Demand Side Management Implementation

in Downstream Digestate Treatment of a Biomethane Biorefinery

Lilli Sophia Röder[1], Arne Gröngröft[1], Julia Riese[2], Marcus Grünewald[2]

[1]Deutsches Biomasseforschungszentrum gemeinnützige GmbH, Leipzig, Germany | [2]Ruhr University Bochum, Bochum, Germany

E2DT Conference – Palermo, Italy 22-25 October 2023

Funded by: Federal Ministry for Digital and Transport

Supervised by: RUB FluidVT

Demand Side Management

Expansion of **renewable energy sources**

Fluctuating power production but **rigid power demand**

Need for more flexibility in the electric power system

Manage power demand to synchronize it with power production

General Definition: Demand side management (DSM) involves actively switching or influencing electricity loads in response to an external price signal

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Demand Side Management

Expansion of **renewable energy sources**

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Manage power demand to synchronize it with power production

General Question: Is my process made for demand side management implementation **from an economic point of view**?

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Demand Side Management

Task 1:	Identification of a new industry area with high DSM that has not yet been optimized for DSM implementation
Task 2:	Development of a decision support tool to help estimate the profitability of a DSM implementation
Task 3:	Application of decision support tool on new industry area in a case study
Task 4:	Dynamic simulation and optimization of a DSM in new process for more realistic consideration
General Question:	Is my process made for demand side management implementation **from an economic point of view**?

→ **Bio-fuel production**

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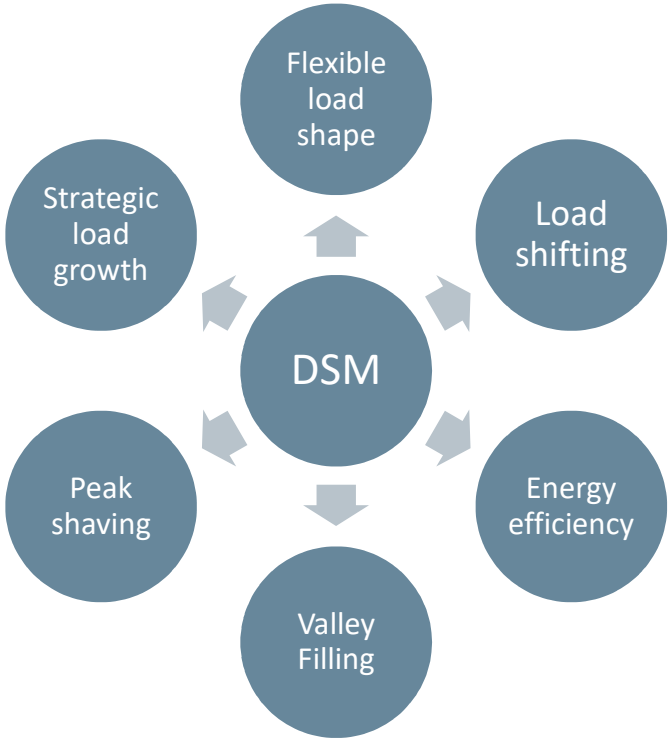
Background Task 2

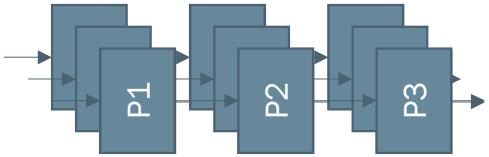
Development of a decision support tool of a DSM implementation



Development of a decision support tool of a DSM implementation

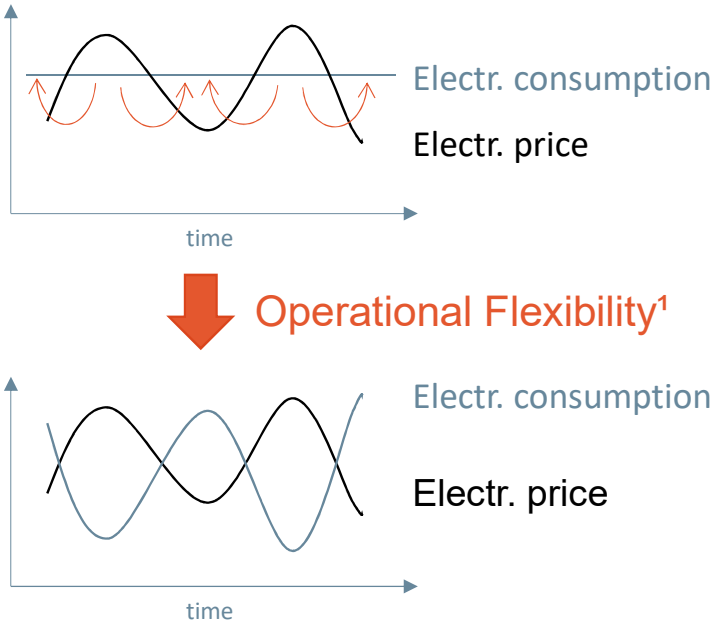
Load shifting

Oversizing



Demand Side:
Continuously operated industry processes

CAPEX $ ↑

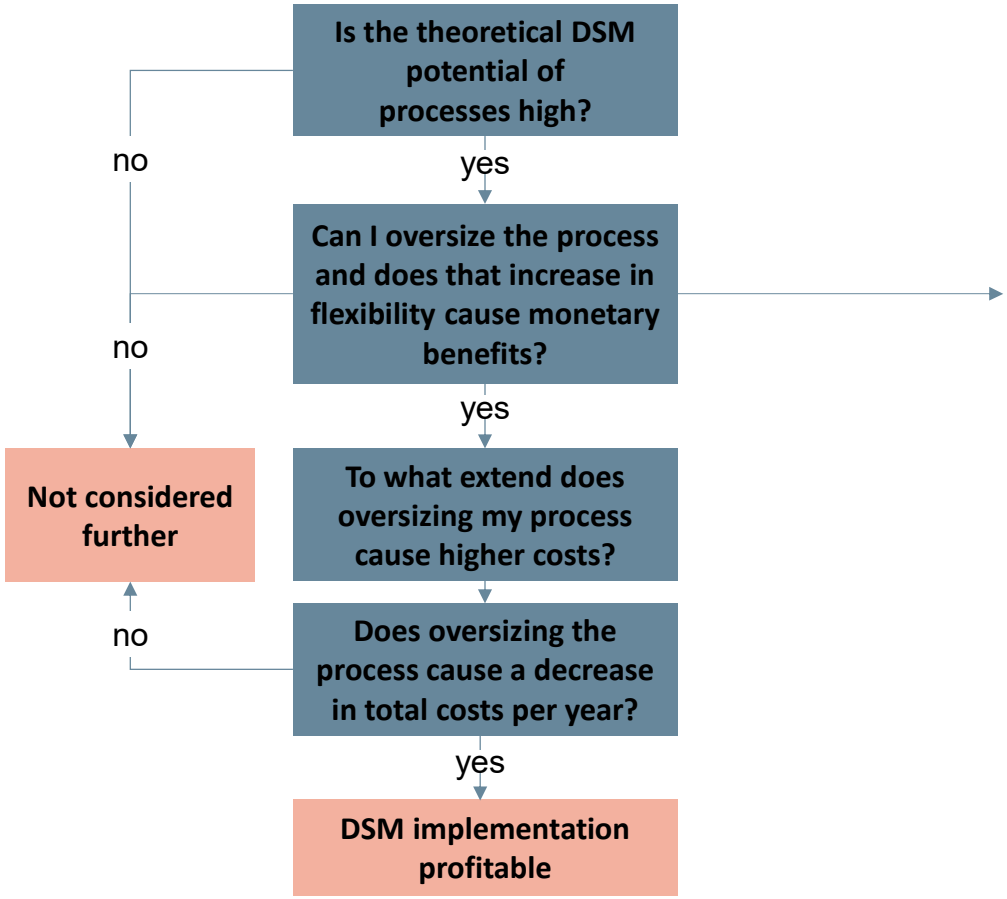


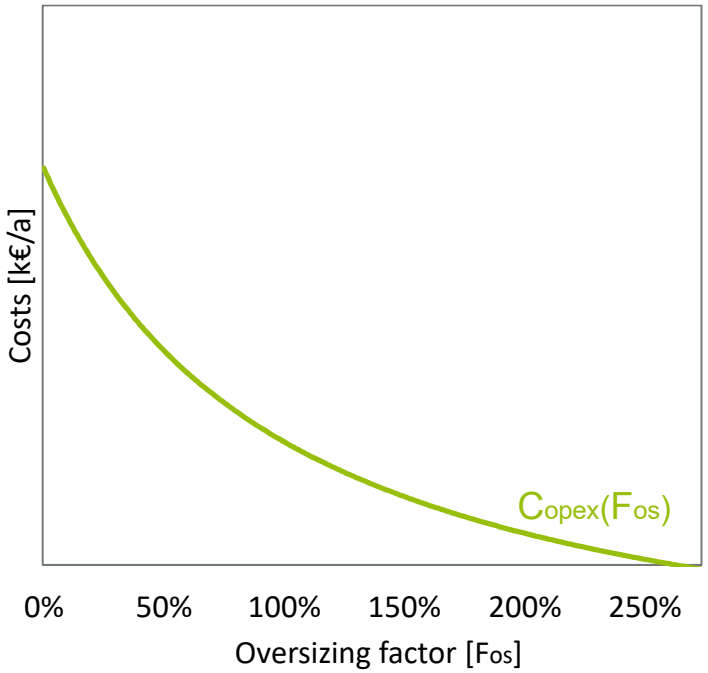
OPEX $ ↓

[1] Bruns et al. (2020) – DOI:10.1002/amp2.10063

Methodology Task 2

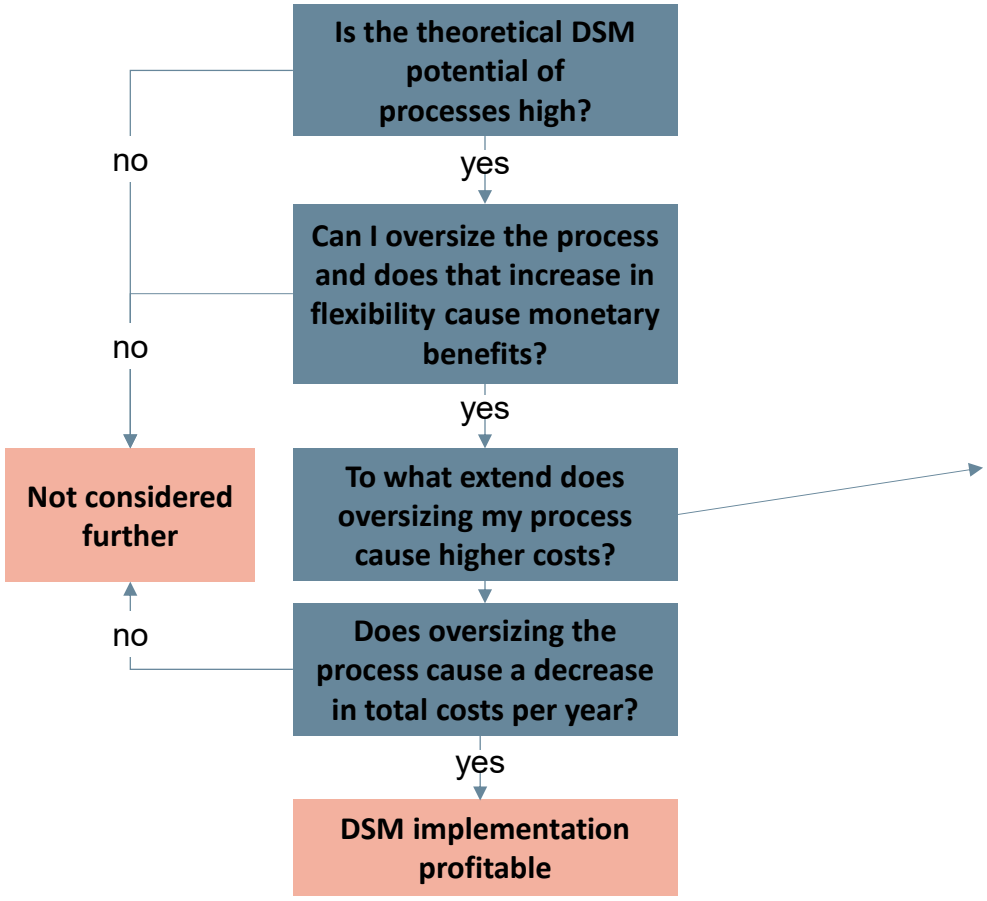
Development of a decision support tool of a DSM implementation

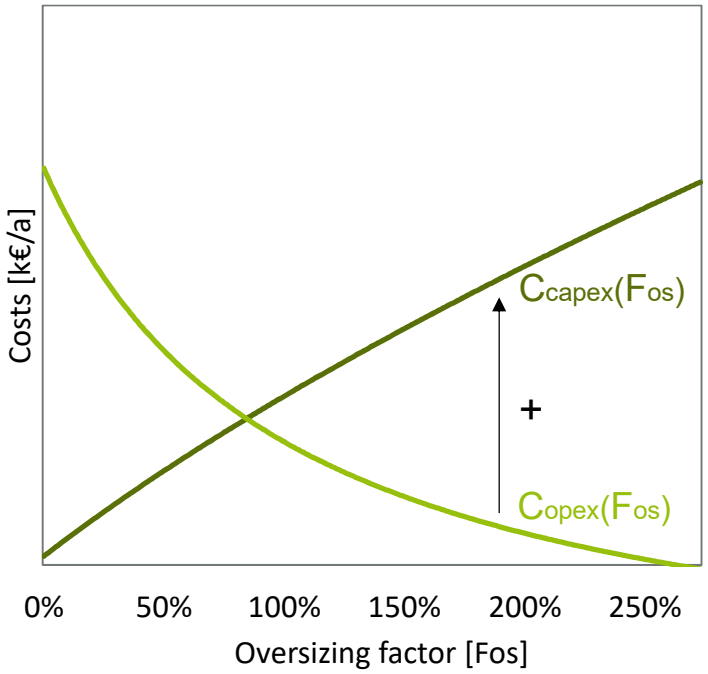




Röder et al. (2023) – DOI: 10.1002/bbb.2558

Development of a decision support tool of a DSM implementation





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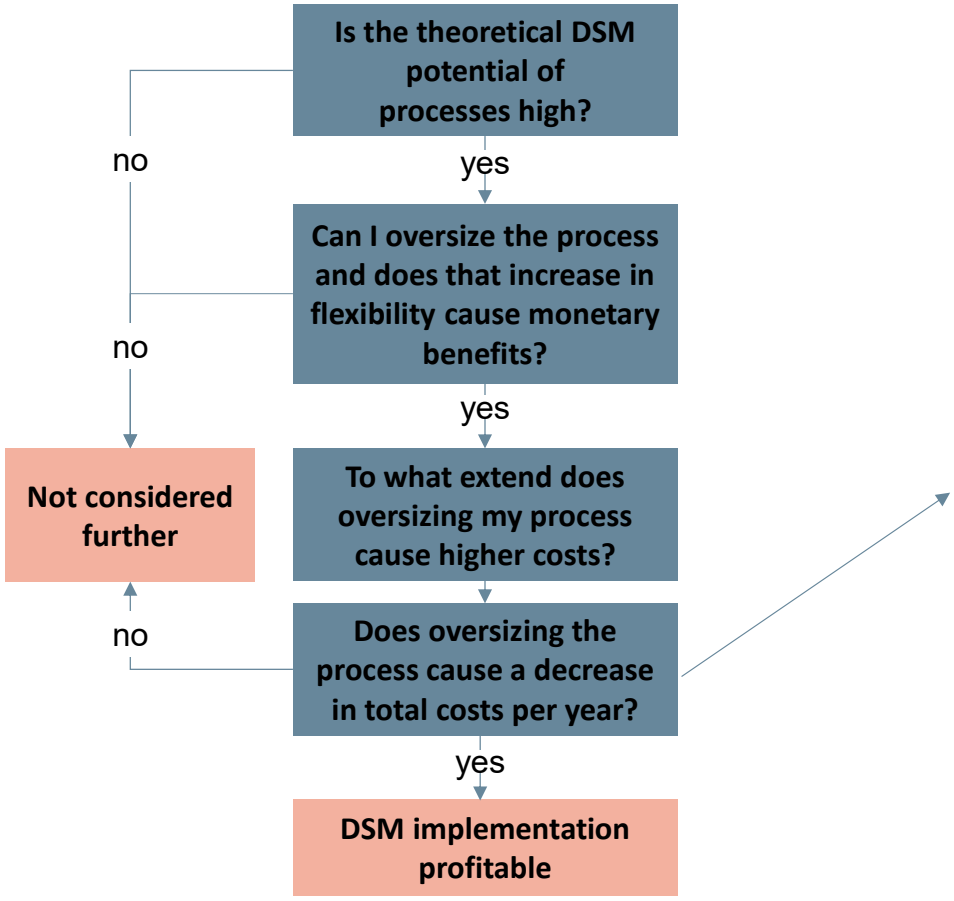

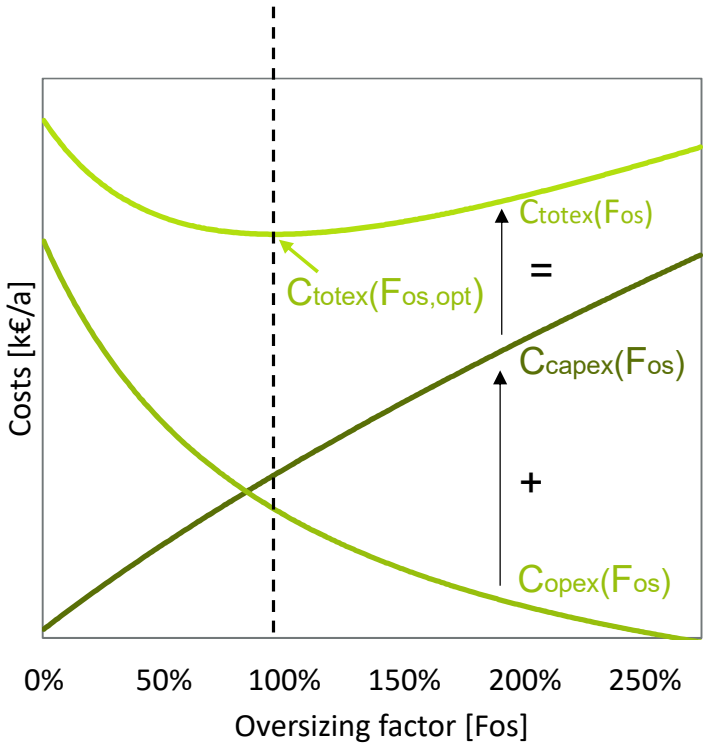

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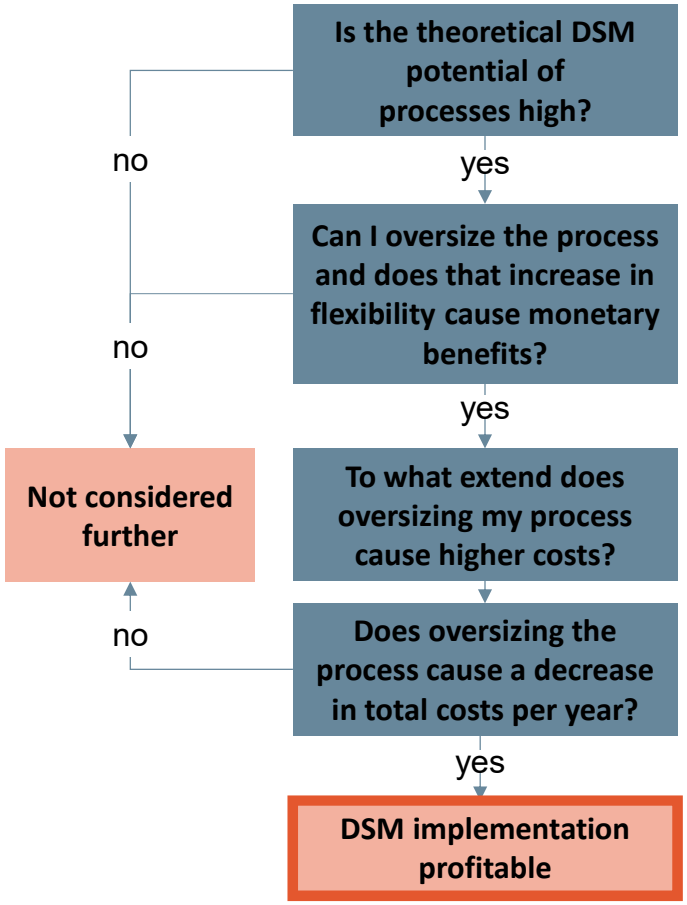

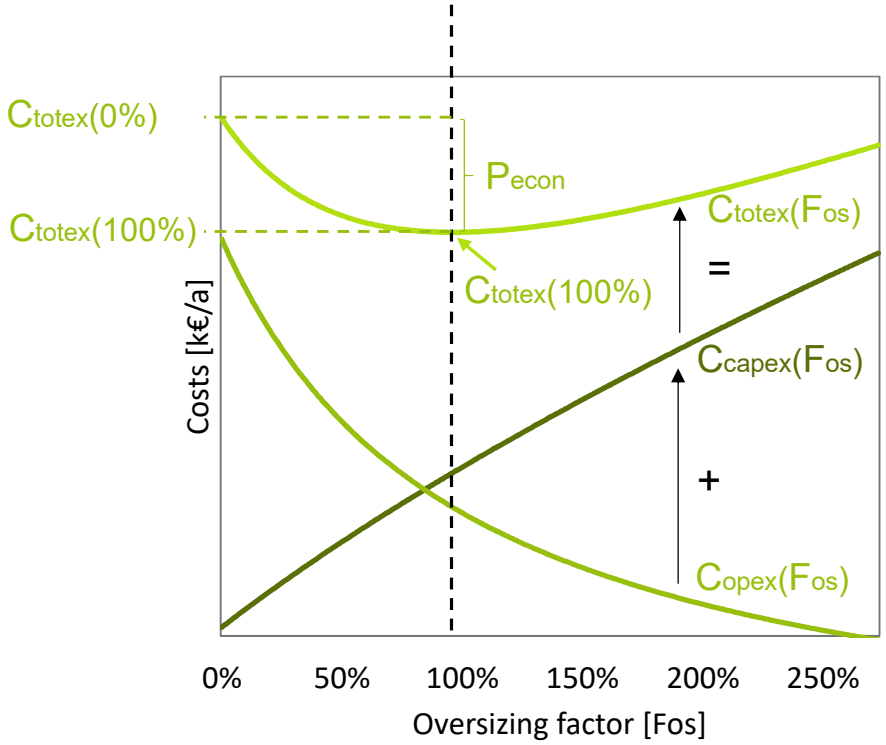

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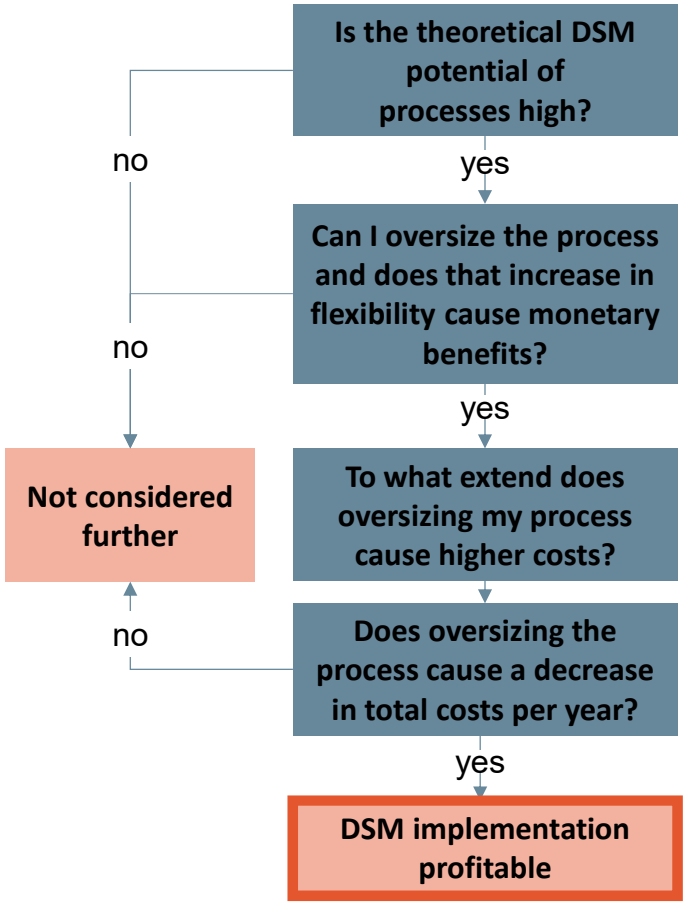
Methodology Task 2

Development of a decision support tool of a DSM implementation



$$C_{opex}(F_{os}) = \left(a_{year} - b_{year} * \left(\tau - \frac{\tau}{F_{os}+1} \right) \right) * EPC * \tau_{op}$$

$$C_{capex}(F_{os}) = I_{ref,P} * r_P * (F_{os}+1)^{R_P} + I_{ref,buf} * r_{buf} * \left(\frac{(\dot{m}_{buf}) * \left(\tau - \left(\frac{\tau}{F_{os}+1} \right) \right)}{V_{ref}} \right)^{R_{buf}}$$

$$C_{totex}(F_{os}) = C_{opex}(F_{os}) + C_{capex}(F_{os})$$

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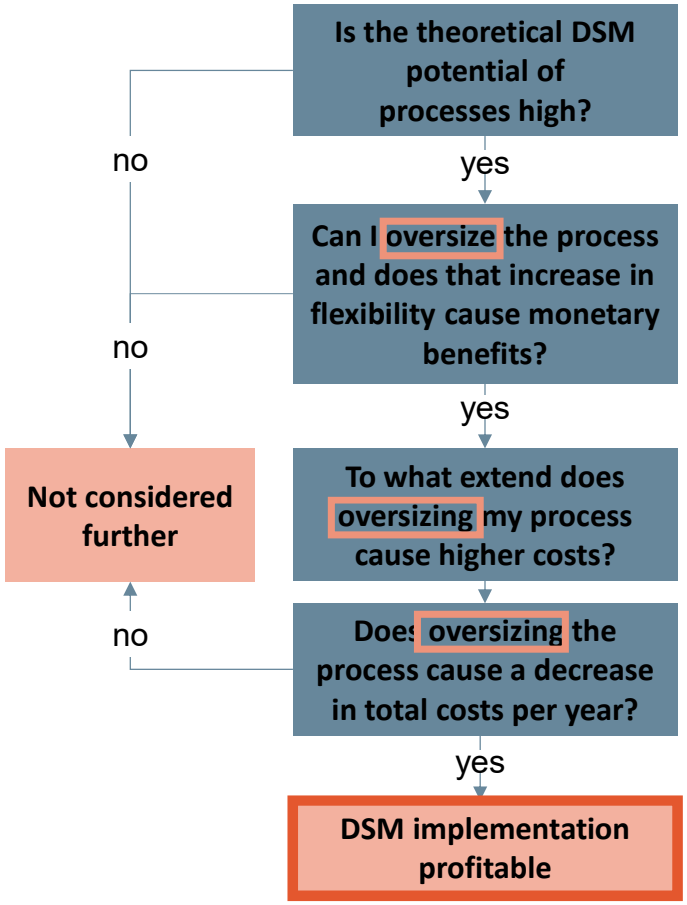
Development of a decision support tool of a DSM implementation



$$C_{opex}(F_{os}) = \left(a_{year} - b_{year} * \left(\tau - \frac{\tau}{F_{os}+1} \right) \right) * EPC * \tau_{oph}$$

$$C_{capex}(F_{os}) = I_{ref,P} * r_P * (F_{os}+1)^{R_P} + I_{ref,buf} * r_{buf} * \left(\frac{(\dot{m}_{buf}) * \left(\tau - \left(\frac{\tau}{F_{os}+1} \right) \right)}{V_{ref}} \right)^{R_{buf}}$$

$$C_{totex}(F_{os}) = C_{opex}(F_{os}) + C_{capex}(F_{os})$$

Task 2: Development of a decision support tool to help estimate the profitability of a DSM implementation

Röder et al. (2023) – DOI: 10.1002/bbb.2558

Steps to answer Task 3 and 4

Aspen Plus simulation of biorefinery described by Etzold et al. (2023)

↓

Transfer of simulated process from Aspen Plus to Aspen Custom Modeler

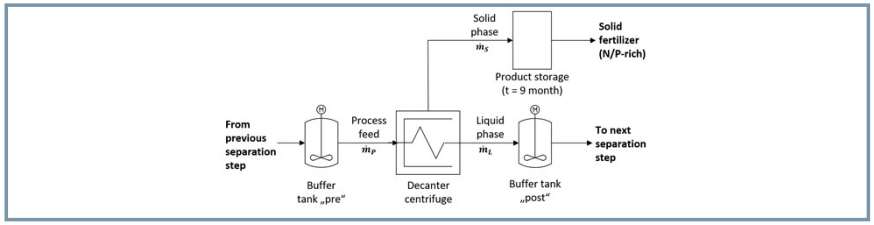
Decision support tool developed by Röder et al. (2023) to analyze economic DSM effects on processes

↓

Implementing Decision Support Tool Methodology into Aspen Custom Modeler Flowsheet

Task 3: **Application of decision support tool on new industry area in a case study**

Task 4: **Dynamic simulation and optimization of a DSM in new process for more realistic consideration**



$$C_{opex}(F_{os}) = \left(a_{year} - b_{year} * \left(\tau - \frac{\tau}{F_{os}+1} \right) \right) * EPC * \tau_{oph}$$

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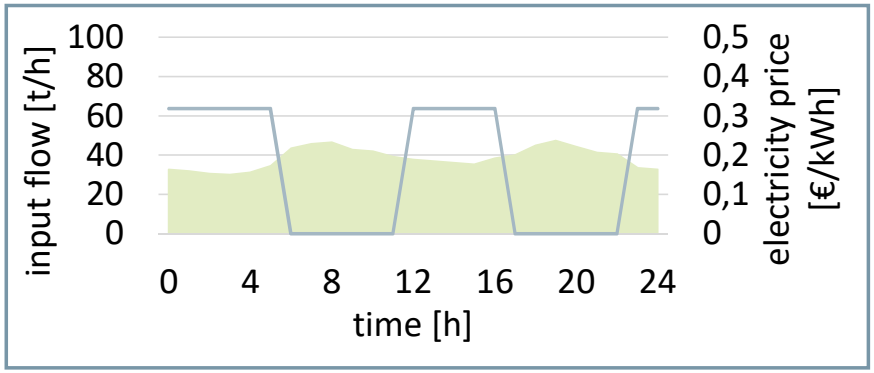
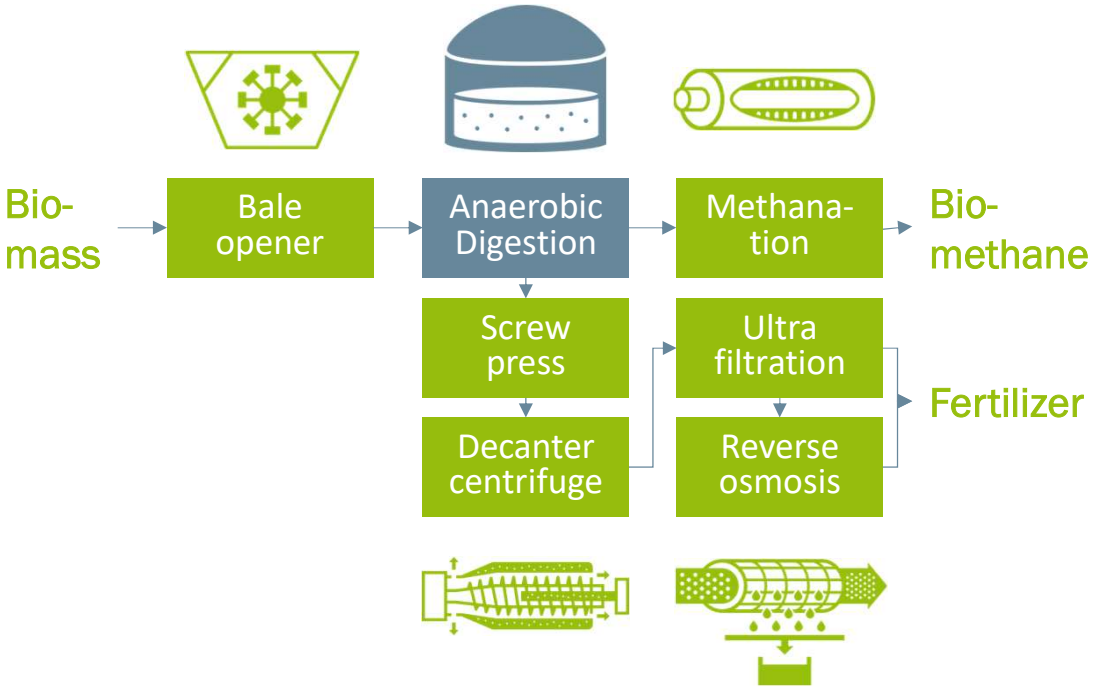


Methodology Task 3

Application of the decision support tool in a case study

Task 3:	**Application of decision support tool on new industry area in a case study**



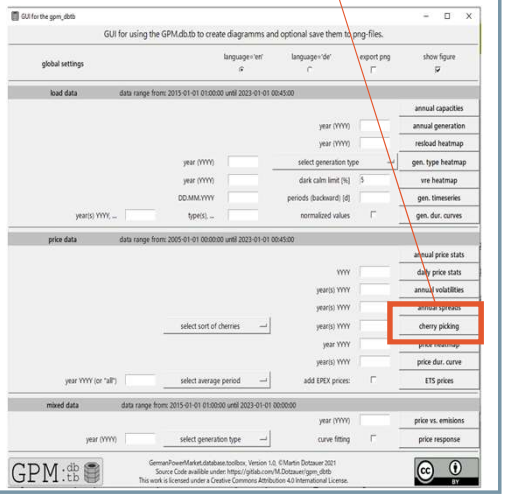
Application of the decision support tool in a case study

Does oversizing the process cause a decrease in total costs per year?

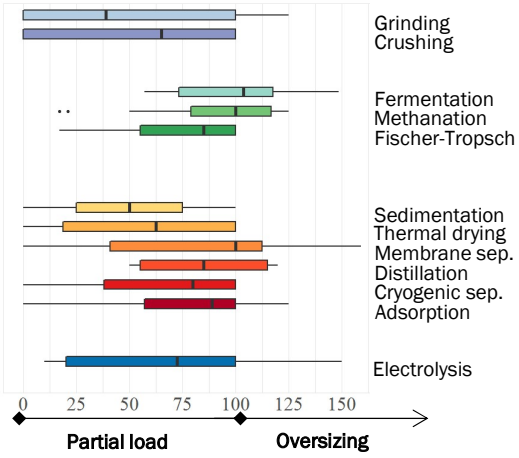
DSM strategies are based on the flexibility to turn a process off at times when prices are high but only serves an economic purpose if the monetary benefits exceed the increase in resulting capital costs

$$C_{totex}(F_{os}) = \left(a_{year} - b_{year} * \left(\tau - \frac{\tau}{F_{os}+1} \right) * (1 - FOP_{min}) \right) * EPC * \tau_{oph} + I_{ref,P} * r_P * (F_{os}+1)^{R_P} + I_{ref,buf} * r_{buf} * \left(\frac{(\dot{m}_{buf}) * \left(\tau - \left(\frac{\tau}{F_{os}+1} \right) \right)}{V_{ref}} \right)^{R_{buf}}$$

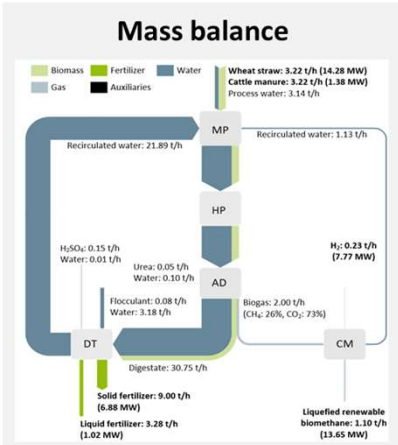
German power market database toolbox [1]

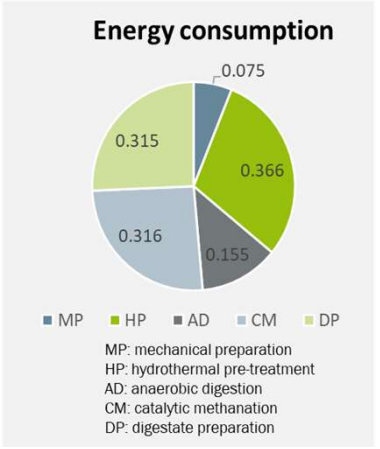


Literature review on DSM options in biofuel production [2]



Techno-economic assessment of novel biorefinery concept [3]





[1] Dotzauer (2020) – Gitlab.com/M.Dotzauer/gpm_dtbt

[2] Röder et al. (2022) – DOI:10.1002/er.8353

[3] Etzold et al. (2023) – DOI: 10.1016/j.biteb.2023.101476

Results Task 3:

Application of the decision support tool in a case study

Does oversizing the process cause a decrease in total costs per year?

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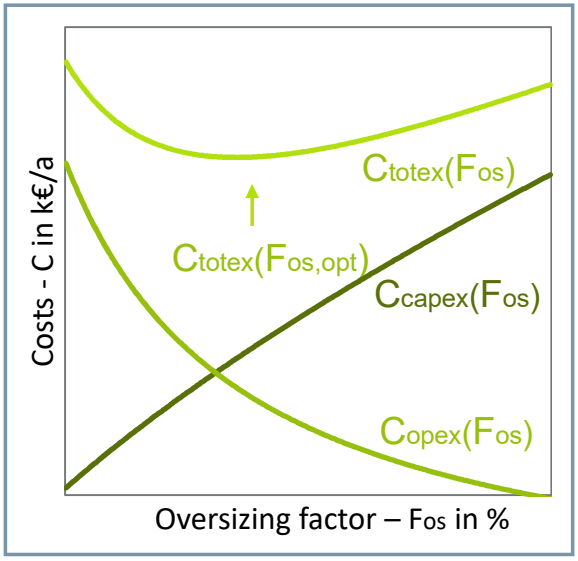


	$C_{totex,0}$ [€/day]	$F_{os,opt}$ [%]	$C_{totex,min}$ [€/day]	P_{econ} [€/day]	t_{pb} [a]
Bale opener	122	90	115		
Straw chopper	269	184	236		
Methanation	1555	0	1555		
Screw press	115	0	115		
Decanter centrifuge	927	209	821		
Ultra filtration	1051	0	1051		
Reverse osmosis	294	372	243		

Results Task 3:

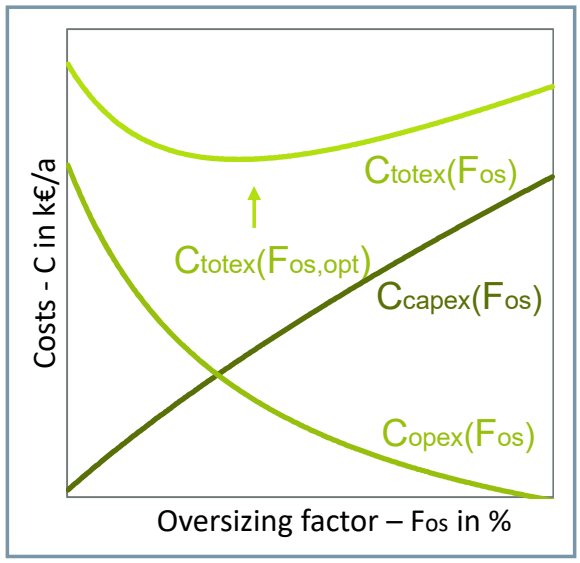
Application of the decision support tool in a case study

Does oversizing the process cause a decrease in total costs per year?

DSM strategies are based on the flexibility to turn a process off at times when prices are high but only serves an economic purpose if the monetary benefits exceed the increase in resulting capital costs

$$P_{econ} = C_{totex}(0\%) - C_{totex}(F_{os,opt})$$

$$t_{pb} = \frac{(C_{capex}(F_{os,opt}) - C_{capex}(0\%)) * t_{dep}}{C_{opex}(0\%) - C_{opex}(F_{os,opt})}$$



	$C_{totex,0}$ [€/day]	$F_{os,opt}$ [%]	$C_{totex,min}$ [€/day]	P_{econ} [€/day]	t_{pb} [a]
Bale opener	122	90	115	7	8
Straw chopper	269	184	236	33	6
Methanation	1555	0	1555		-
Screw press	115	0	115		-
Decanter centrifuge	927	209	821	105	8
Ultra filtration	1051	0	1051		-
Reverse osmosis	294	372	243	51	6

Methodology Task 4:

Dynamic optimization of process to evaluate DSM implementation

Aspen Plus simulation of biorefinery described by Etzold et al. (2023) transferred to Aspen Custom Modeler

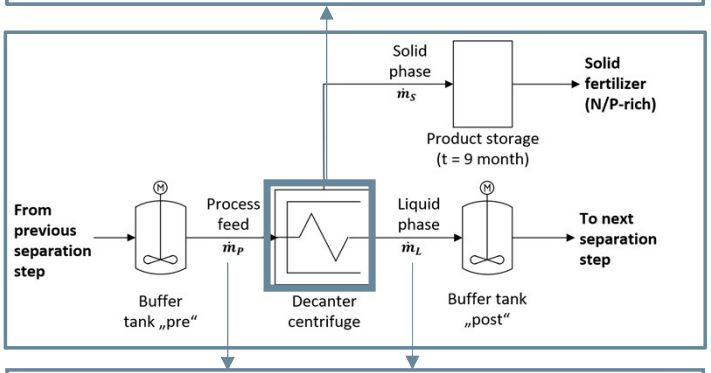
Oversizing factors F_{os} are predefined, to values are close to the value found in the pre-calculation but serve more realistic values in steps of 25%

$F_{os,opt}$ defines maximum throughput through process in dynamic simulation and equipment sizing

Dynamic optimization reacts to average electricity price curve for electricity prices in 2022 for 24 hours

Values for dynamic simulation:

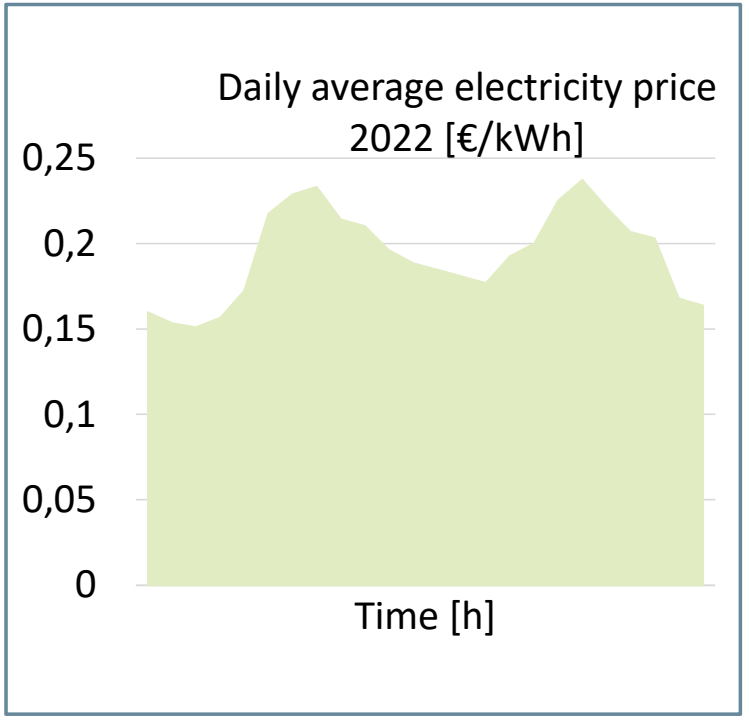
$F_{os,opt}$= 200 % ± 25%



Dynamic constraints:

$$\dot{m}_{p,max} = \dot{m}_{p,norm} * (1 + F_{os})$$

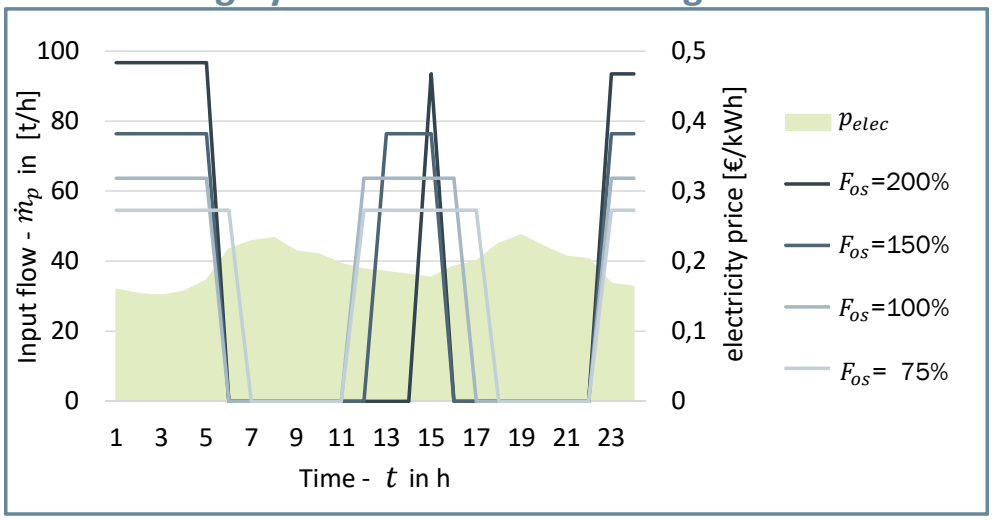
$$\int^{24} \dot{m}_{L,DSM} = \int^{24} \dot{m}_{L,norm}$$



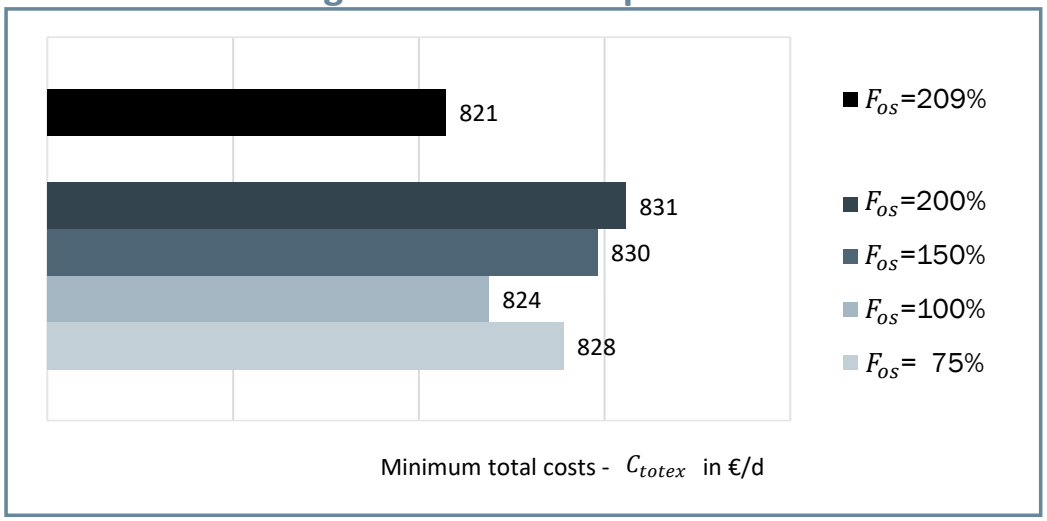
Results Task 4:

Dynamic optimization of process to evaluate DSM implementation

Resulting dynamic mass flow through decanter



Resulting economic DSM potential



- The resulting values for C_{totex} are lower for all F_{os} factors than those for 200%, where optimal oversizing was initially assumed
- In dynamic simulation result for optimal oversizing factor is F_{os}=100%
- Deviations occur from steady-state results due to the switch-on and off times of the processes

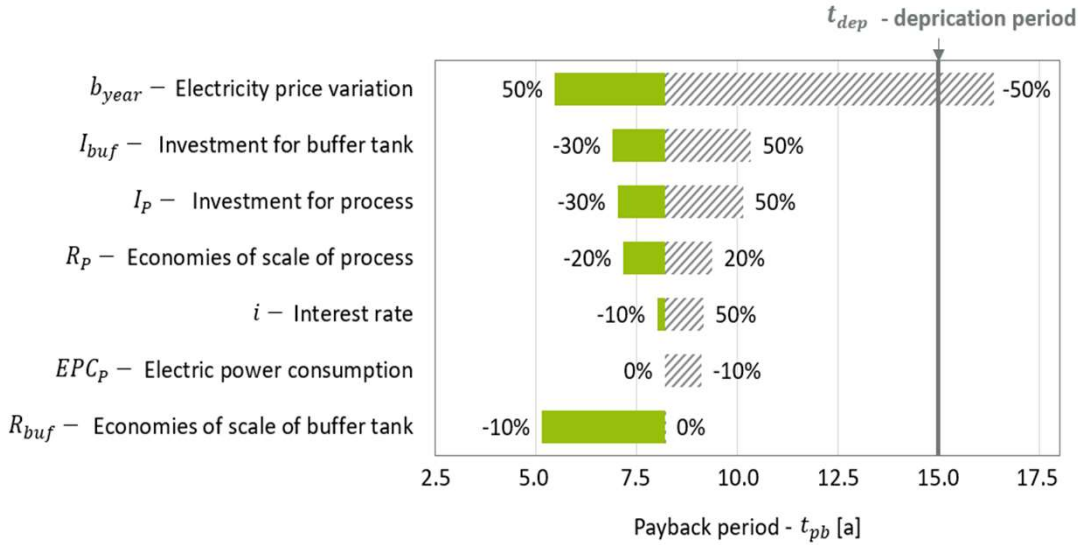
Sensitivity Analysis

Does oversizing the process cause a decrease in total costs per year?

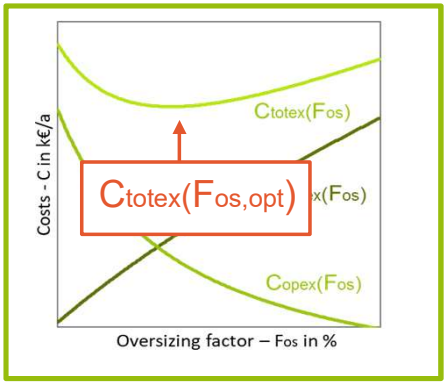
Implementing DSM only serves an economic purpose if the monetary benefits exceed this increase in capital costs

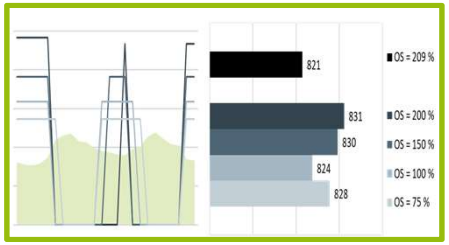
	Used Value	Optmistic uncertainty	Pessimistic uncertainty
b_{year}	0.0038 €/kW*h²	50%	-50%
I_{P}, I_{buf}	22 k€, 197 k€	-30%	50%
R_{P}	0.6	-20%	20%
i	11%	-10%	50%
EPC_{P}	174 kW	0%	-10%
R_{buf}	1.0	-10%	0%

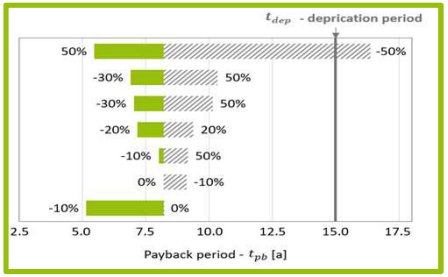
Sensitivity analysis



Summary







- A tool for assessing economic parameters in DSM implementation for continuously operated processes has been proposed.
- The key aspect is determining the extent to which a process step should be oversized to maximize flexibility but not incur excessive additional costs.
- For the optimal oversizing factor a lower value was obtained in the dynamic simulation in comparison to the initial steady-state assumption, due to different electricity prices and reaction times in the dynamic perspective
- The biggest factors uncertainties influencing the economic profitability of DSM in continuously operated processes are electricity price fluctuations and investment costs for process and intermediate storage.

Outlook

	$C_{totex,0}$ [€/day]	$F_{os,opt}$ [%]	$C_{totex,min}$ [€/day]	P_{econ} [€/day]	t_{pb} [a]
Bale opener	122	90	115	7	8
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Ultra filtration	1051	0	1051		-
Reverse osmosis	294	372	243	51	6

Two of four processes in digestate treatment cascade suitable for DSM

→ Outlook: Could making the intermediate steps more flexible further minimize the total cost of the cascade?

Thank you for your attention!

Lilli Sophia Röder
Department of Biorefineries
Research Associate at Separation Techniques and Process development

DBFZ Deutsches Biomasseforschungszentrum gemeinnützige GmbH
Torgauer Straße 116
D-04347 Leipzig

lilli.Sophia.roeder@dbfz.de
+49 (0)341 2434-424

Funded by: Federal Ministry for Digital and Transport
Supervised by: RUB FluidVT