Optimal Dispatch for CHP Units under Solar Production Uncertainty

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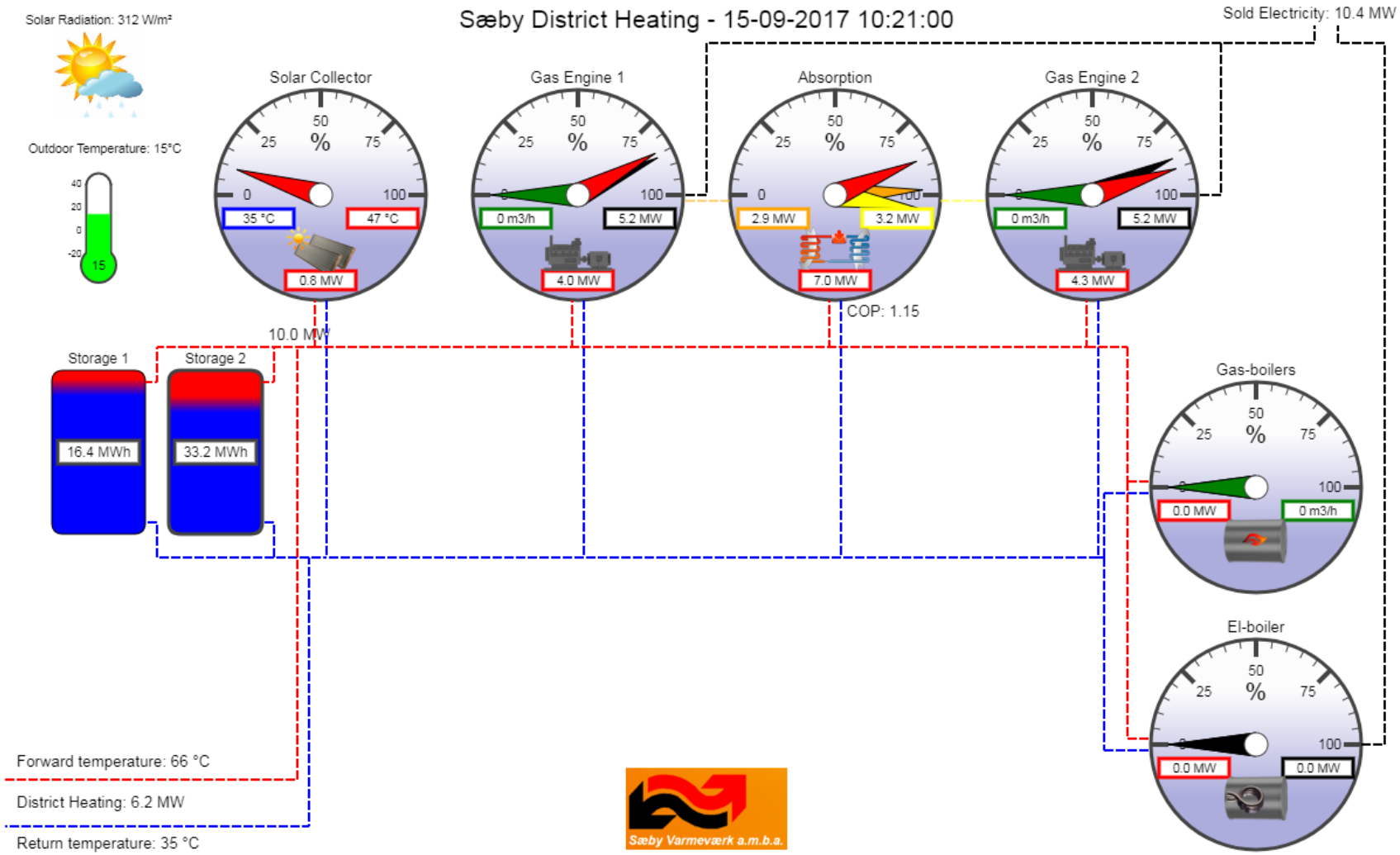
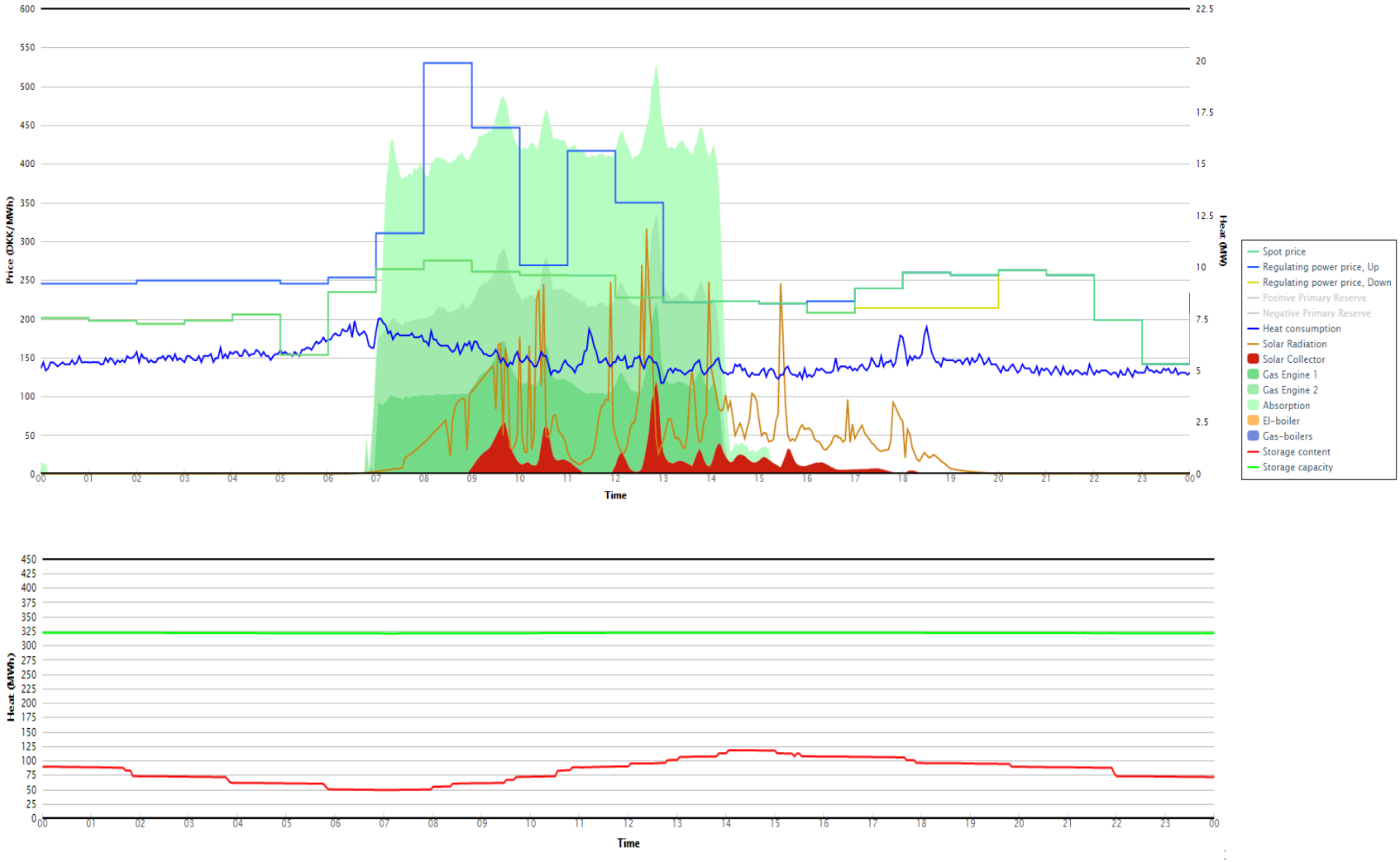
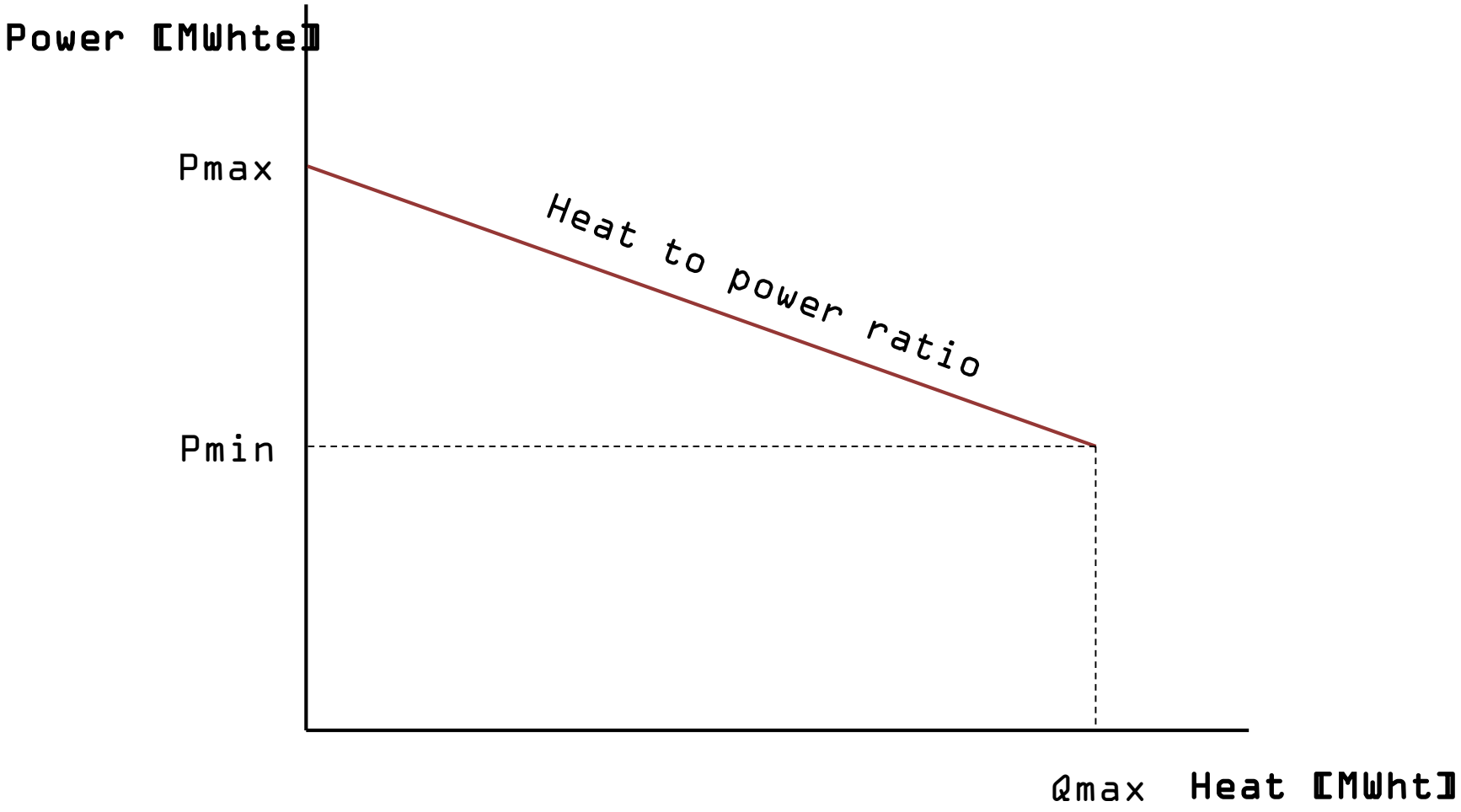


Source: https://www.emd.dk/plants/saeby/

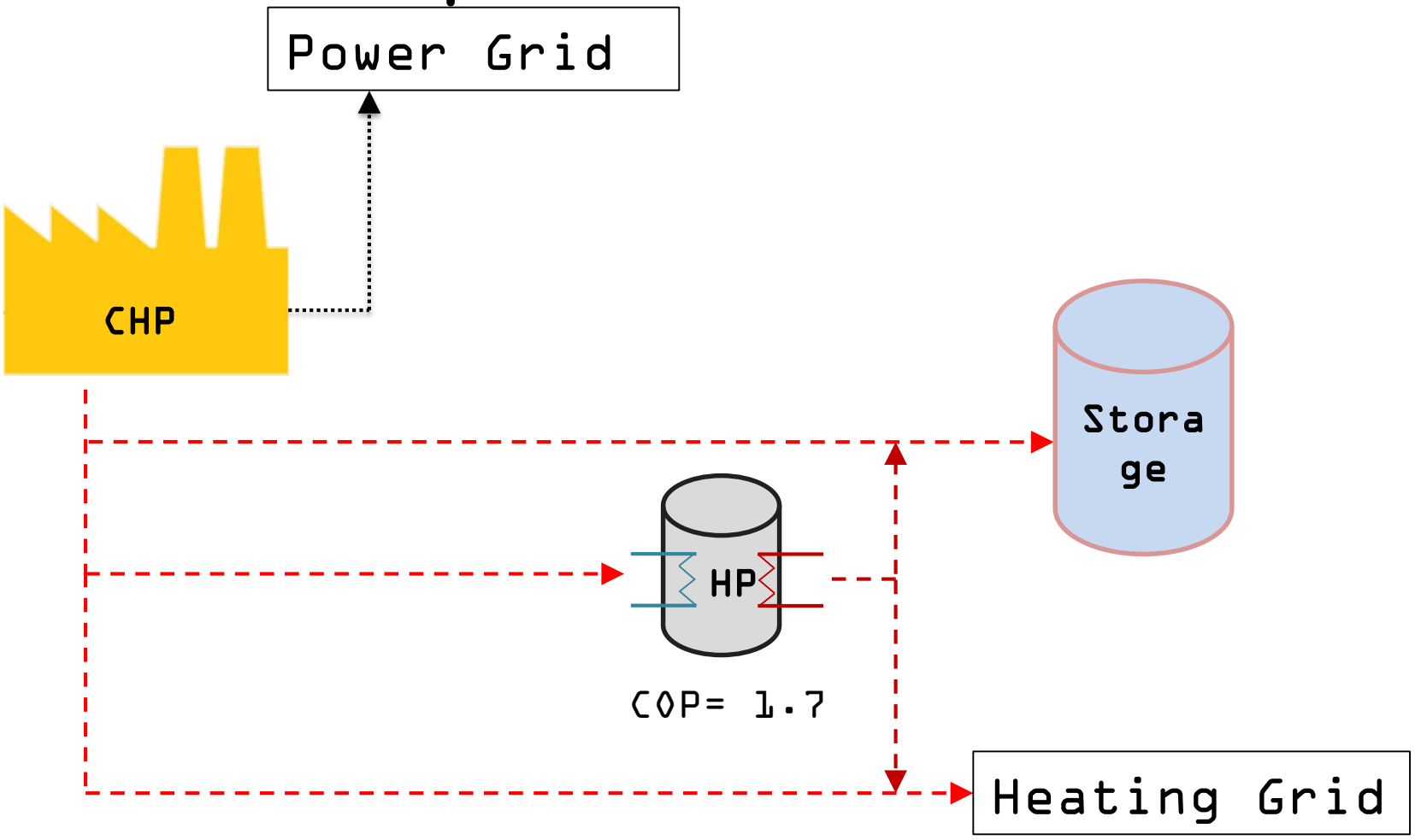


Source: https://www.emd.dk/plants/saeby/

Back pressure CHP unit

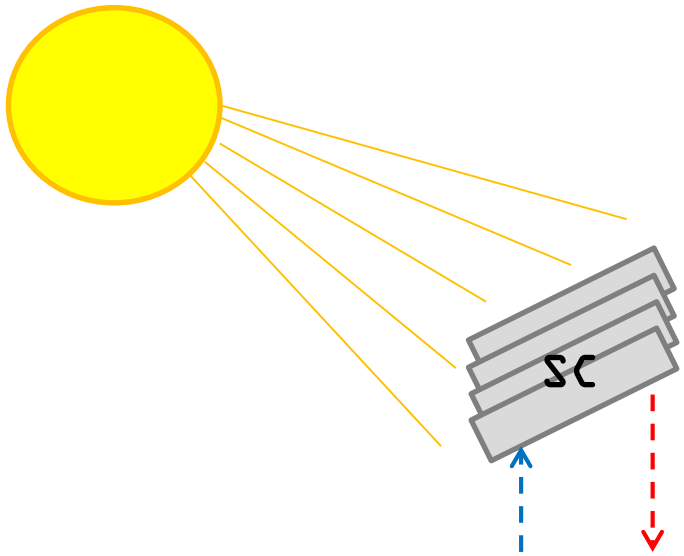


Absorption Heat Pump



Solar Collector

Directly affected by the solar radiation but with a certain lag. Maybe a **state-space model** could be the optimal to describe the dynamics of the system.



HEAT ECONOMIC DISPATCH

$$\left.\begin{array}{l}\mathbf{H} = \{\text{CHP, GB1 and GB2}\} \\ \mathbf{T} = \{t_1, t_2, ..., |T|\}\end{array}\right\} \text{ Sets}$$

$$\text{minimize} \quad \sum_{t \in \mathbf{T}} \sum_{h \in \mathbf{H}} \left(\frac{C^{\mathrm{F}_{(h)}}}{\varepsilon_{(h)}} + C^{\mathrm{T}}_{(h)} + C^{\mathrm{O\&M}}_{(h)} + C^{\mathrm{CO_2}}_{(h)} \right) \cdot q_{(h,t)}$$

$$\text{subject to} \quad \sum_{h \in \mathbf{H}} q_{(h,t)} + q^{\mathrm{SC}}_{(t)} = L^{\mathrm{H}}_{(t)} \quad : \lambda^{\mathrm{H}}_{(t)} \qquad \forall t \in \mathbf{T}$$

$$q_{(h,t)} \leq \overline{Q}_{(h)} \qquad \forall t \in \mathbf{T}, \forall h \in \mathbf{H}$$

Parameters

Marginal Value

Variables

Uncertainty

BIDDING PRICE FOR CHP [DKK\MWh]

$$\lambda_{(t)}^{\mathrm{CHP}} = \frac{C_{\mathrm{CHP}}^{\mathrm{F}}}{\varepsilon_{(\mathrm{CHP})}} + C_{\mathrm{CHP}}^{\mathrm{T}} + C_{\mathrm{CHP}}^{\mathrm{O\&M}} + C_{\mathrm{CHP}}^{\mathrm{CO_2}} - \lambda_{(t)}^{\mathrm{H}}$$

UNIT COMMITMENT OF THE SYSTEM

Bidding price

$$\text{minimize} \quad \sum_{t \in \mathbf{T}} \left(\lambda^{\text{CHP}}_{(t)} - \lambda^{\text{P}}_{(t)} \right) p^{\text{CHP}}_{(t)} + C^{\text{GB}}_{(t)} q^{\text{GB}}_{(t)}$$

subject to

$$q_{(h,t)} \leq \overline{Q}_{(h)} \quad \forall t \in \mathbf{T}, \forall h \in \mathbf{H}$$

Maximum heat production

$$q^{\text{CHP}}_{(t)} = \Xi \cdot p^{\text{CHP}}_{(t)} \quad \forall t \in \mathbf{T}$$

$$p^{\text{CHP}}_{(t)} \leq \overline{P} \cdot x_{(t)} \quad \forall t \in \mathbf{T}$$

$$\underline{R} \leq p^{\text{CHP}}_{(t)} - p^{\text{CHP}}_{(t-1)} \leq \overline{R} \quad \forall t \in \mathbf{T}$$

$$\sum_{t-UT+1}^{t} y_{(\tau)} \leq x(t) \quad \forall t \in \mathbf{T}$$

$$\sum_{t-DT+1}^{t} z(\tau) \leq 1 - x(t) \quad \forall t \in \mathbf{T}$$

$$y_{(t)} - z(t) = x(t) - x(t-1) \quad \forall t \in \mathbf{T}$$

Technical operation of CHP

$$q_{(h,t)} = s^{\text{IN}}_{(t)} + q^{\text{DH}}_{(t)} \quad \forall t \in \mathbf{T}, \forall h \in \{GB, SC\}$$

$$q^{\text{CHP}}_{(t)} = s^{\text{IN,CHP}}_{(t)} + q^{\text{DH,CHP}}_{(t)} + q^{\text{HP}}_{(t)} \quad \forall t \in \mathbf{T}, \forall h \in \{GB, SC\}$$

$$s_{(t)} = s_{(t-1)} + \sum_{h} s^{\text{IN}}_{(h,t)} + q^{\text{HP}}_{(t)} - s^{\text{OUT}}_{(t)} \quad \forall t \in \mathbf{T}$$

$$\underline{S} \leq s_{(t)} \leq \overline{S} \quad \forall t \in \mathbf{T}$$

Storage and DH operation

$$\sum_{h} q^{\text{DH}}_{(h,t)} + s^{\text{OUT}}_{(t)} = L^{\text{H}}_{(t)}$$

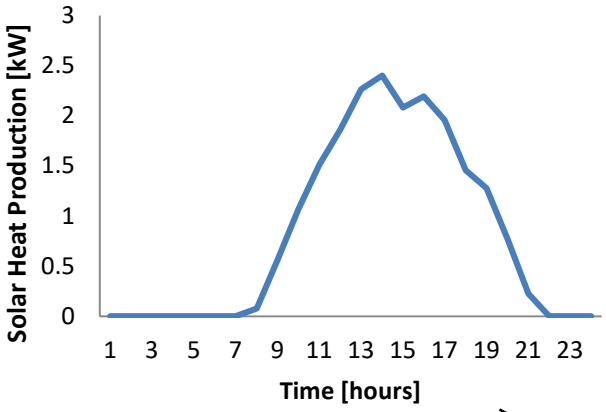
Balance

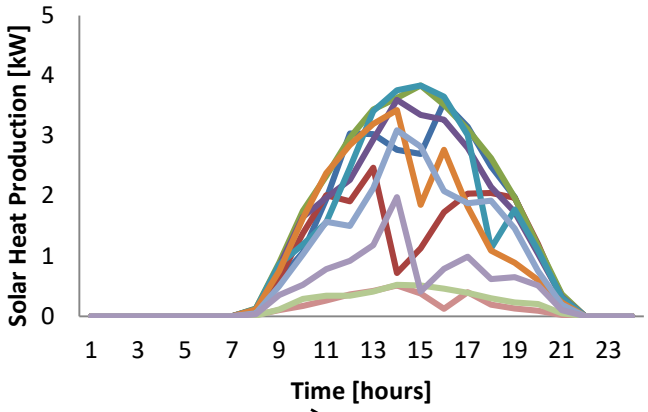
STOCHASTIC UNIT COMMITMENT

First-stage Decisions } Power bid to the DA market

Uncertainty } Heat produced by solar collectors

Second-stage Decisions } Operation of the DH system





Solve ED neglecting solar collector

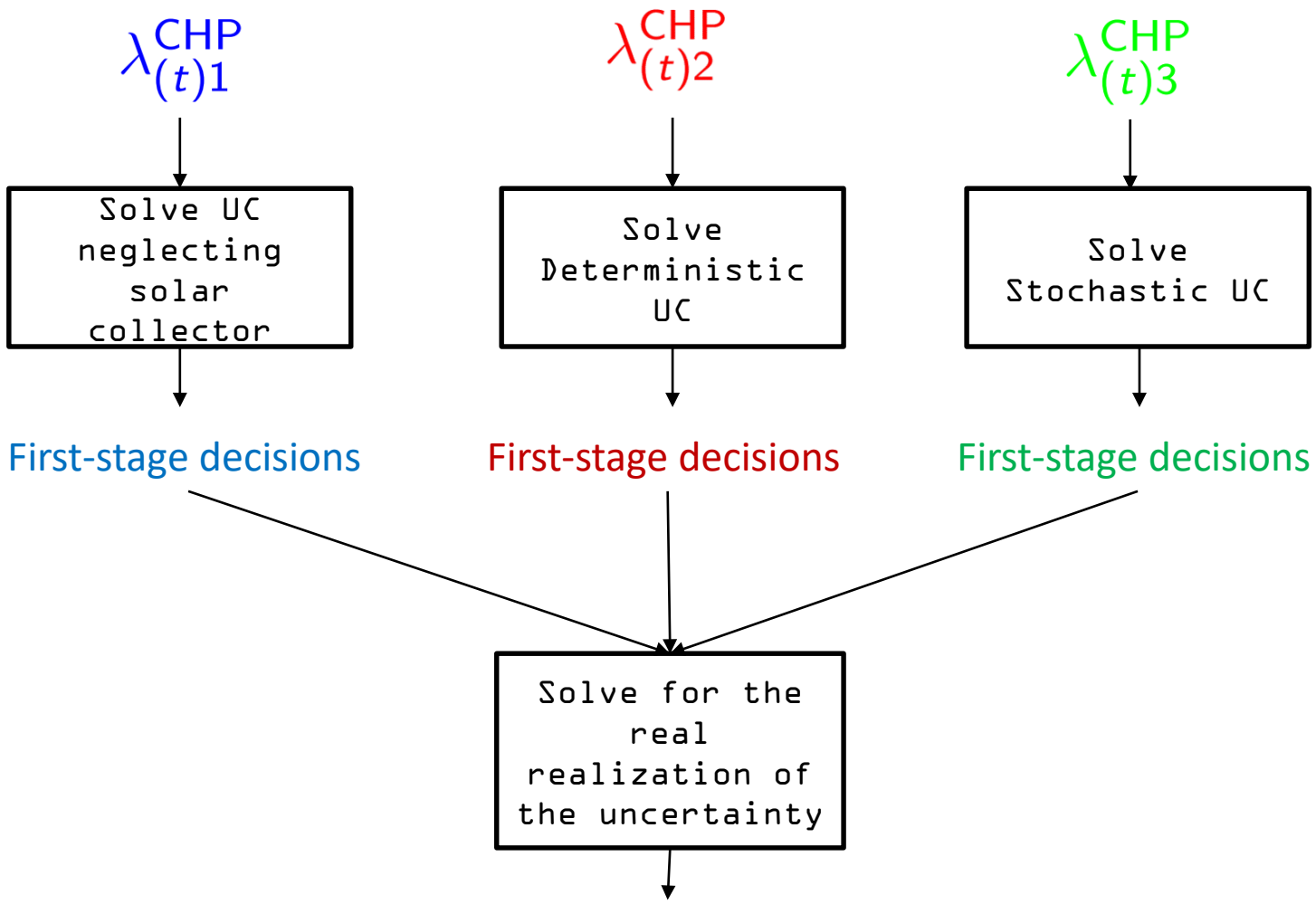
Solve ED considering no uncertainty

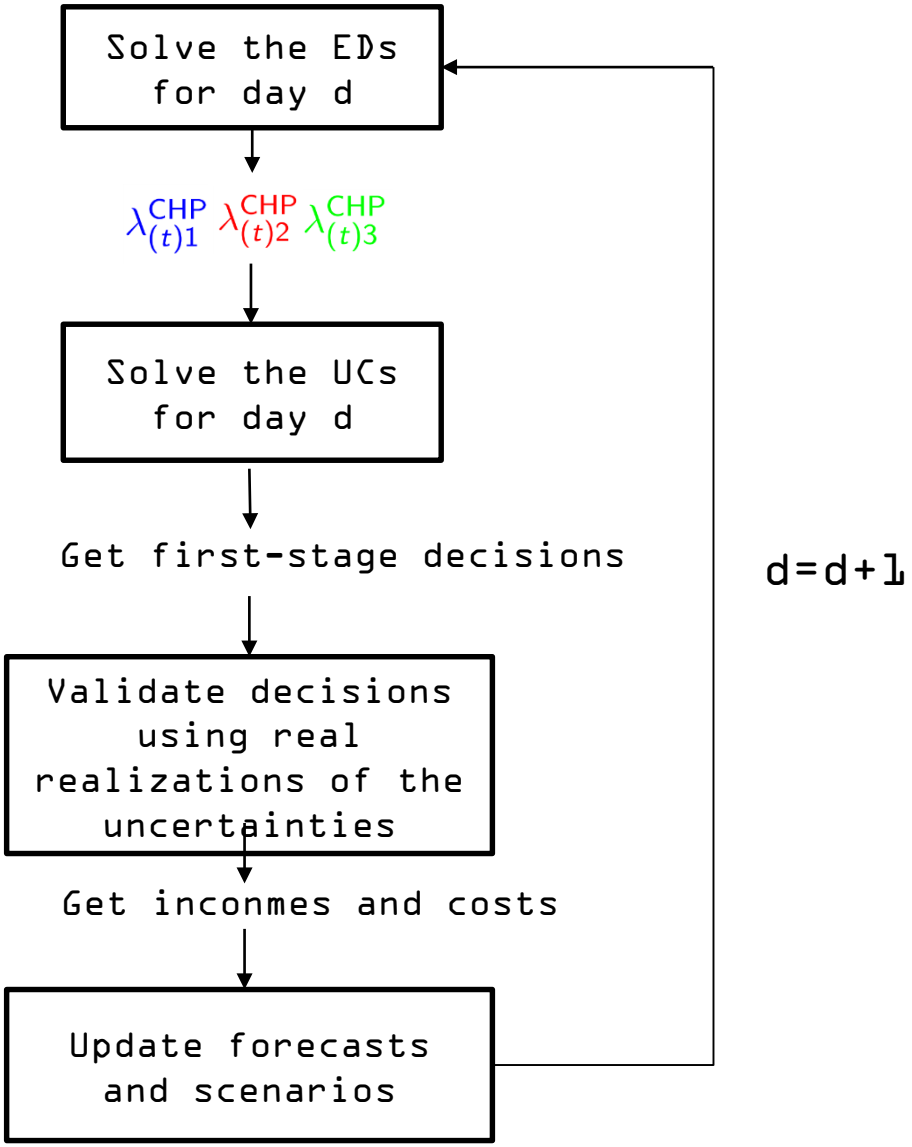
Solve EDs considering uncertainty as scenarios

$$\lambda^{\text{CHP}}_{(t)1}$$

$$\lambda^{\text{CHP}}_{(t)2}$$

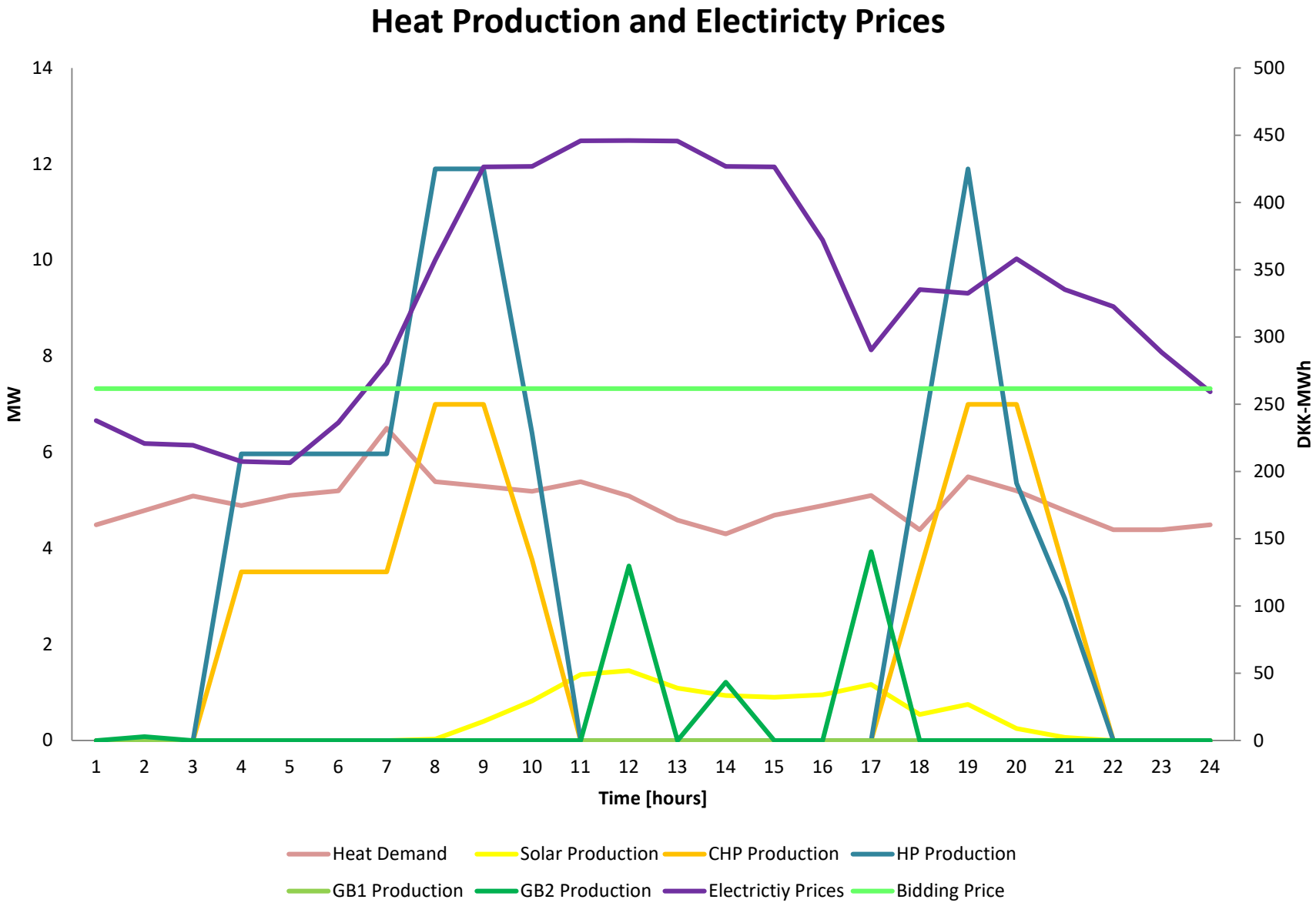
$$\lambda^{\text{CHP}}_{(t)3} = \sum_{\omega} \pi_{\omega} \lambda^{\text{CHP}}_{(\omega,t)3}$$

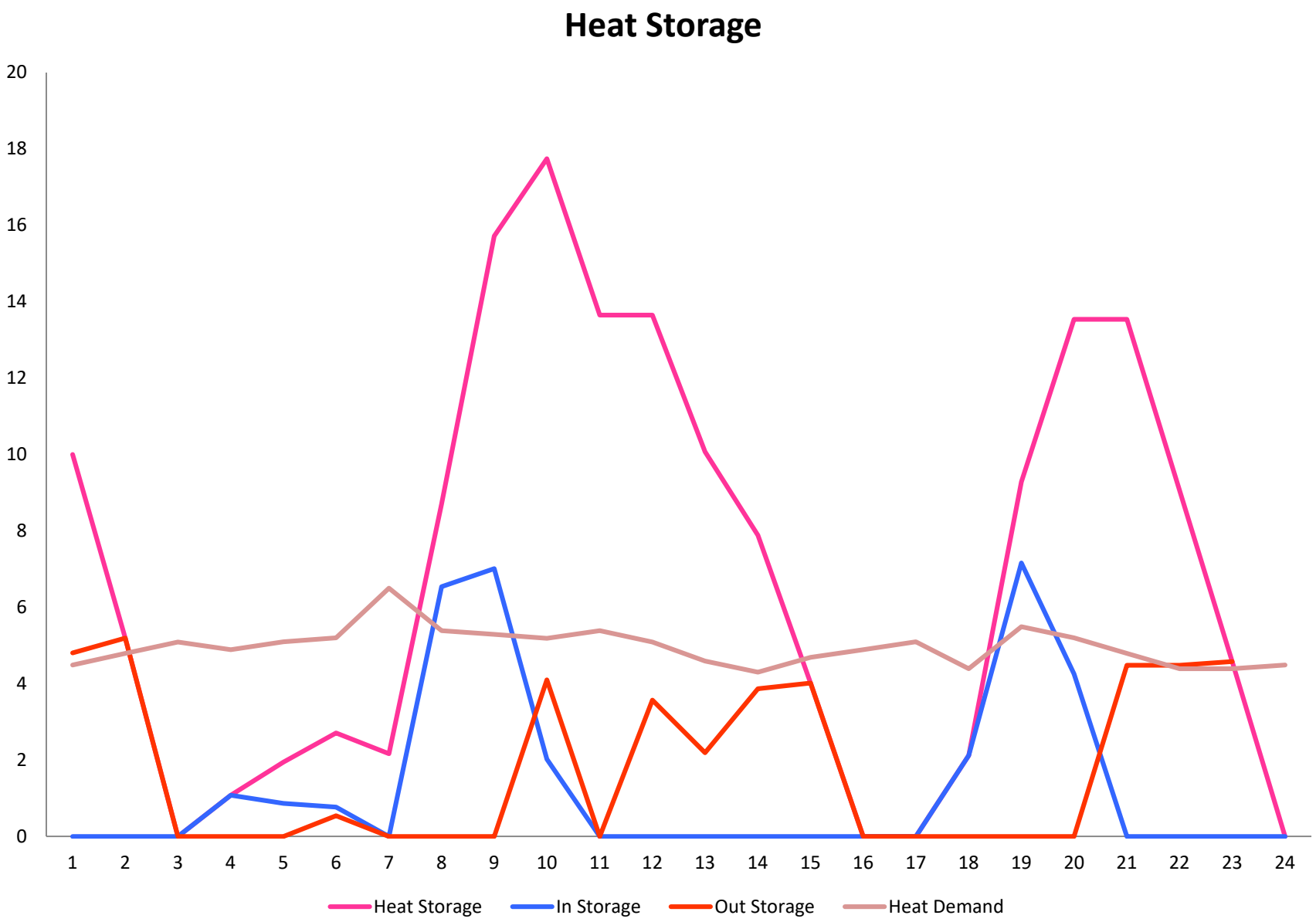

$\lambda^{CHP}_{(t)1}$
$\lambda^{CHP}_{(t)2}$
$\lambda^{CHP}_{(t)3}$
Solve UC neglecting solar collector
Solve Deterministic UC
Solve Stochastic UC
First-stage decisions
First-stage decisions
First-stage decisions
Solve for the real realization of the uncertainty
Check total costs and inconmes

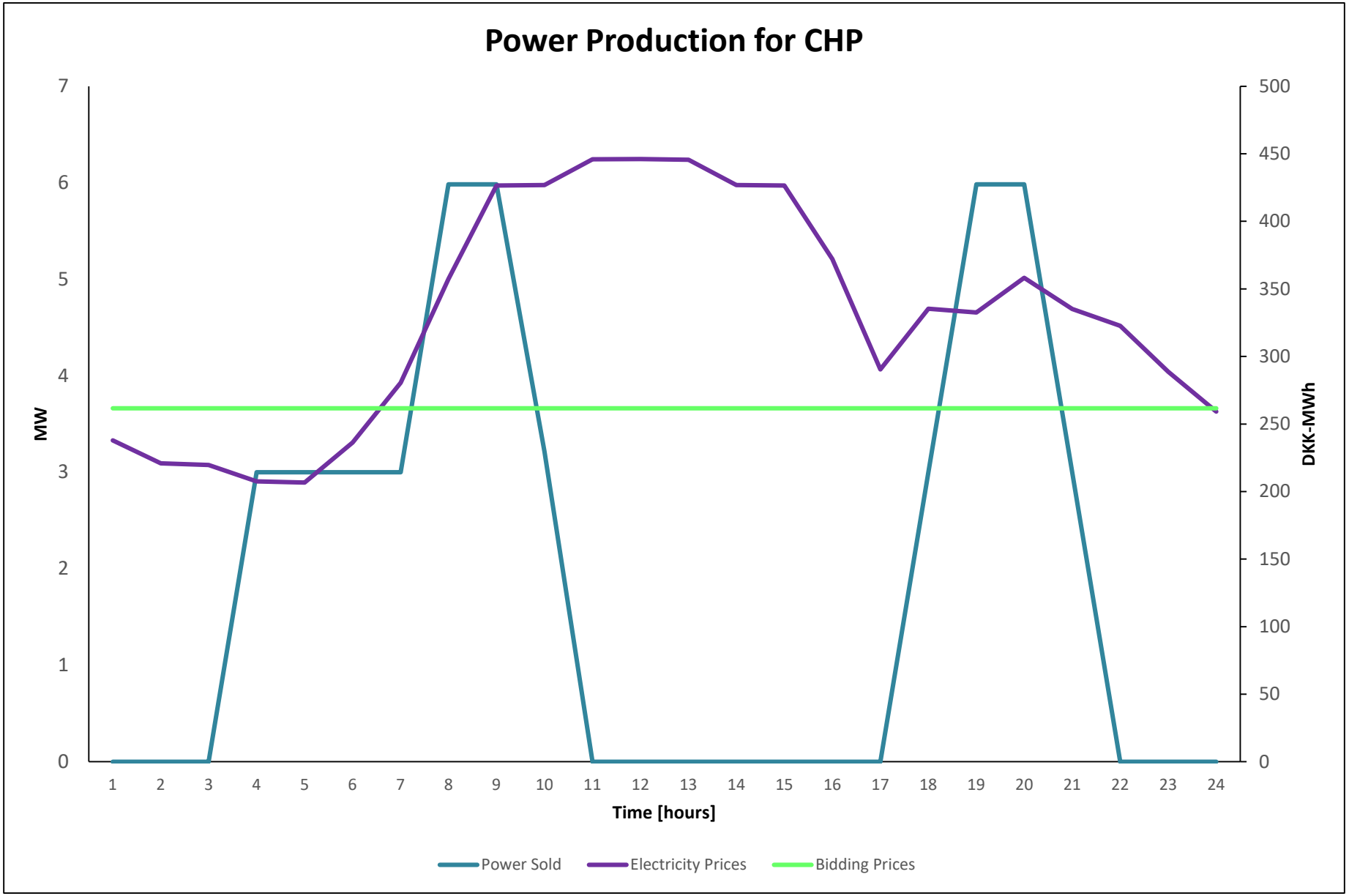

Solve the EDs for day d
$\lambda^{CHP}_{(t)1}$ $\lambda^{CHP}_{(t)2}$ $\lambda^{CHP}_{(t)3}$
Solve the UCs for day d
Get first-stage decisions
Validate decisions using real realizations of the uncertainties
Get inconmes and costs
Update forecasts and scenarios
d=d+1

5 Days Study

	Non Uncertainty	Deterministic	Stochastic
Day 1	-22106,82	-14176,98	-20646,87
Day 2	-24347,25	-20962,1	-18145,23
Day 3	-42229,16	-41193,59	-28147,14
Day 4	-24647,91	-21702,36	-25342,36
Day 5	-26555,22	-18886,29	-24871,04
	-139886,36	**-116921,32**	**-117152,64**


Heat Production and Electiricty Prices
MW
DKK-MWh
Time [hours]
0
2
4
6
8
10
12
14
0
50
100
150
200
250
300
350
400
450
500
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
Heat Demand
Solar Production
CHP Production
HP Production
GB1 Production
GB2 Production
Electrictiy Prices
Bidding Price


Heat Storage
20
18
16
14
12
10
8
6
4
2
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
Heat Storage
In Storage
Out Storage
Heat Demand


Power Production for CHP
MW
DKK-MWh
Time [hours]
0
1
2
3
4
5
6
7
0
50
100
150
200
250
300
350
400
450
500
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
Power Sold
Electricity Prices
Bidding Prices

THANK YOU

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