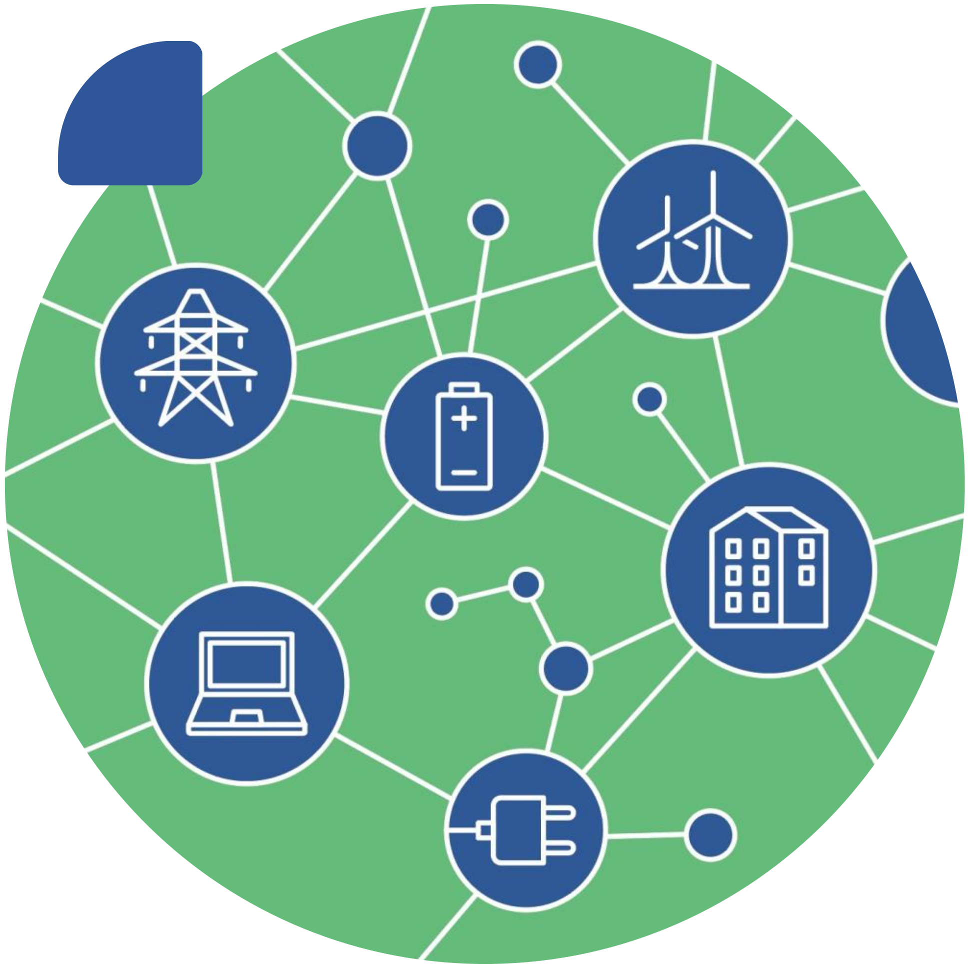


OSMOSE

OPTIMAL SYSTEM-MIX OF FLEXIBILITY SOLUTIONS FOR EUROPEAN ELECTRICITY

WP7 Scaling up and replication

T7.3 Methodology for optimal design of BESS

June 18th, 2020 | **Webinar**

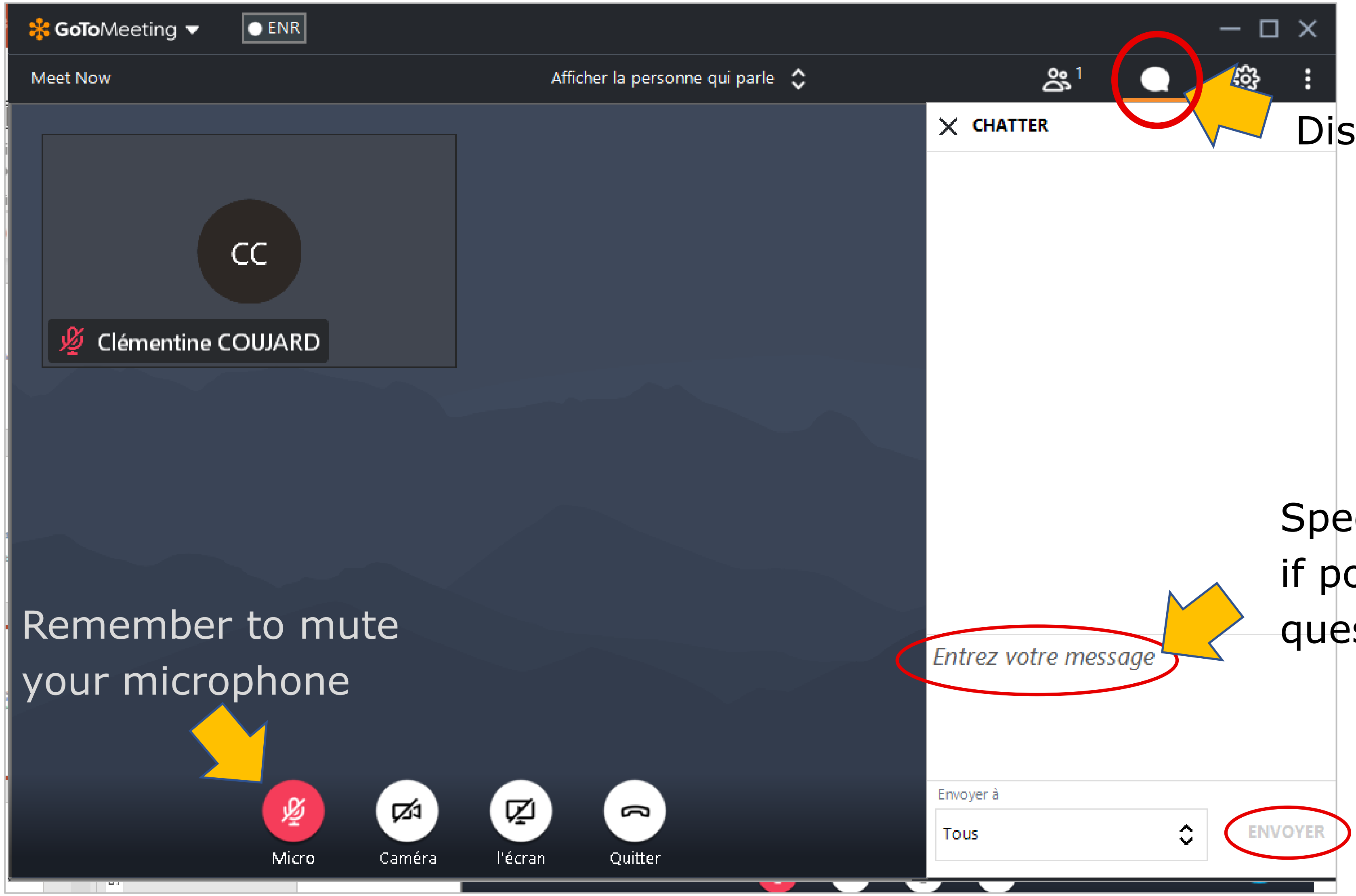
Benoît RICHARD | CEA

Agenda

1. Introduction to the OSMOSE project
2. Presentation of the work on BESS optimal sizing methodology
3. Q&A session

Webinar process

- Use the chat box to write your questions
- The moderator will synthesise all questions and introduce them after the presentation
- The deliverable associated to the work presented today and the slides are available on OSMOSE website : www.osmose-h2020.eu/deliverables
- The webinar is recorded and will be published in OSMOSE website

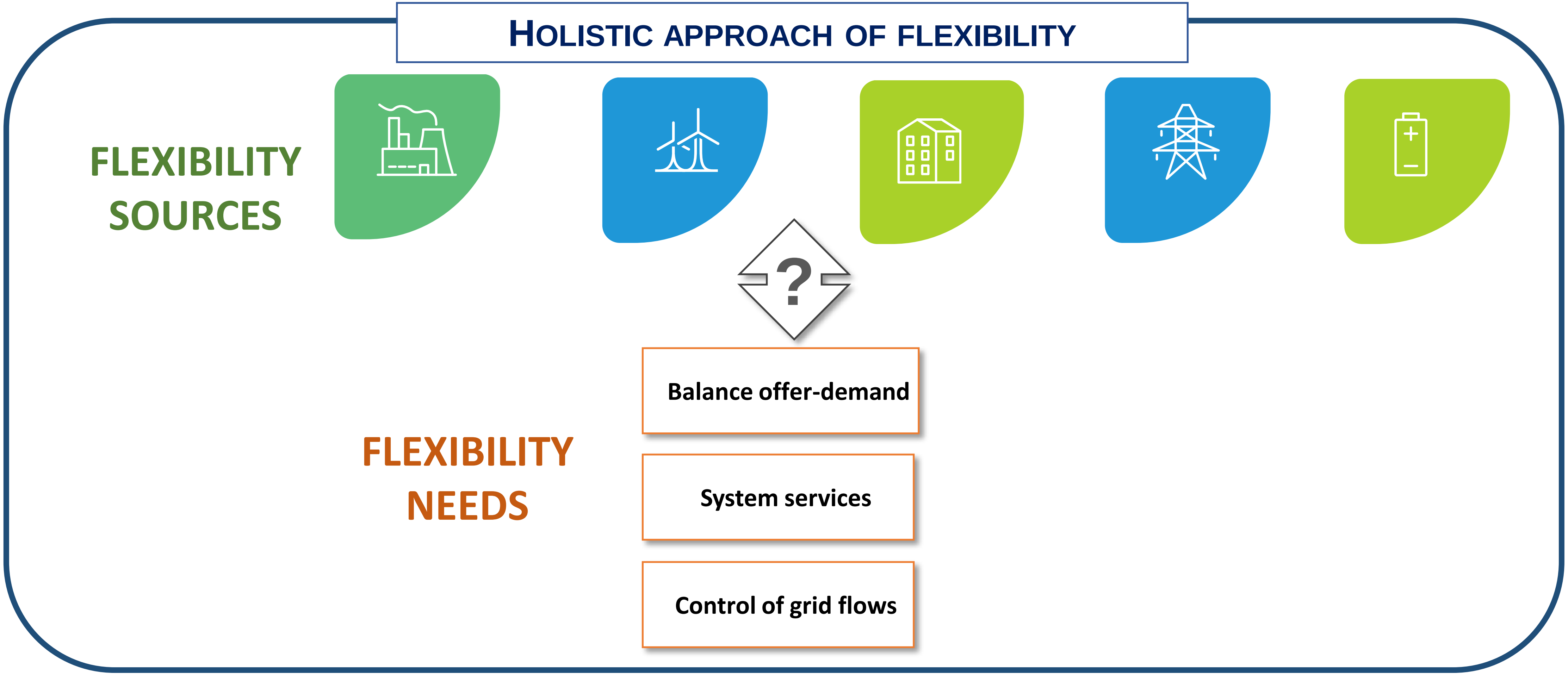


Display CHATTER

Specifiy slide number if possible in your question

Combining new needs and solutions

HOLISTIC APPROACH OF FLEXIBILITY



The consortium

- ✓ H2020 EU funded
- ✓ 28M€ budget
- ✓ 33 partners
- ✓ Leaders: **RTE**, REE, TERNA, ELES, CEA, TUB
- ✓ 2018 – 2021

Overview

Methods and simulations

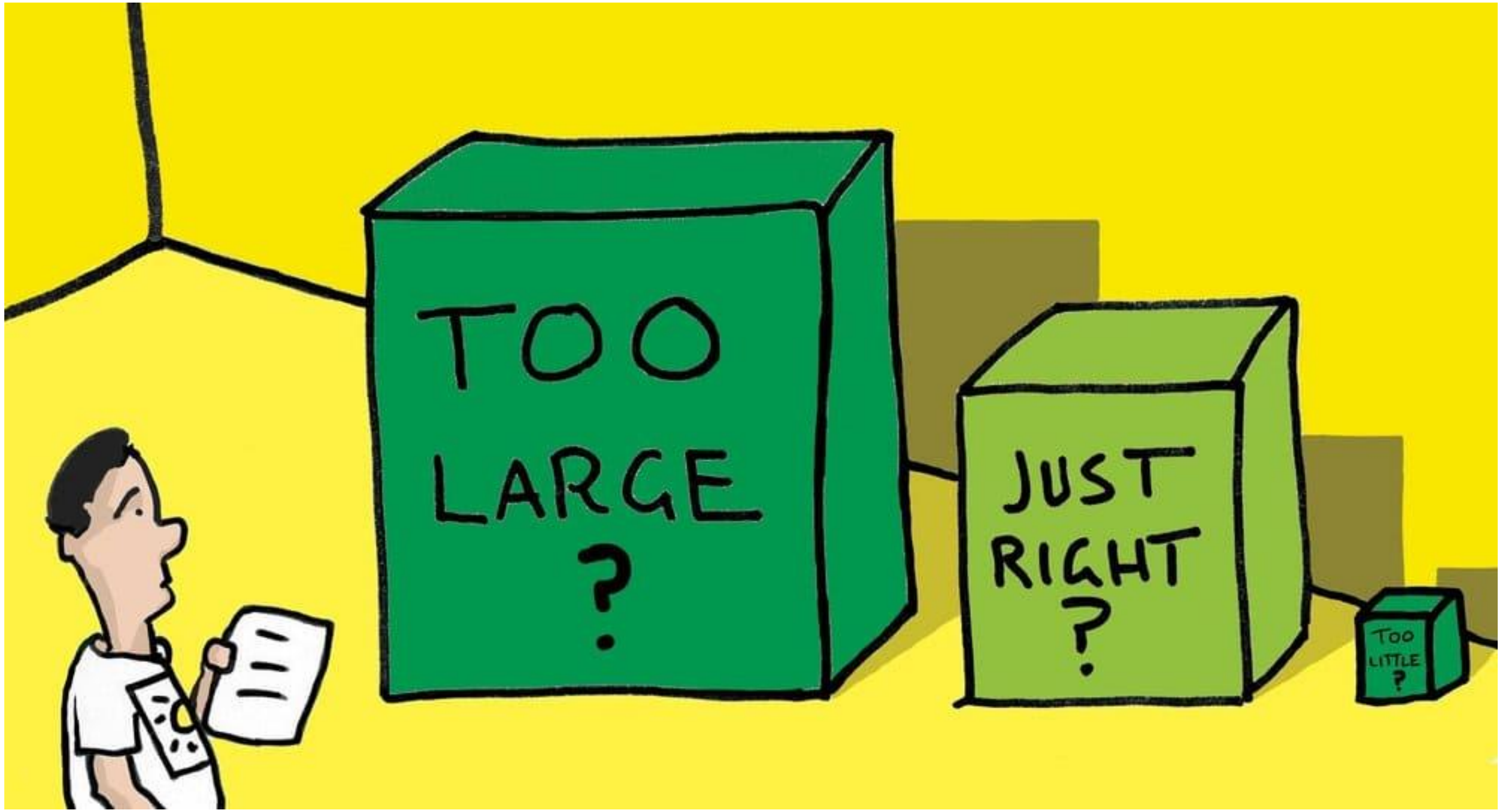
- Technische Universität Berlin — Optimal mix of flexibilities (WP1)
- Rte — Market designs and regulations (WP2)

Demonstrators

- Rte — Grid forming by multi-services hybrid storage (WP3)
- Red Eléctrica de España — Multi-services by different storage and FACTS devices (WP4)
- Terna Group — Multi-services by coordinated grid devices, large demand-response and RES (WP5)
- ELES — Near real-time cross-border energy market (WP6)

CEA tech — Scaling-up & replication (WP7)

Sub-Task 7.3.1 Battery Energy Storage Systems (BESS) optimal sizing methodology



Agenda

1. General problem of BESS sizing
2. Optimal sizing method implemented
3. Illustrative BESS use cases
4. Sensitivity analysis
5. Conclusion

Agenda

1. **General problem of BESS sizing**
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WP7

General problem of BESS sizing

Energy / power application needs ?

BESS efficiency ?

Battery ageing ?

Project lifetime ?

BESS SIZING IS NOT EASY !

EMS control ?

Forecast errors ?

Sollicitation profiles ?

Generation costs ?
Utilities prices ?

IN MOST CASES

Sizing on « worst case » scenario

UNDERSIZED

- Service not correctly achieved
- Battery to replace sooner than expected due to intense cycling

OPTIMAL SIZE ?

FOSTER THE COMPETITIVENESS OF BESS AS FLEXIBILTY SOURCE

OVERSIZED

- Higher CAPEX / OPEX budget than necessary
- Financial brake on investment

What are the most influencing factors to consider in a BESS sizing procedure ?

D7.5

“Methodology report for application-specific design of BESS”

Dissemination level : public

1 Implementation of an optimal sizing method

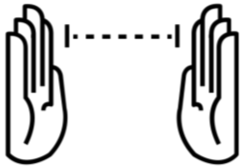
Deterministic method using numerical simulation

2 Sensitivity analysis

- ***Identify the key drivers for BESS optimal size determination***

EMS control
Forecast errors
Battery ageing
BESS *efficiency*
Sollicitation profiles

- ***Quantify their impact on sizing results***



Strong impact ?

Low impact ?

Agenda

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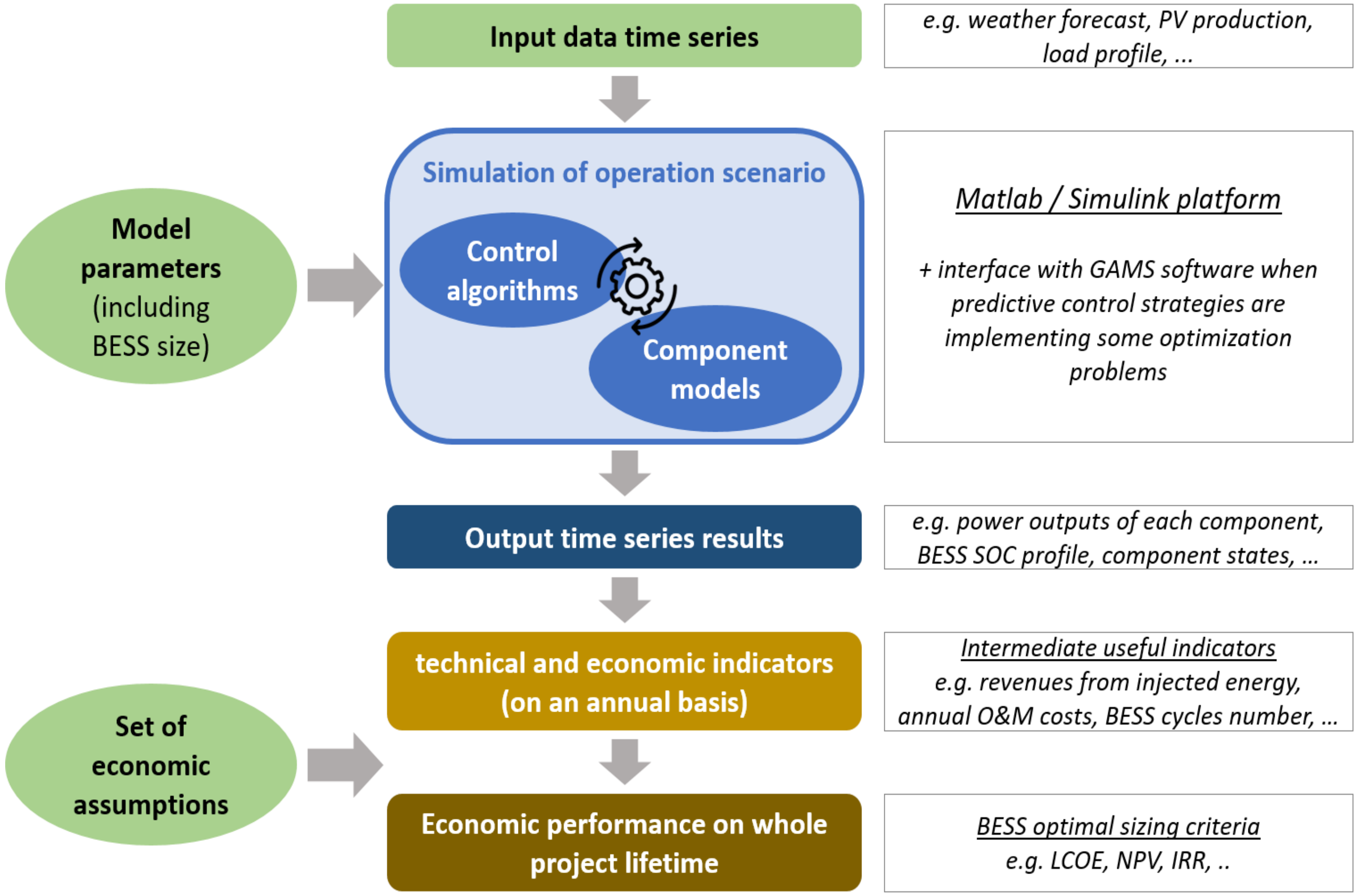
WP7

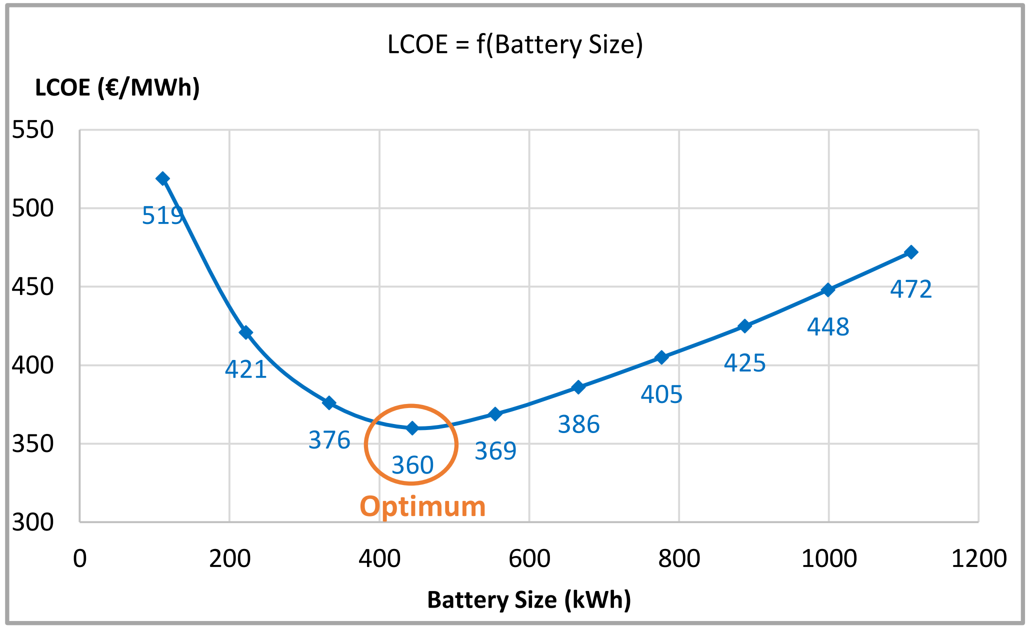
Optimal sizing method implemented

Synoptic of the simulation-based method implemented



Optimal sizing indicator

Criteria	Formula	Details
Levelized Cost of Energy	$\boldsymbol{LCOE} = \dfrac{\sum_{n=0}^{N} \dfrac{CAPEX_n + OPEX_n}{(1+r)^n}}{\sum_{n=0}^{N} \dfrac{E_n}{(1+r)^n}}$	$CAPEX_n$: Investment costs of year n $OPEX_n$: O&M costs of year n E_n : total electrical energy generated in the year n r : discount rate N : project lifetime
Net Present Value	$\boldsymbol{NPV} = \sum_{n=0}^{N} \dfrac{CF_n}{(1+r)^n}$	CF_n : cash flow of year n r : discount rate N : project lifetime
Internal Rate of Return	$\sum_{n=0}^{N} \dfrac{CF_n}{(1+\boldsymbol{IRR})^n} = 0$	CF_n : cash flow of year n IRR : internal rate of return N : project lifetime



Agenda

1. General problem of BESS sizing
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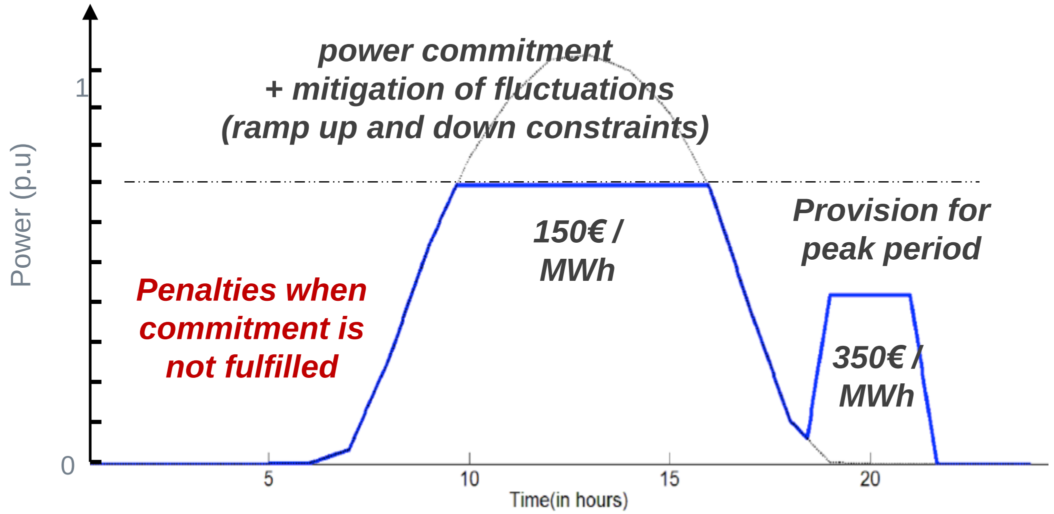
2 illustrative BESS application cases have been used for optimal sizing analysis

PV smoothing and peak shaving

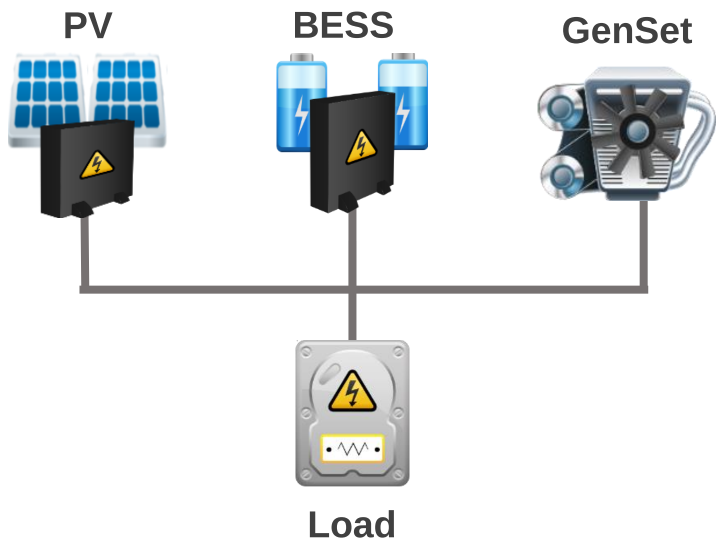
(Call for tenders – French Energy Regulatory Commission)



BESS optimal size is obtained when benefits are maximum over the project lifetime

Sizing Criteria = NPV (Net Present Value)

Hybrid microgrid



BESS optimal size is obtained when load can be fed at minimum cost of energy produced

Sizing Criteria = LCOE (Levelized Cost Of Energy)

Agenda

1. General problem of BESS sizing
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4. **Sensitivity analysis**
5. Conclusion

Sensitivity analysis

Factors investigated through sensitivity analysis
Precision of the BESS efficiency
Degradation of battery capacity due to ageing
Degree of technical modelling
Simulation time-step
Control strategy
Forecast quality

Sensitivity analysis

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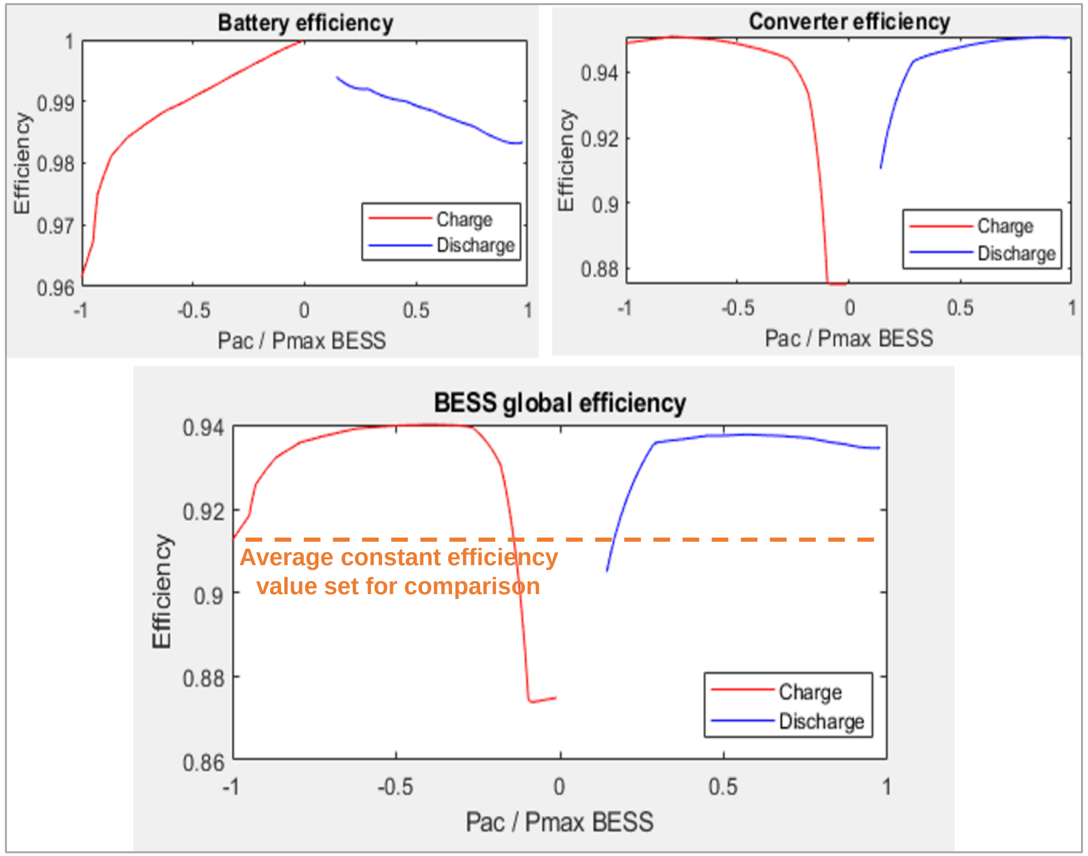
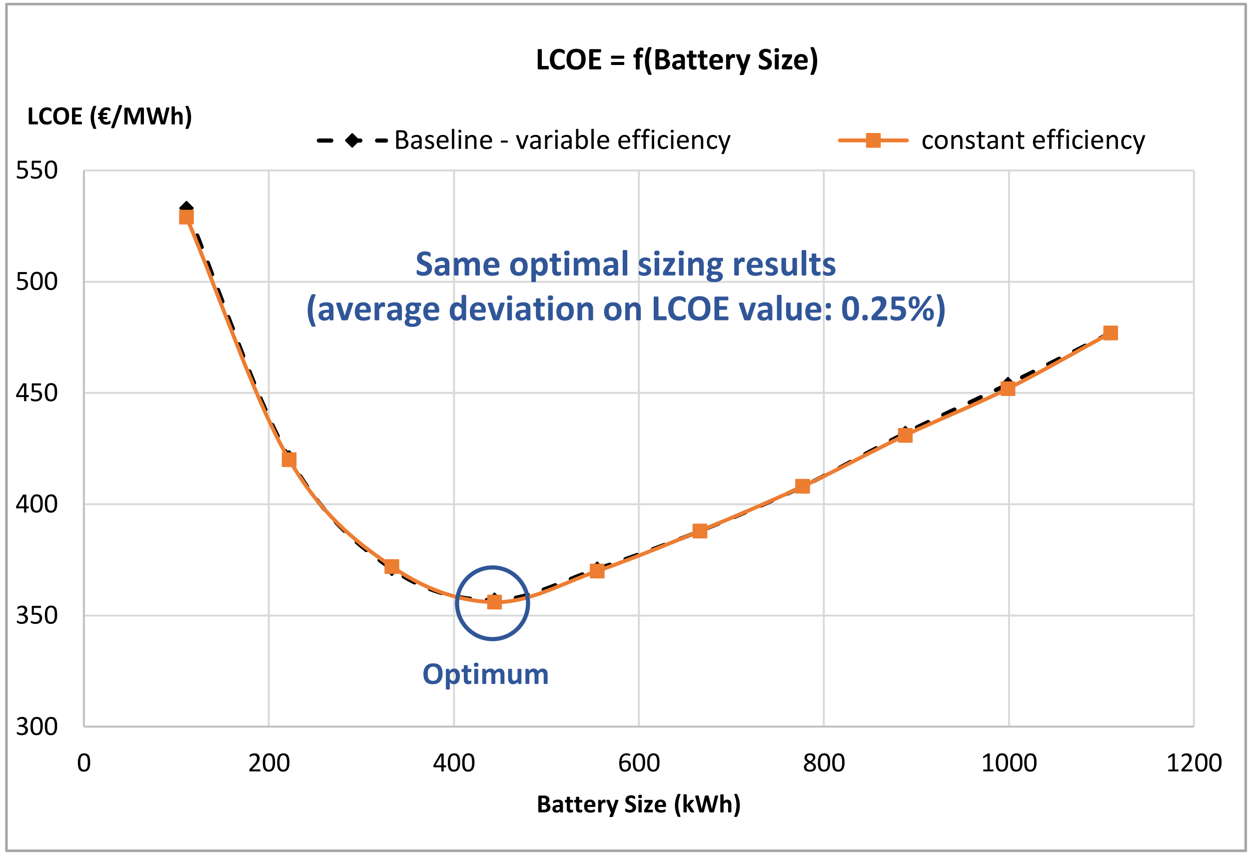
WP7

Influence of BESS efficiency precision

Precision of the BESS efficiency		
Precision of the BESS efficiency	*Baseline*	BESS model parameters include tables of precise efficiency values varying according to temperature, current and SOC
	Comparative	BESS efficiency is set up as a constant value (average efficiency)



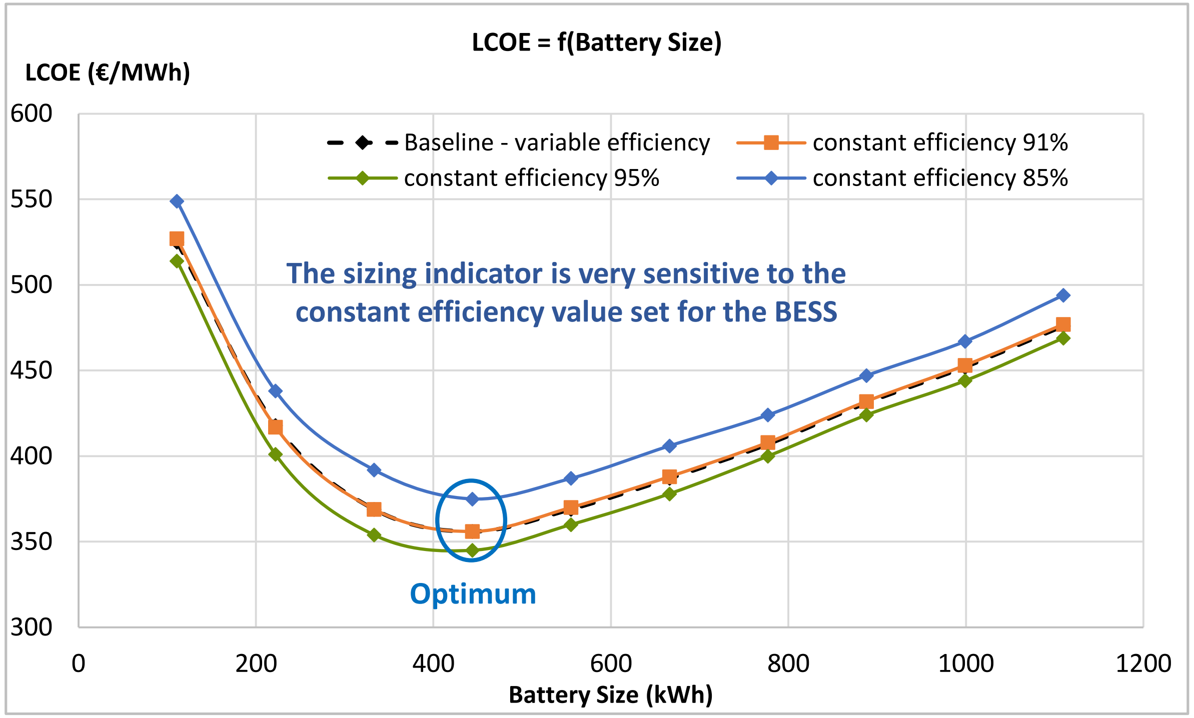
BESS precise efficiency behavior

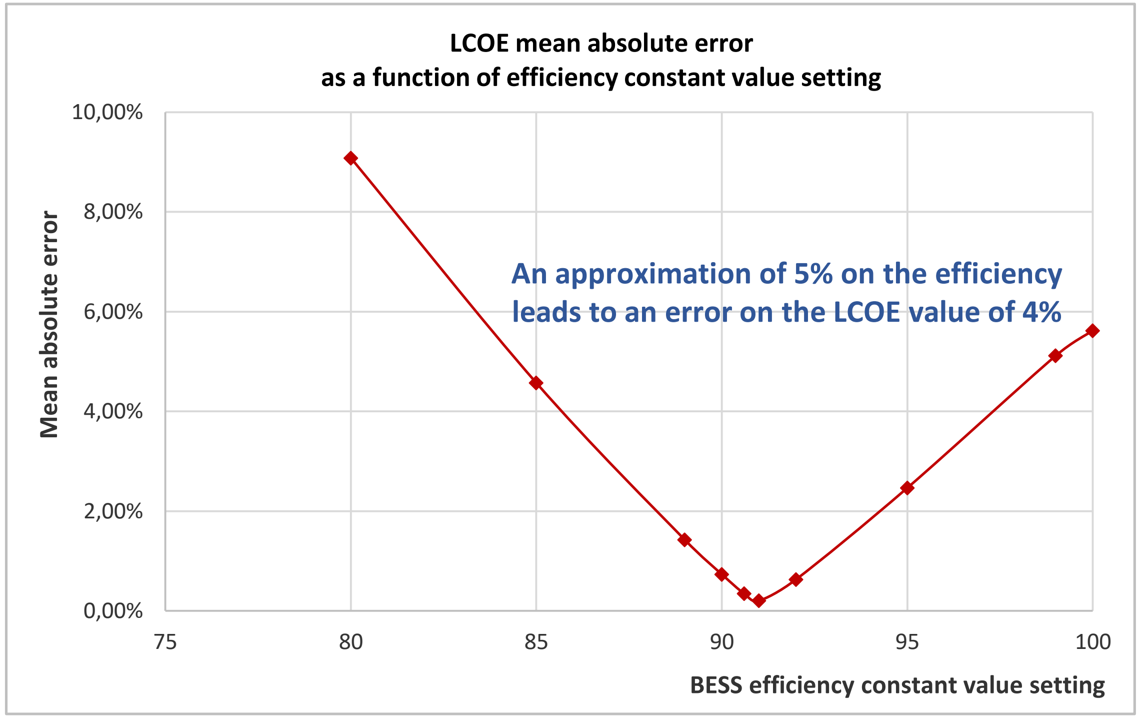


A variable efficiency behavior can be approximated by an average efficiency single value without any impact on optimal sizing

Influence of BESS efficiency precision

How precisely must be set the average constant efficiency value?





The average efficiency value must be set precisely since the sizing indicator is strongly affected by this parameter
An error on BESS efficiency value causes an error bordering on the same magnitude on the sizing indicator

Sensitivity analysis

Factors investigated through sensitivity analysis
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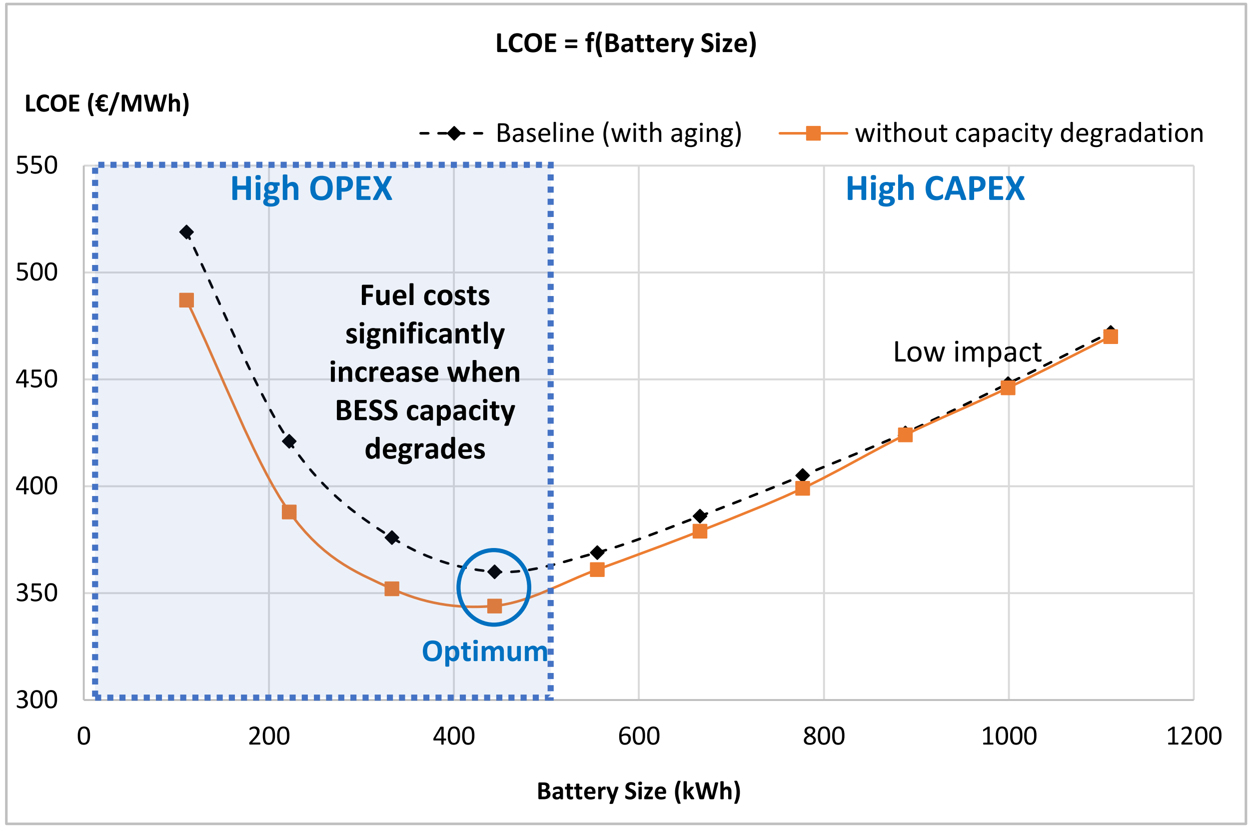
WP7

Influence of ageing

Degradation of battery capacity due to ageing	*Baseline*	BESS model parameters include ageing data / battery capacity degradation is continuously computed over time
	Comparative	Battery capacity remains constant over time



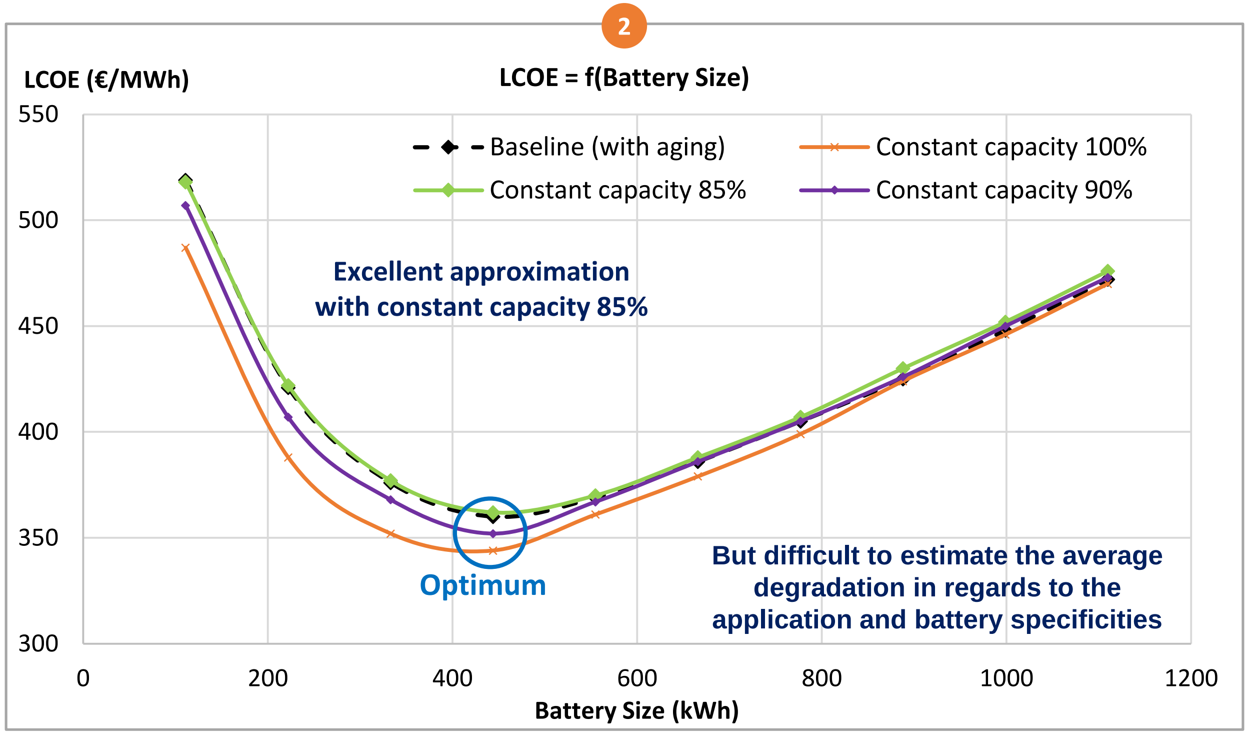
	Baseline scenario - Ageing taken into account	Comparative scenario - Without capacity degradation	
BESS size (kWh)	LCOE (€/MWh)	LCOE (€/MWh)	Relative error
111	**519**	487	**6,17%**
222	**421**	388	**7,84%**
333	**376**	352	**6,38%**
444	**360**	344	**4,44%**
555	**369**	361	**2,17%**
666	**386**	379	1,81%
777	**405**	399	1,48%
888	**425**	424	0,24%
999	**448**	446	0,45%
1110	**472**	470	0,42%
		Mean error	**3,14%**

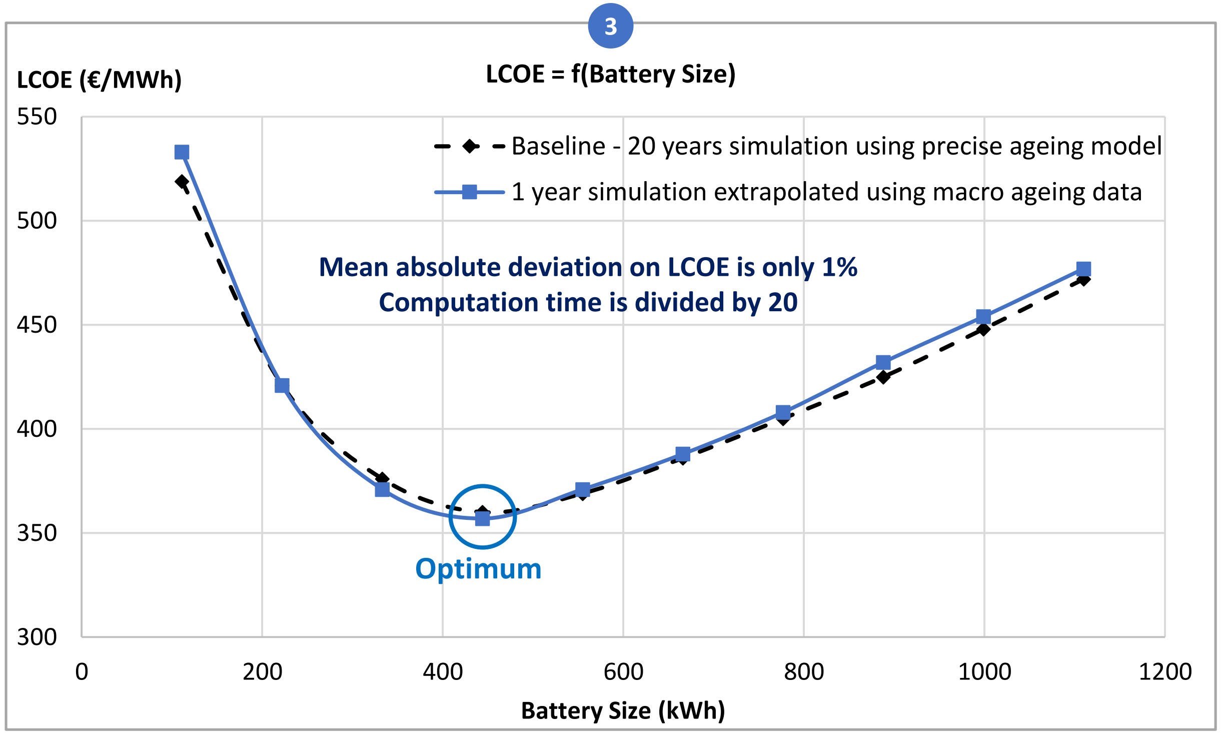
Strong impact when LCOE is mainly composed of OPEX generation costs
➡ BESS capacity degradation must be taken into account in optimal sizing

WP7

Comparison of different methods to estimate ageing

Aging estimation method	1-baseline SOH computation integrated into BESS model: capacity degradation calculated at each time-step	2 Simulation with constant but moderately degraded battery capacity over project lifetime	3 Yearly estimates of performances degradation use of macro ageing data in post-processing calculations
Pros	• Results are the most precise	• Ease of implementation	• Rough ageing estimates more easy to obtain • Faster calculations
Cons	• In-depth ageing parameter values difficult to collect • Ageing modelling requires expert skills • Computational extensive time for simulation	• It may be difficult to find the appropriate average constant degraded capacity value	• Possible loss of precision on sizing indicator results





Appropriate confidence levels can be obtained through approximation when detailed ageing lab-extracted data are not available

WP7

Sensitivity analysis

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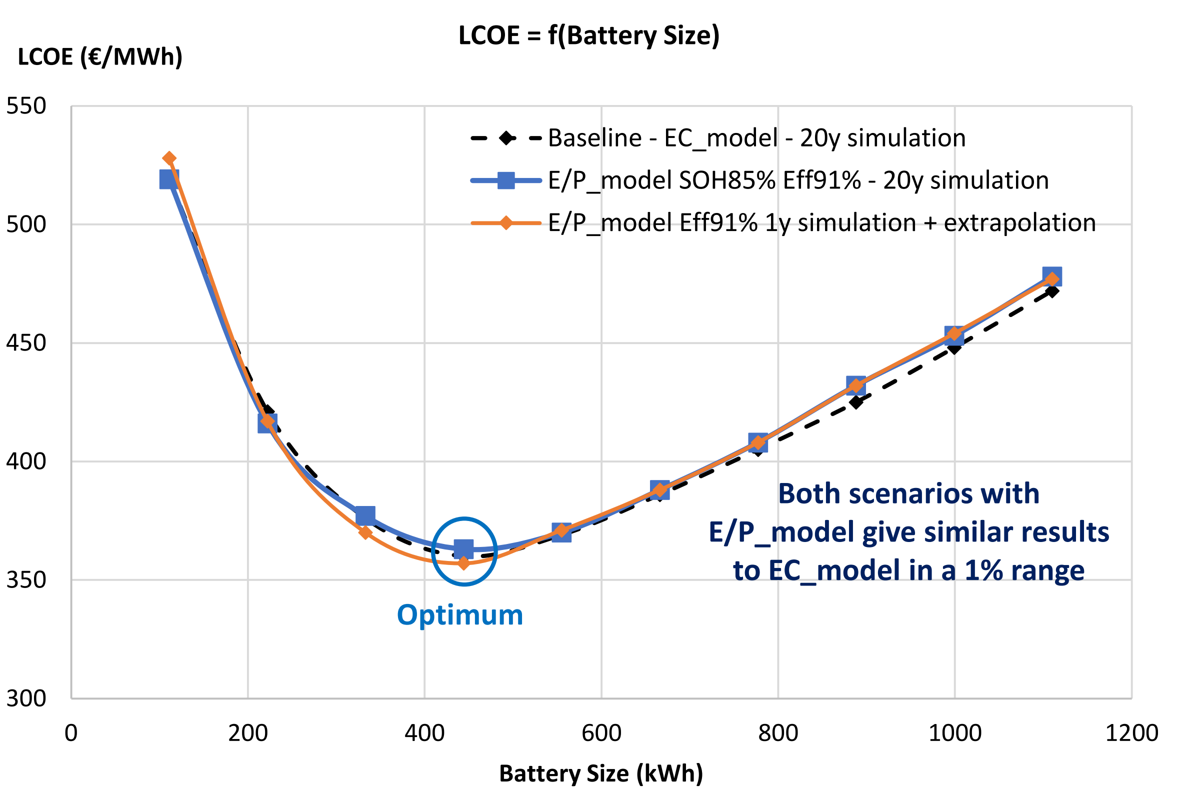
Influence of degree of technical modelling

Degree of technical modelling of the BESS component		
	Baseline	In-depth performances battery modelling based on equivalent-circuit equations (EC_model) *OCV + resistance detailed tables / precise SOH computation module*
	Comparative	Simplified modelling of the energy/power behavior of the BESS (E/P_model) *BESS global efficiency constant value / SOH not computed during simulation*



	EC model dyn. ageing variable eff. 20y simu	E/P model cst SOH 85% cst eff. 91% 20y simu		E/P model cst eff.91% 1y simu + extrapolation	
BESS size (kWh)	**LCOE (€/MWh)**	**LCOE (€/MWh)**	**Relative error**	**LCOE (€/MWh)**	**Relative error**
111	**519**	519	0,00%	528	1,73%
222	**421**	416	1,19%	417	0,95%
333	**376**	377	0,27%	370	1,60%
444	**360**	363	0,83%	357	0,83%
555	**369**	370	0,27%	371	0,54%
666	**386**	388	0,52%	388	0,52%
777	**405**	408	0,74%	408	0,74%
888	**425**	432	1,65%	432	1,65%
999	**448**	453	1,12%	454	1,34%
1110	**472**	478	1,27%	477	1,06%
		Mean error	**0,79%**	**Mean error**	**1,10%**
Computation time / config	hh:mm:ss **01:10:00**	hh:mm:ss **00:10:00**	time reduction factor **7**	hh:mm:ss **00:00:30**	time reduction factor **140**

Optimal sizing <u>does not require a high degree of technical modelling</u>
Using a simplified BESS model leads to similar results while saving significant computation time

Sensitivity analysis

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Influence of simulation time-step

WP7

Simulation time-step		
	Baseline	Time-step of 1 mn
	Comparative #1	Time-step of 10 mn
	Comparative #2	Time-step of 1 hour

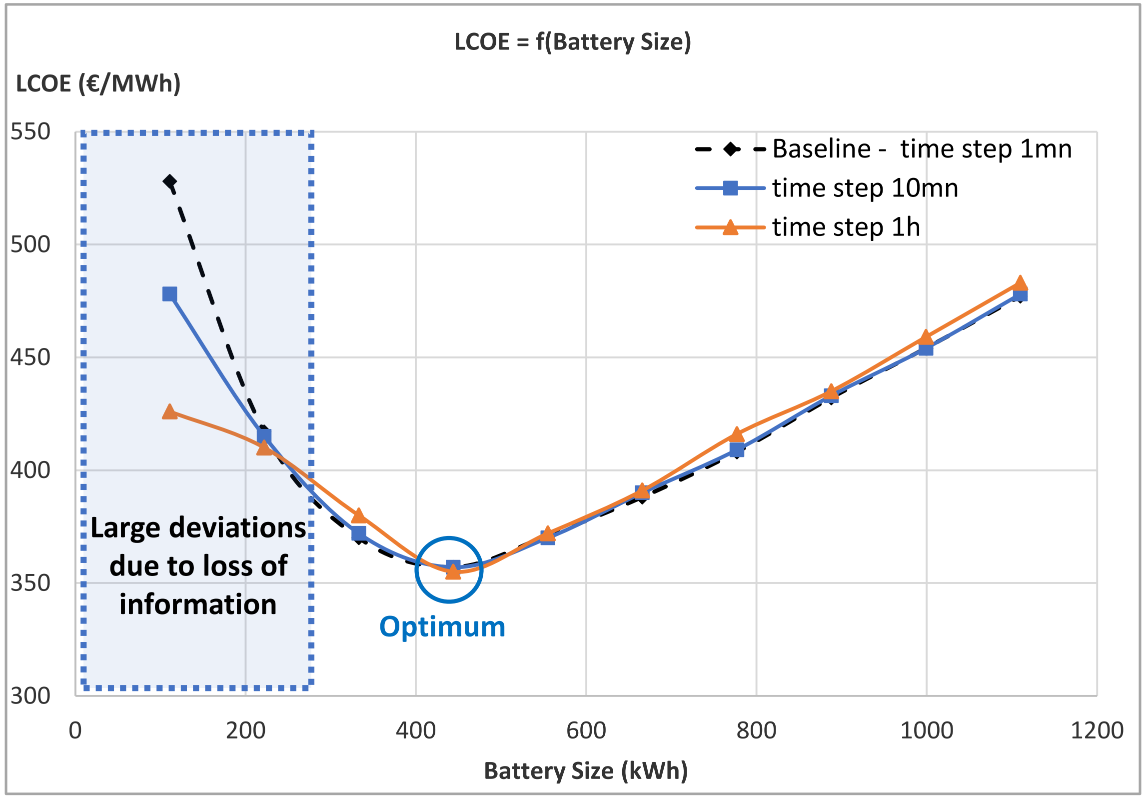
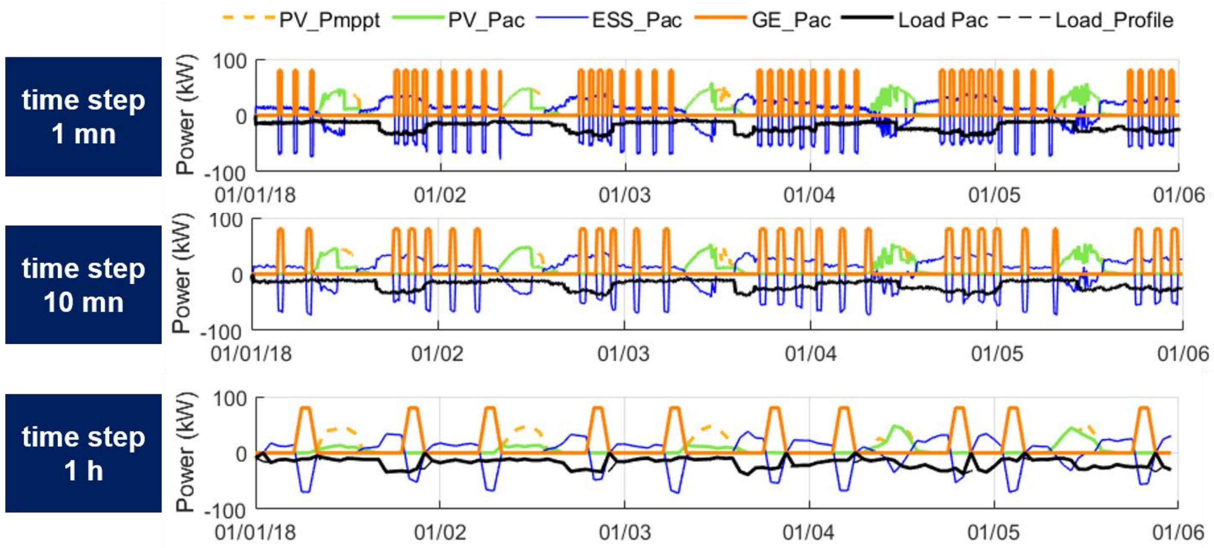


Illustration of loss of information about the many brief restarts of the fuel generator

5 days operation period simulated at different time-steps (smallest BESS size)



The influence of the simulation time-step strongly depends on the application time constants related to the events impacting the operation costs or incomes. With PV fluctuation or fuel generator operation a time-step of 10mn is acceptable.

WP7

Sensitivity analysis

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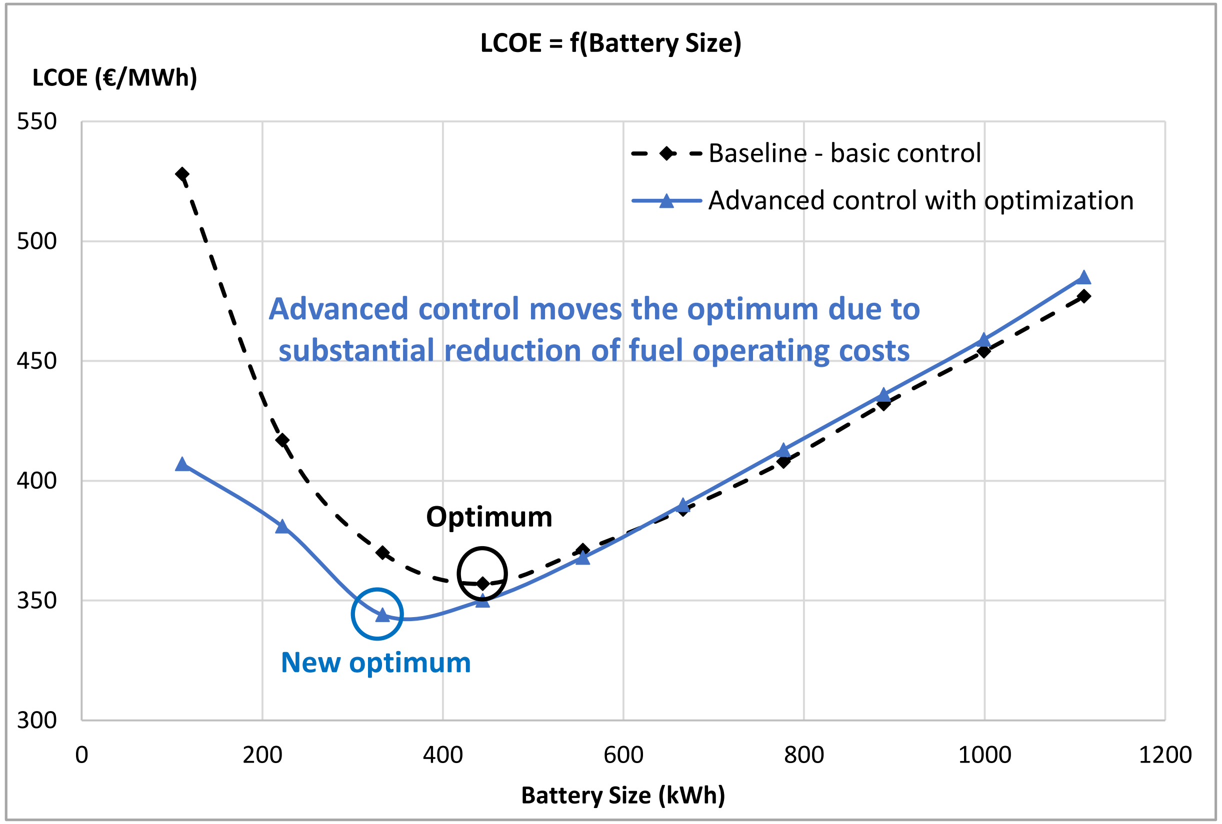
Influence of control strategy

Degree of complexity of control algorithms		
	Baseline	Basic control algorithms
	Comparative	Advanced control algorithms (including optimization)



	Baseline scenario - Basic control strategy	Comparative scenario - Advanced control with optimisation	
BESS size (kWh)	LCOE (€/MWh)	LCOE (€/MWh)	LCOE variation
111	**528**	407	-22,92%
222	**417**	381	-8,63%
333	**370**	344	-7,03%
444	**357**	350	-1,96%
555	**371**	368	-0,81%
666	**388**	390	0,52%
777	**408**	413	1,23%
888	**432**	436	0,93%
999	**454**	459	1,10%
1110	**477**	485	1,68%
Optimal LCOE variation between the 2 scenarios			-3,64%

Strong impact: different control strategies may lead to a different optimal BESS size
It is therefore recommended to clearly define the control strategy before determining the optimal size

WP7

Sensitivity analysis

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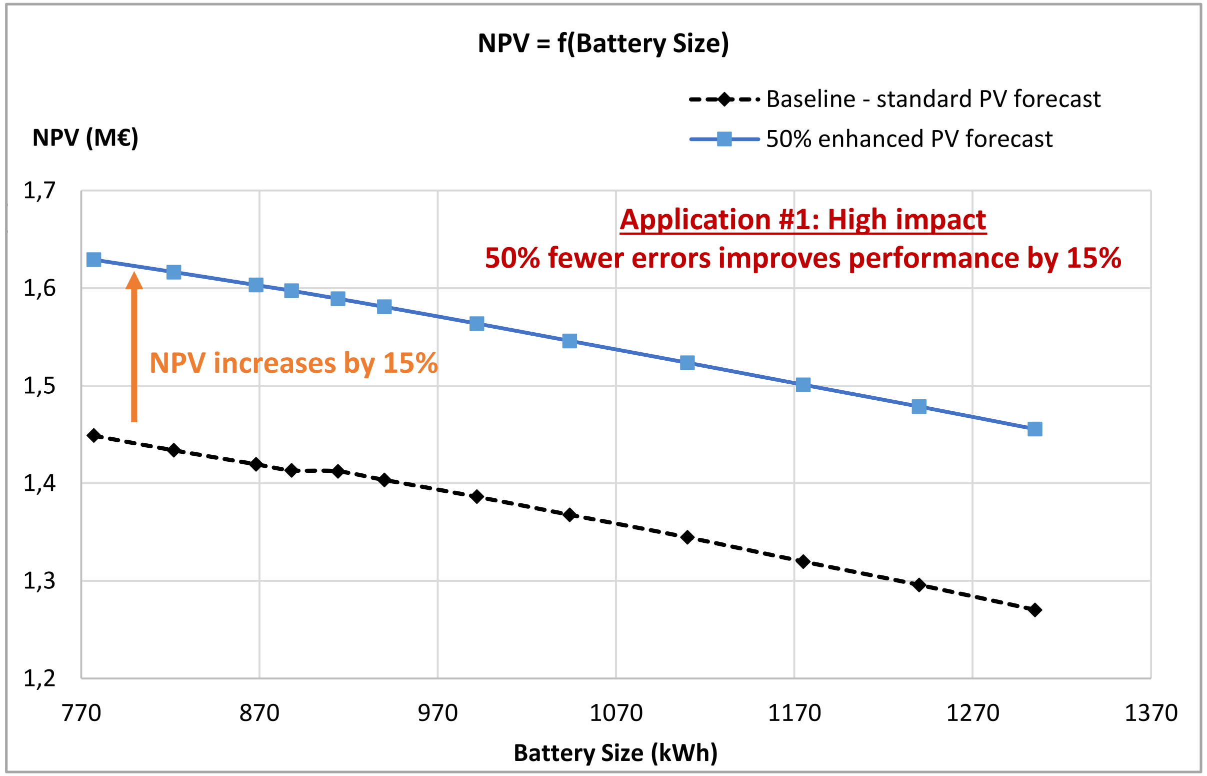
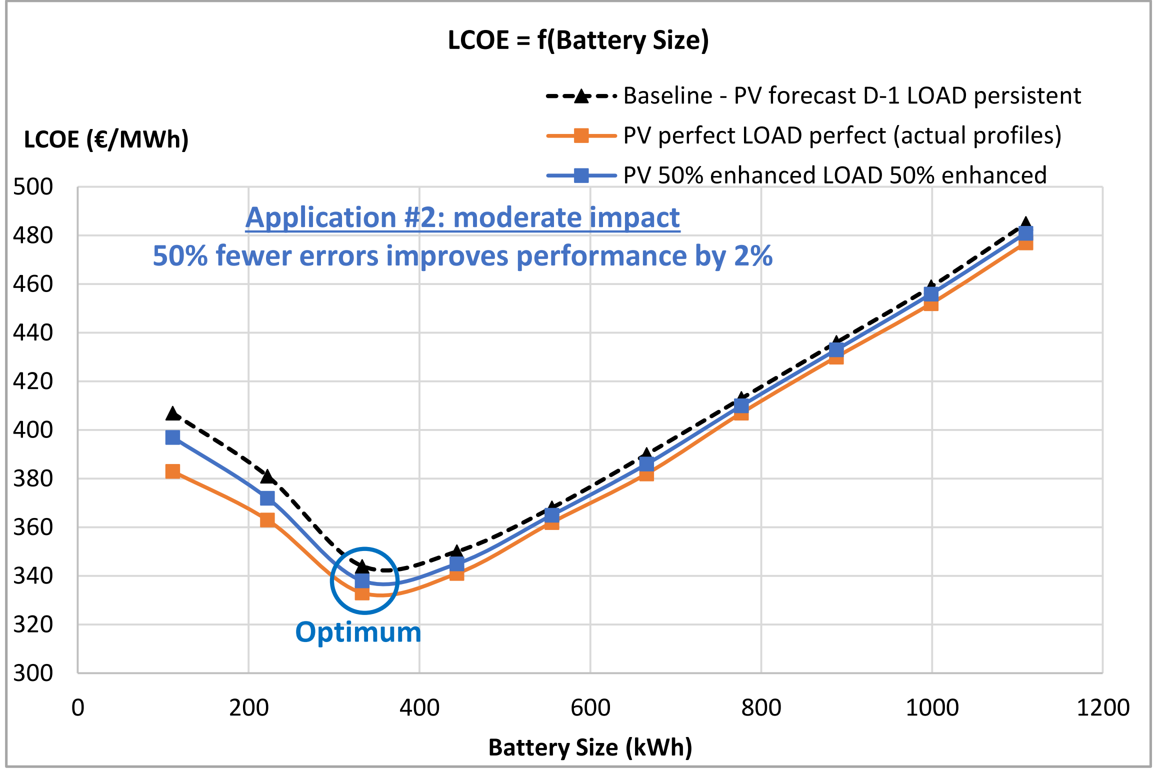
WP7

Influence of forecast quality

Forecast quality when predictive control is facing forecast errors		
	Baseline	PV: standard day-1 forecast / Load: persistence day+7
	Comparative #1	PV: perfect forecast (actual PV production) / Load: perfect forecast (actual consumption)
	Comparative #2	PV / Load: enhanced forecast with 50% fewer errors





Highly depends on the application purpose: if the main function of BESS is to compensate for forecasting errors in the RE sources, forecast quality is of the highest importance for optimal sizing

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Conclusion

Sensitivity study conclusions

Factor	Conclusion
Precision of the BESS efficiency	Variable efficiency **can be approximated by an average efficiency single value**
Degradation of battery capacity due to ageing	Ageing **must be taken into account in optimal sizing** Appropriate confidence levels can be obtained through approximation
Degree of technical modelling	Optimal sizing **does not require a high degree of technical modelling**
Simulation time-step	**Impact depends on the application time constants** For PV or fuel generator operation, time-step of 10mn is suitable
Control strategy	**Strong impact**
Forecast quality	**Highly depends on the application purpose** Significant impact when the main function of the BESS is to compensate for forecasting errors

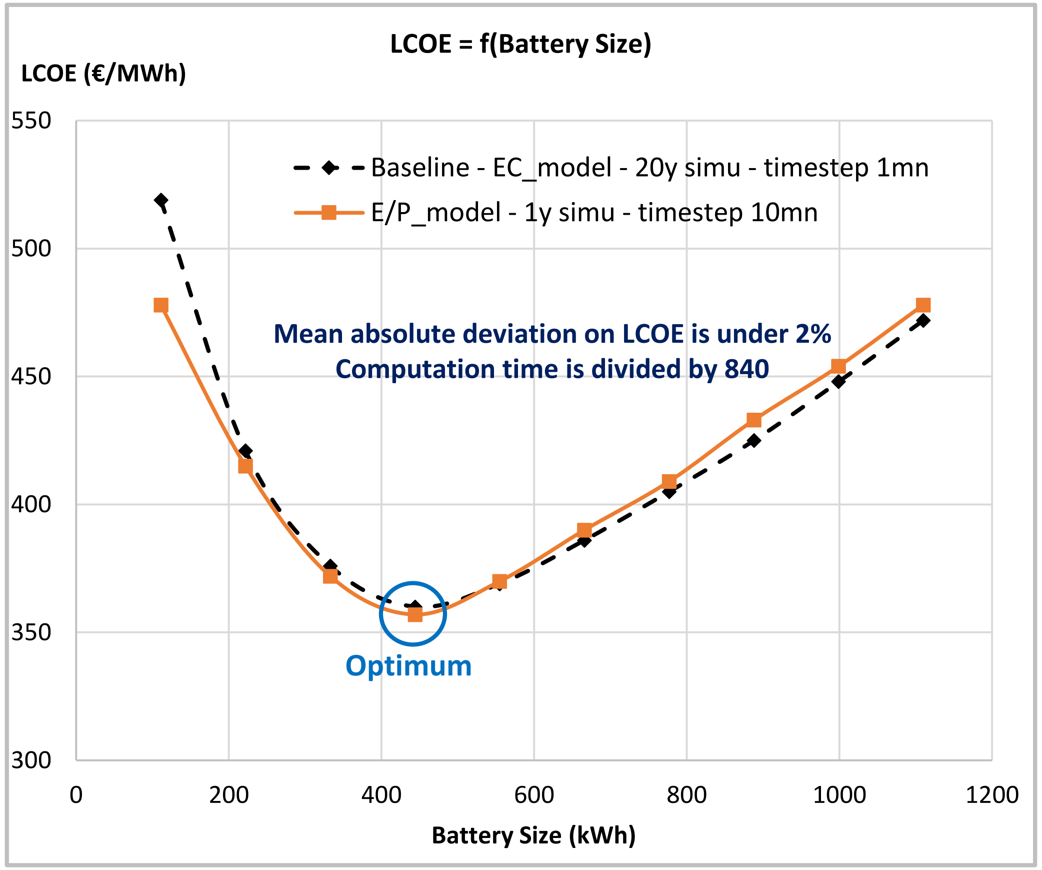
These conclusions help to:

- **concentrate the effort on the crucial factors**
- **identify where computation time can be saved without degrading the accuracy of the result**

Conclusion

Conclusive approximation ➡ trade-off between accuracy of the result and calculation time

Factor	Implementation
Degree of technical modelling	Simplified BESS model
Precision of the BESS efficiency	average efficiency value
Degradation of battery capacity due to ageing	approximation
Simulation time-step	Time-step of 10 mn



	Baseline scenario - EC_model 20y simulation time step 1mn	Approximation - E/P_model 1y simulation time step 10mn	
BESS size (kWh)	LCOE (€/MWh)	LCOE (€/MWh)	Relative error
111	519	478	7,90%
222	421	415	1,43%
333	376	372	1,06%
444	360	357	0,83%
555	369	370	0,27%
666	386	390	1,04%
777	405	409	0,99%
888	425	433	1,88%
999	448	454	1,34%
1110	472	478	1,27%
		Mean error	1,80%
Computation time / config	hh:mm:ss 01:10:00	hh:mm:ss 00:00:05	time reduction factor 840

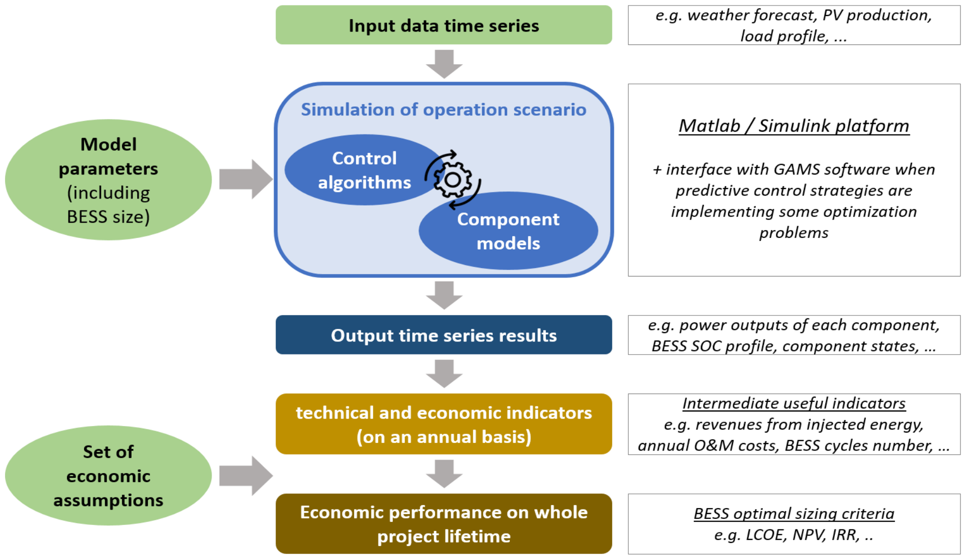
By putting into practice the study sensitivity study conclusions, calculation time can be divided by 840 with an average error below 2% compared to the baseline (most precise) scenario

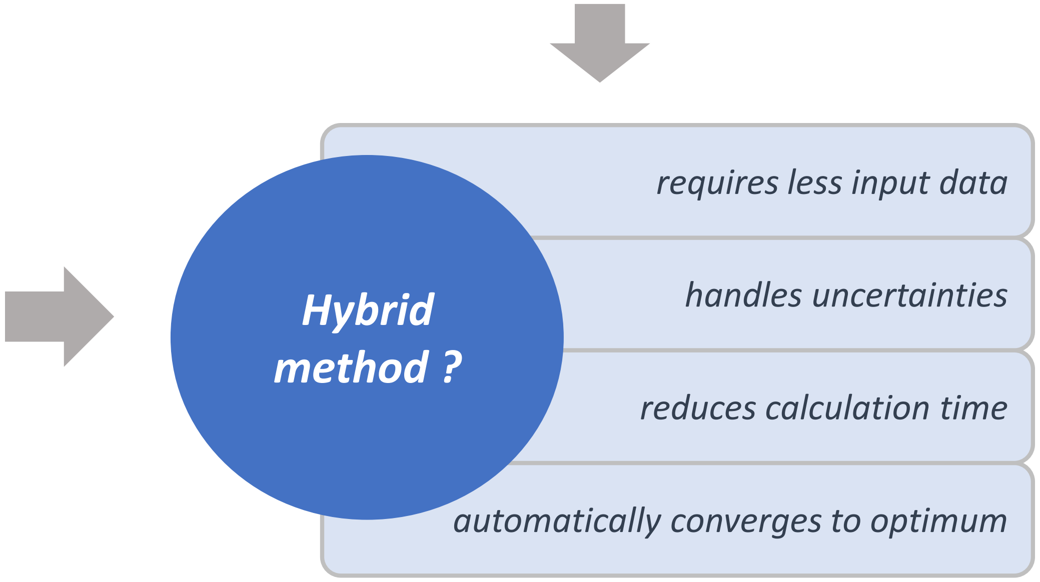
Potential method improvements

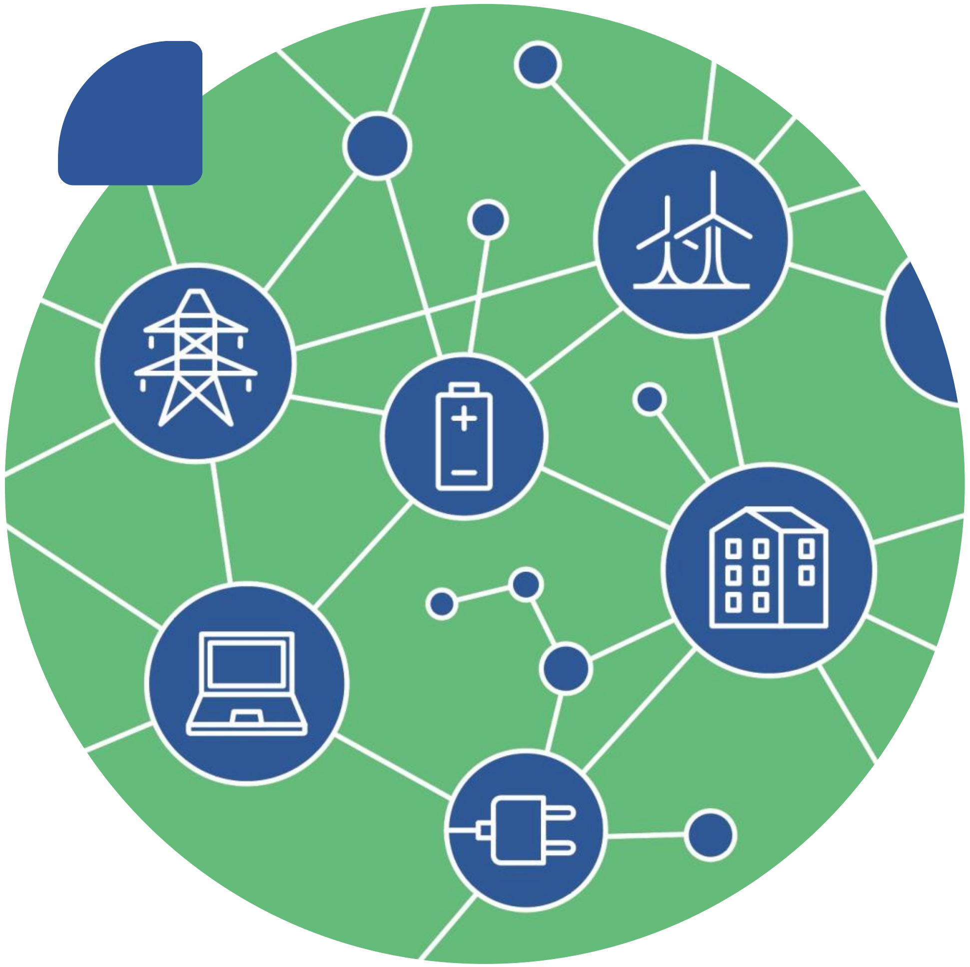
The very deterministic simulation-based method used for optimal sizing:

- **was well suited for the sensitivity analysis purposes**
- **has some weaknesses**
  - Requires to collect a large amount of data
  - Doesn't take into account uncertainties
  - Needs large number of simulations to reach the optimum

- **could be combined with other techniques such as:**
  - Probabilistic / stochastic methods,
  - Direct search algorithms:
    - Mathematical optimisation
    - Heuristic approaches







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Thank you !