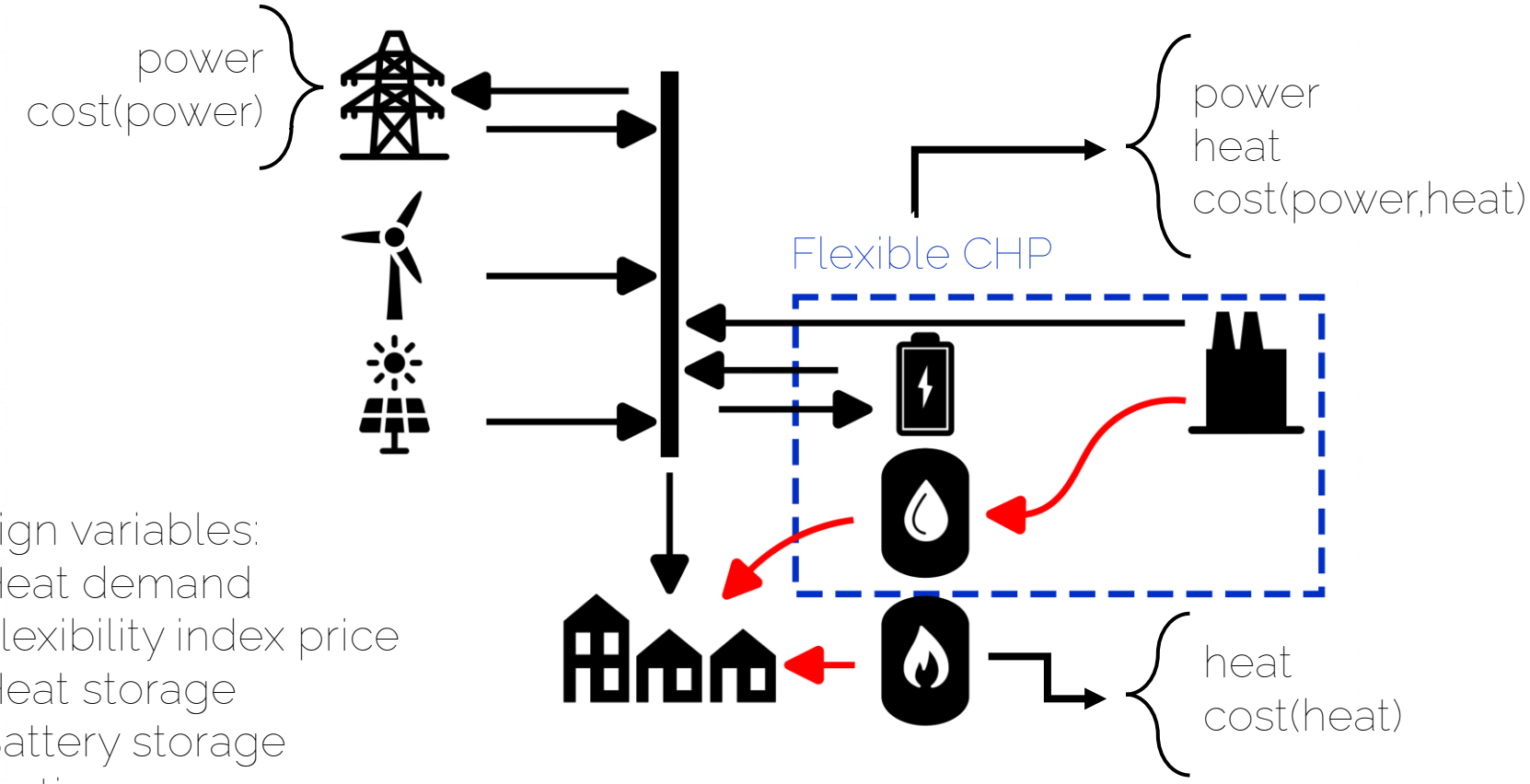
Design variables:
- Heat demand
- Flexibility index price

Objectives:
- maximize revenue CHP
- maximize flexibility index



Design variables:
- Heat demand
- Flexibility index price
- Heat storage

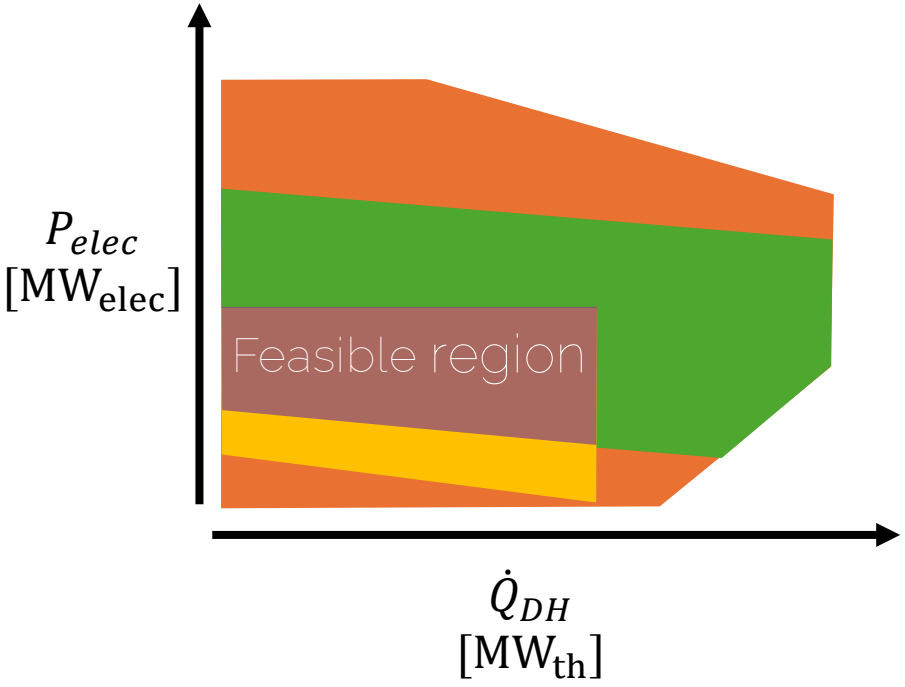
Objectives:
- maximize revenue CHP
- maximize flexibility index

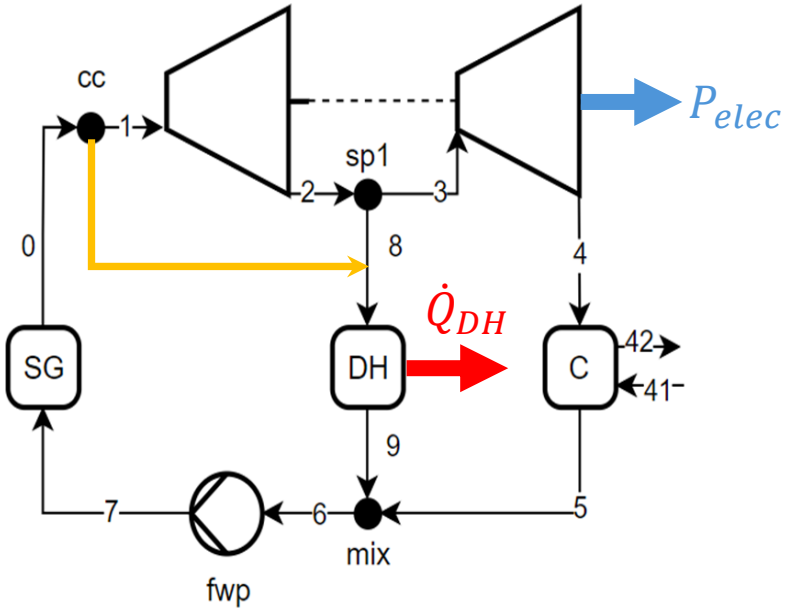


Design variables:
- Heat demand
- Flexibility index price
- Heat storage
- Battery storage

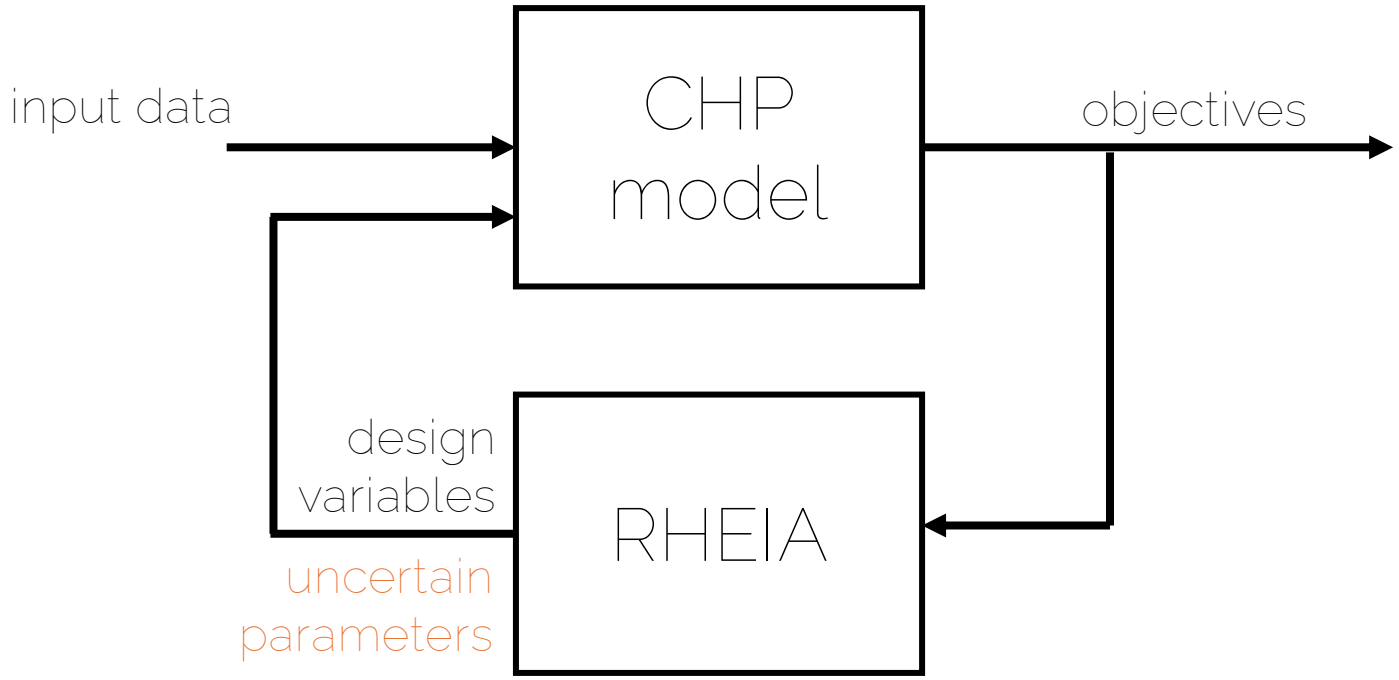
Objectives:
- maximize revenue CHP
- maximize flexibility index

In the future, CHP adaptations will be included to improve revenue and flexibility





The genetic algorithm adapts the capacities to find an optimal design under uncertainties



Conclusions

- an uncertain biomass and waste potential in the future in Belgium
- The performance of CHP plant is modelled
- Revenue and flexibility index will be optimized
- Additional components and uncertainties will be included

BERA workshop

29/11/2024

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ENTRAS