

Integrating Renewable Energy and Hydrogen Storage into the FCC

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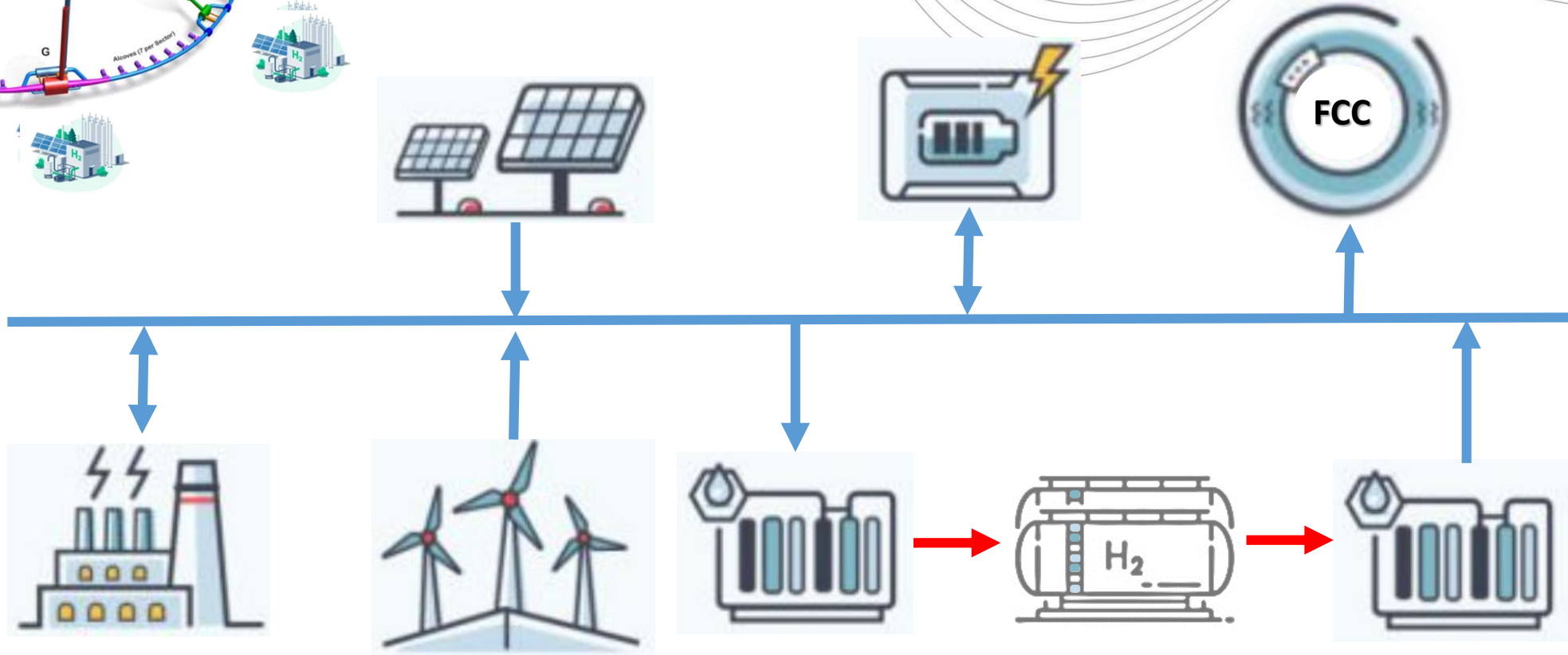
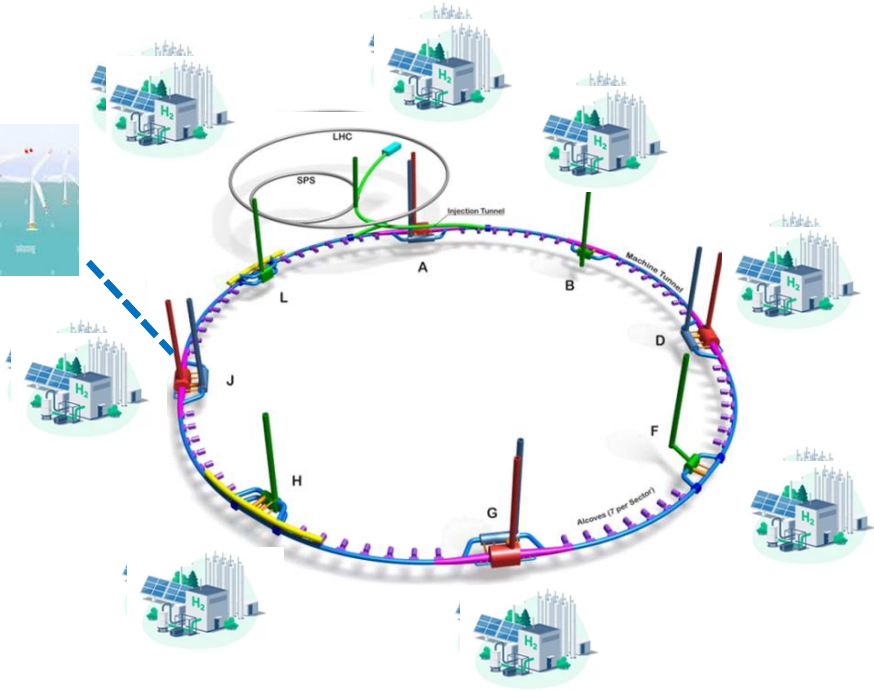
Summary

- Context of the case study
- Load and its specific conditions
- Energy sources and hydrogen vector
- Energy management and technical analysis
- Economic analysis and its environmental impact
- Conclusions

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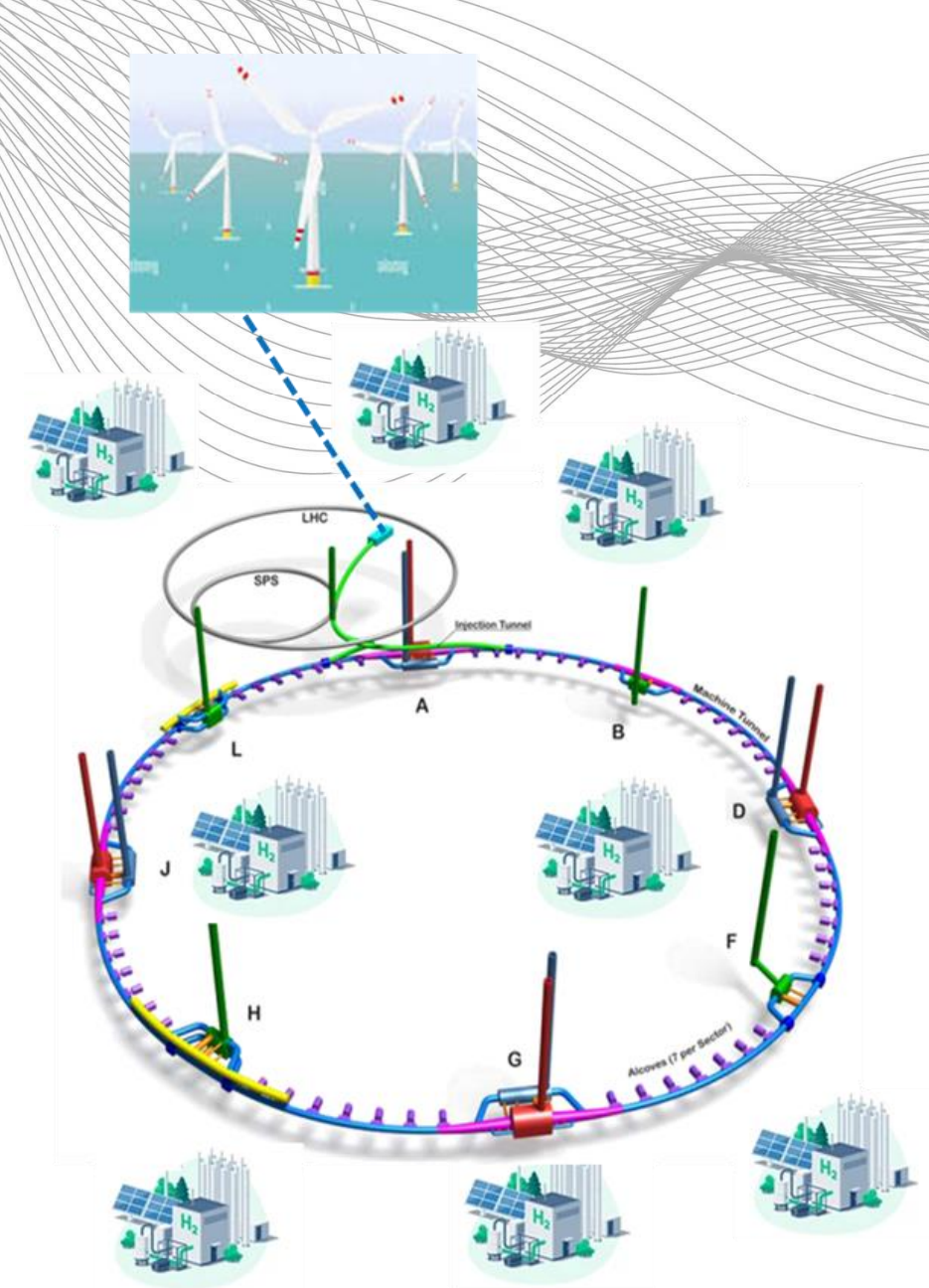
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Case study



Objectives of the study

- Pre-sizing infrastructure, integrating constraints. Battery storage added to complement H2 storage;
- Evaluate main constraints linked to pre-sizing, especially H2 storage size ;
- Evaluate grid services with battery and H2 storages regarding energy indicators (autonomy)
- Assess device costs environmental macro-indicators in this smart microgrid over its operating life.

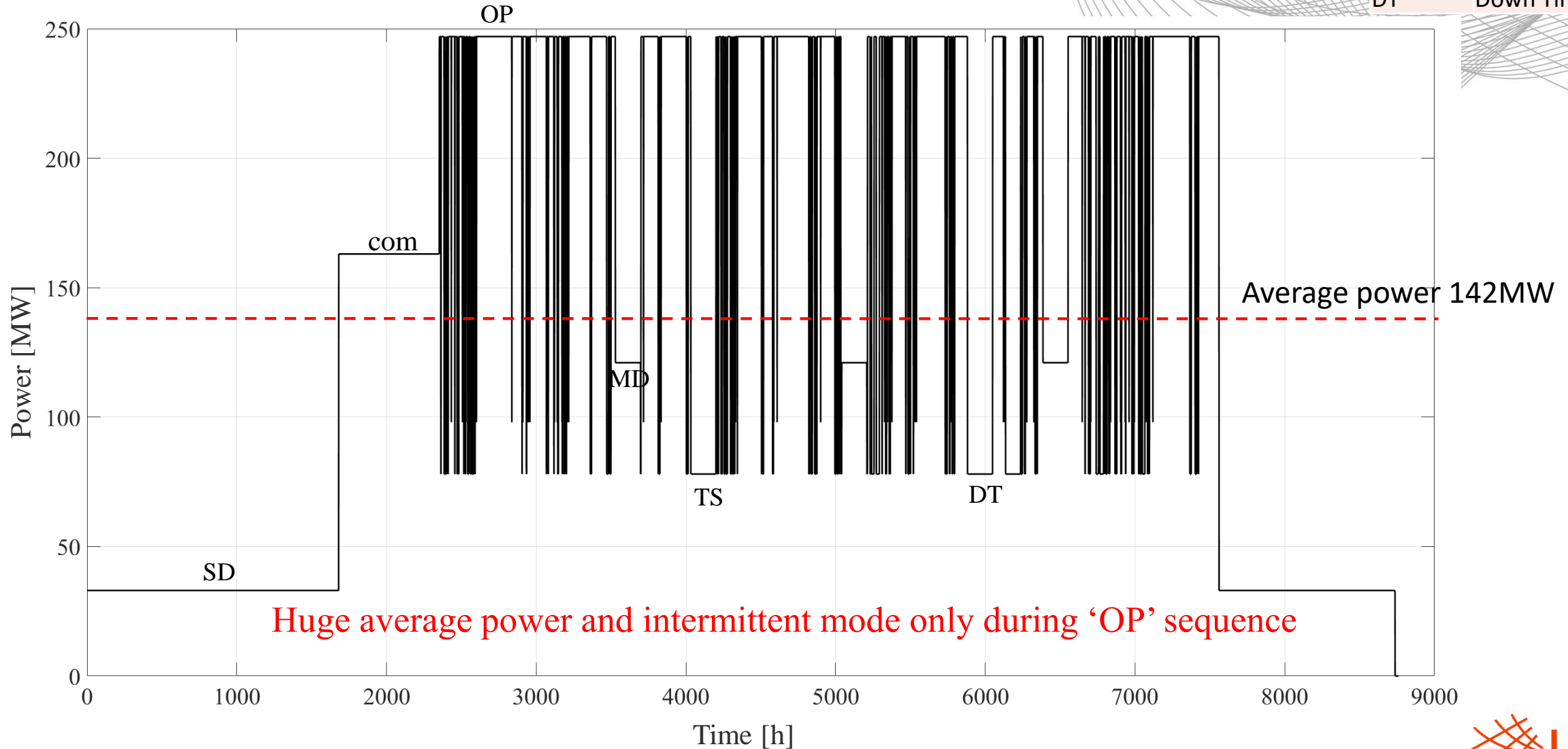


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CERN energy demand profile estimated for the FCC

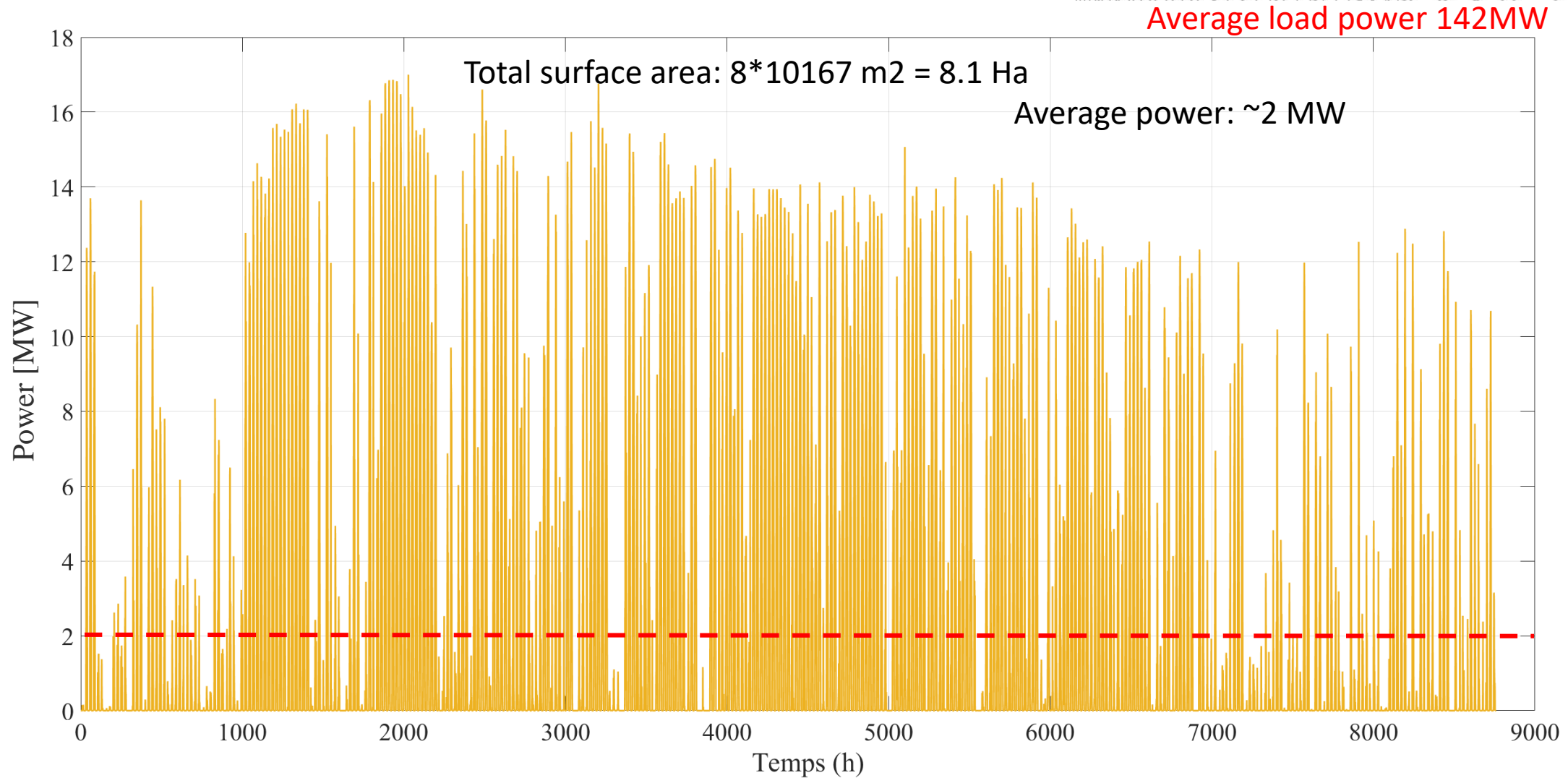
SD	Shut Down
com	Commissioning
OP	Operation
MD	Machine development
TS	Technical Stop
DT	Down Time



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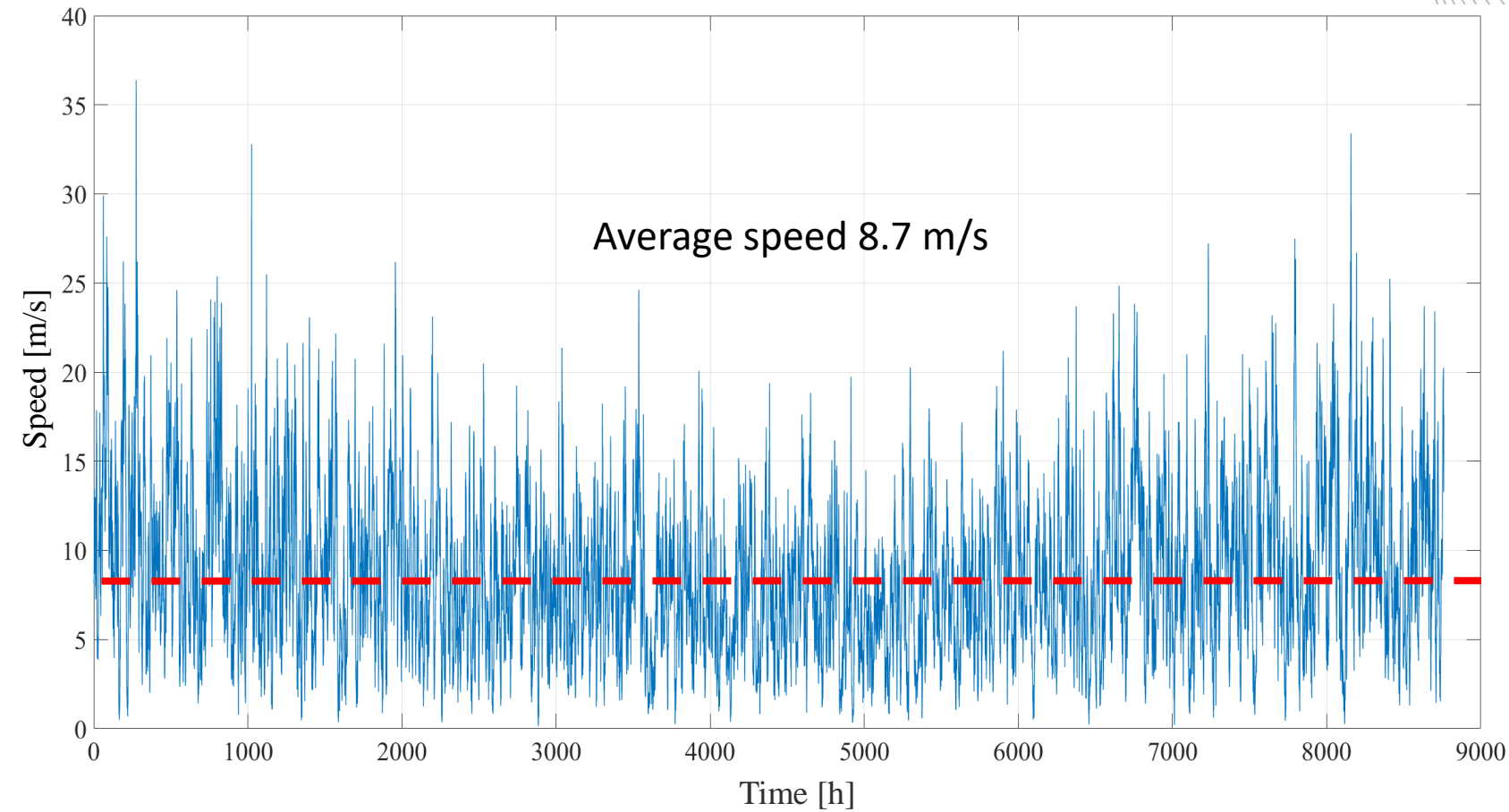
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Profile of local solar PV production



Solar PV production model :
$$P_{pv} = irr A \left\{ \eta \left[1 + \beta \left(\left(T_{amb} + \frac{irr}{1000} NOCT \right) - 25 \right) \right] \right\}$$

Offshore wind profile

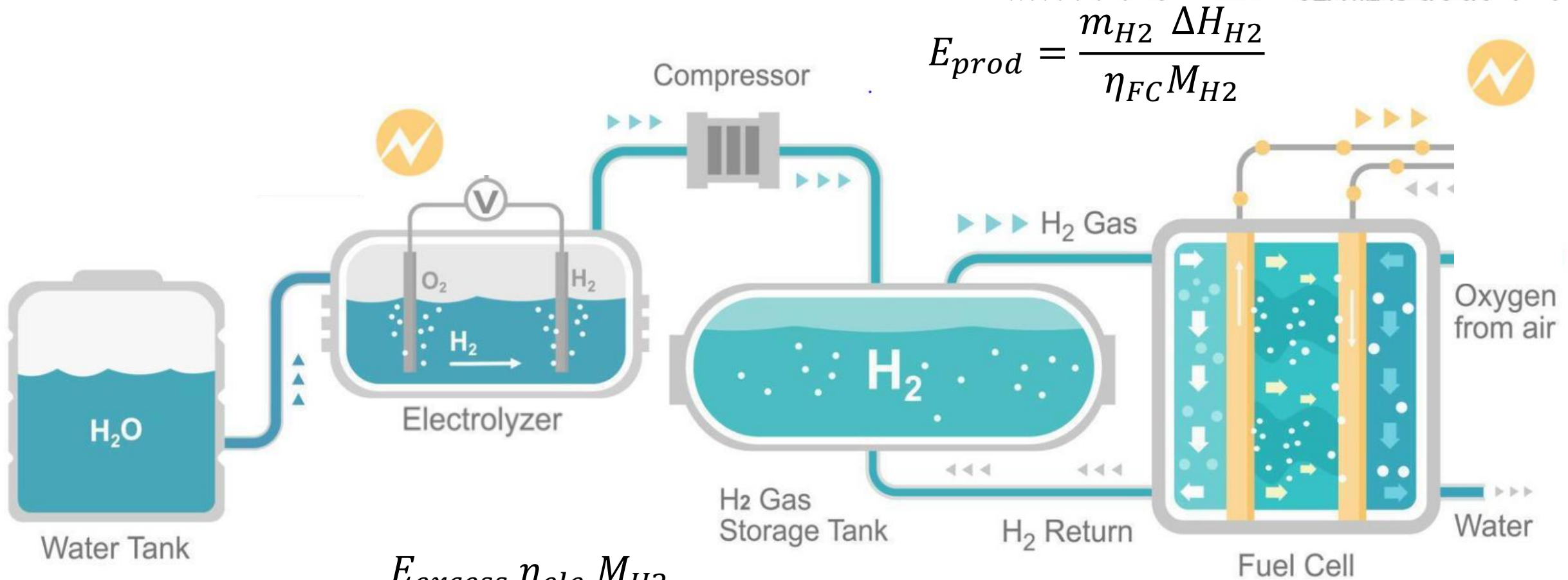


Wind production based on PPA:
$$P_{wind} = \frac{1}{2} \rho_{air} S v^3 C_p$$

Enercon E-115 3.000



Structure of a hydrogen system



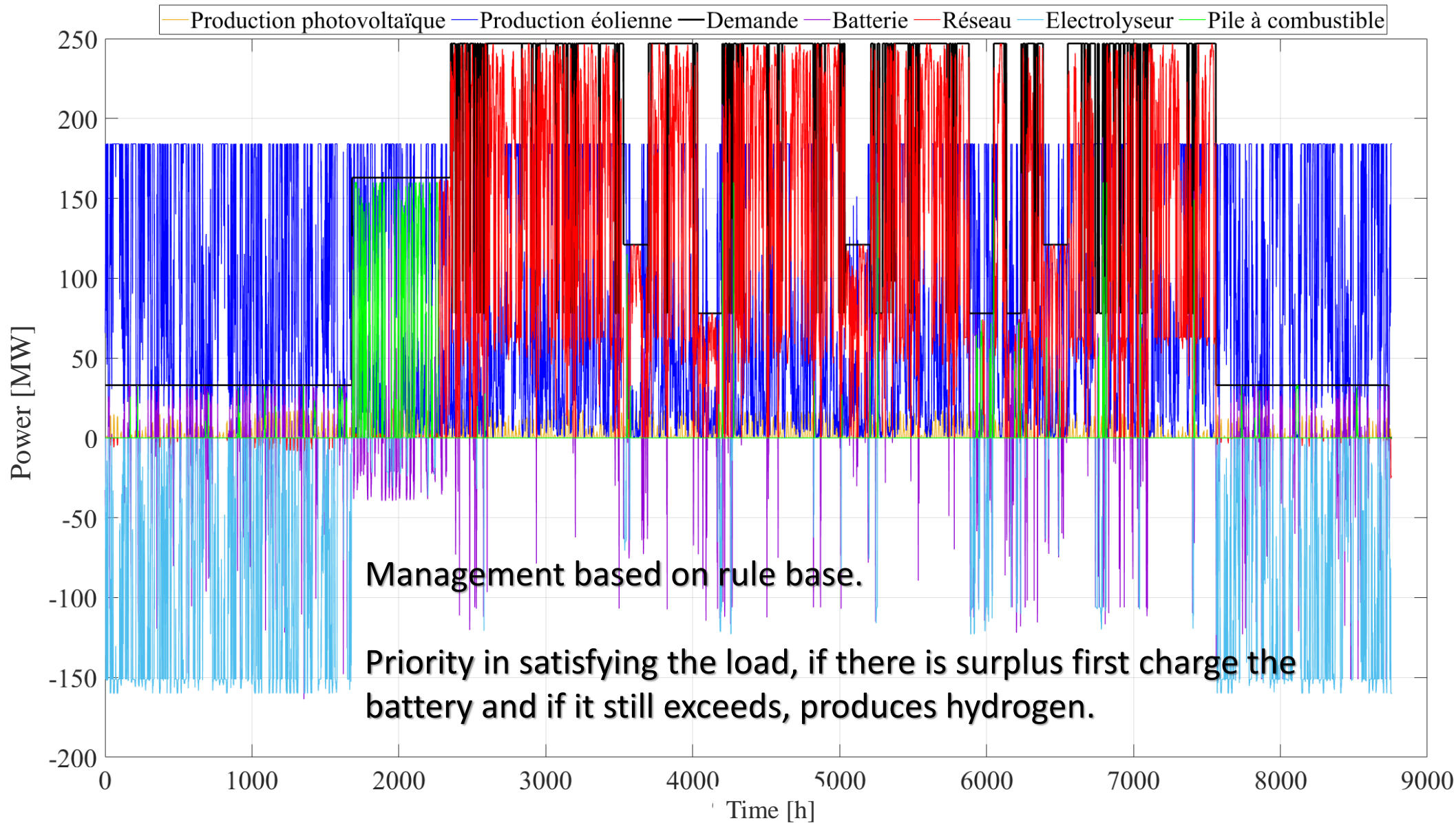
$$E_{prod} = \frac{m_{H_2} \Delta H_{H_2}}{\eta_{FC} M_{H_2}}$$

$$m_{H_2} = \frac{E_{excess} \eta_{ele} M_{H_2}}{\Delta H_{H_2}}$$

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Hybrid microgrid energy flow over 1 year



Measuring the annualized percentage of self-consumption

$$\tau_{sh} = 100 * \left(1 - \frac{\sum P_{Grid}}{\sum P_{load}} \right)$$



Total network consumption



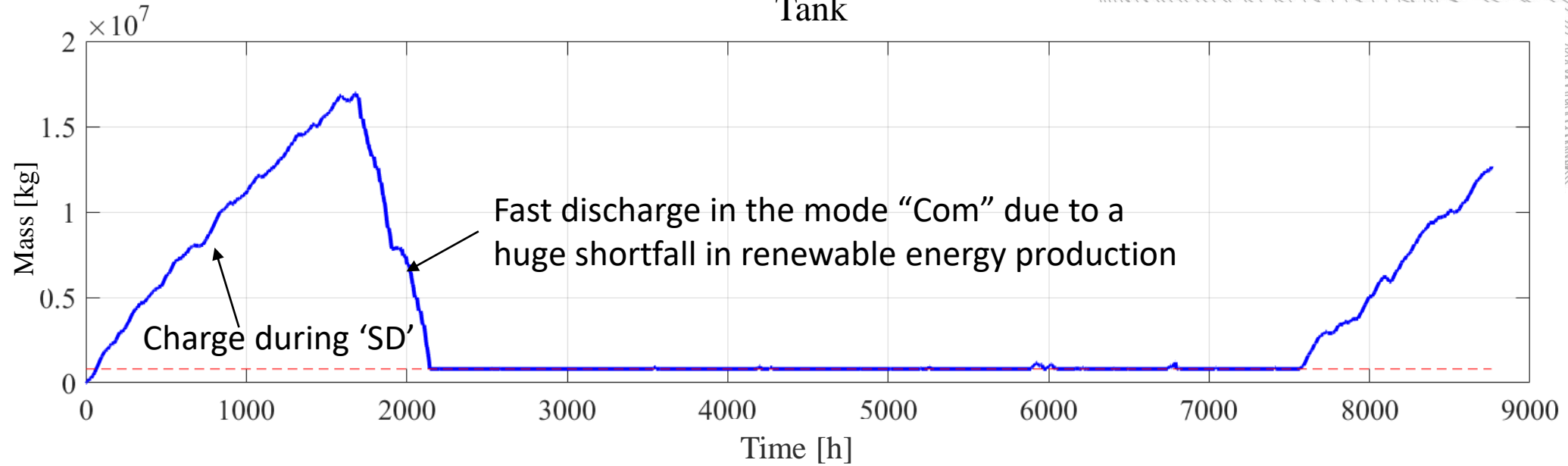
Total self-consumption

τ_{sh} equal to 46,5%

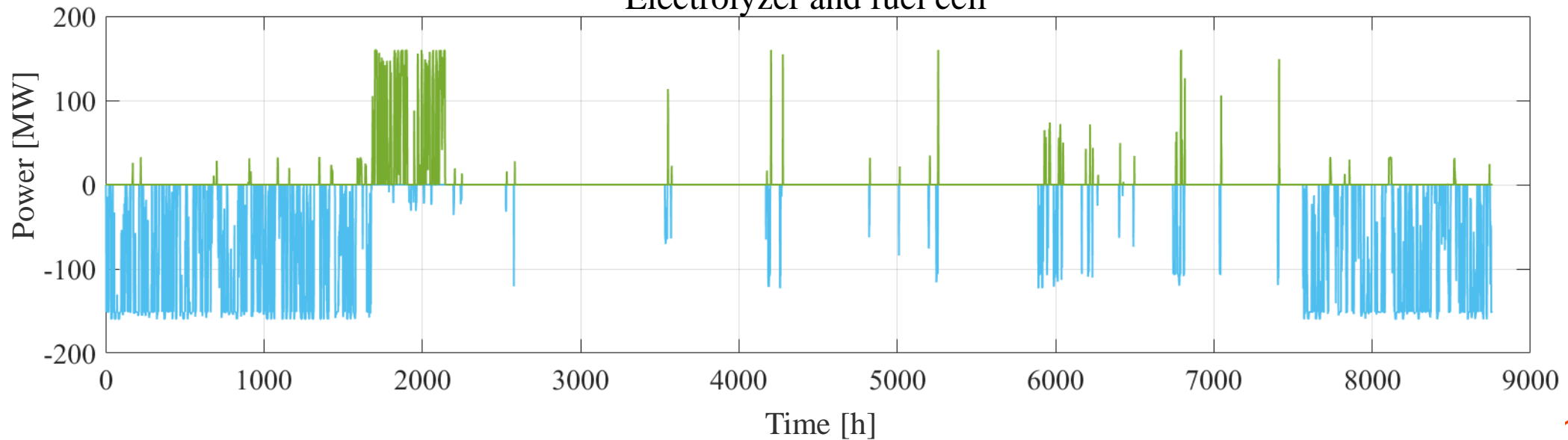
E_{net} : -470 GWh/an

Behavior of the hydrogen chain over a year

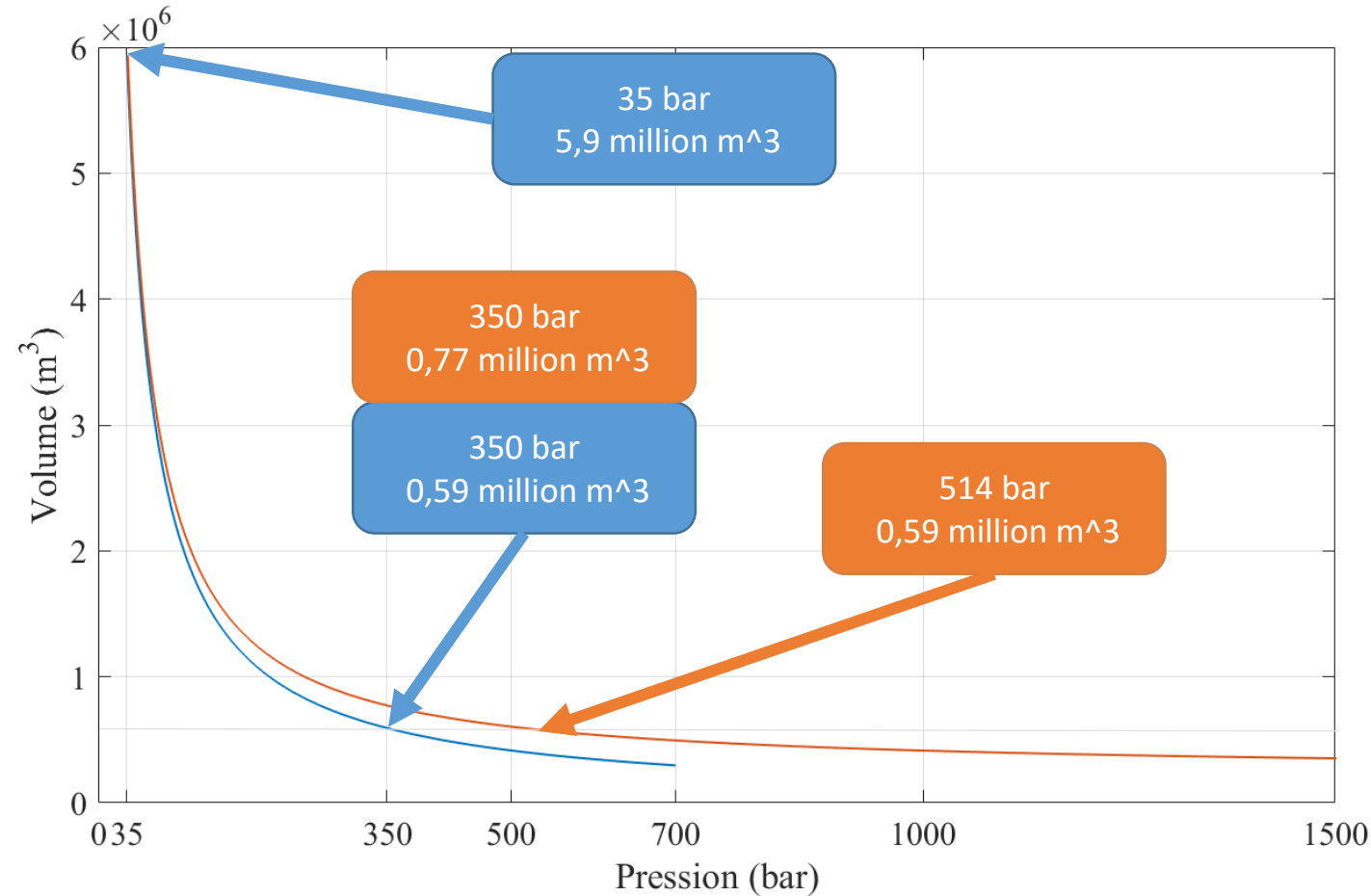
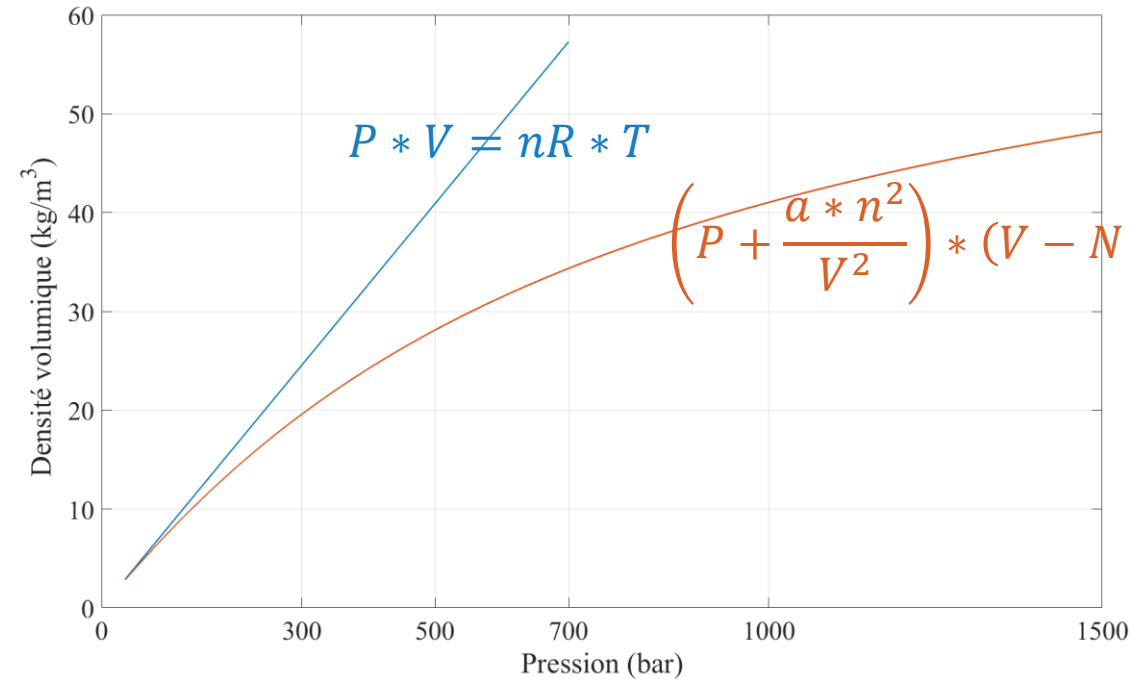
Tank



Electrolyzer and fuel cell



Volume required, depending on storage pressure for H2



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Parameters for economic and environmental impact analysis

	CAPEX	OPEX	Emission factor	Lifetime
Grid	-	80 €/MWh	55 kgCO ₂ eq/MWh	-
Photovoltaic panel	1500 k€/MWc	-	304000 kgCO ₂ eq/MWc	15 years
Wind generator	-	80 €/MWh	15kg/MWh	30 years
Battery	285 k€/MWh	-	130000 kgCO ₂ eq/MWh	7,5 years
Electrolyzer	1000 k€/MW	-	190000 kgCO ₂ eq/MW	5 years
Fuel cell	1000 k€/MW	-	405000 kgCO ₂ eq/MW	5 years

Estimated costs and CO2 emissions

	Grid	Grid + Pv+ Wind	Grid+ Pv +Wind + Batt	Grid+ Pv +Wind + Batt+ H2	Unit
Renewable share	0	41,04	43,59	46,51	%
OPEX	Grid	99,9	58,9	56,3	M€
	PV	0	0	0	M€
	wind	0	60,1	60,1	M€
	Batt	0	0	0	M€
	H2	0	0	0	M€
CAPEX	Grid	0	0	0	M€
	PV	0	24,4	24,4	M€
	Wind	0	0	0	M€
	Batt	0	0	91,2	M€
	H2	0	0	0	320
Net Present Cost	1498,5	1809,4	1952,8	2869,9	M€
Diff %	-	-20,75%	-30,32%	-91,52%	%
Emissions OPEX	6,87E+07	4,05E+07	3,87E+07	3,67E+07	Tons CO2eq
Emissions CAPEX	0	4,95E+06	4,65E+07	1,42E+08	Tons CO2eq
Total emissions	6,87E+07	4,54E+07	85286000	178490000	
Diff %	-	33,84%	-24,18%	-159,88%	%

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- Energy demand has a pronounced seasonal component due to various operating modes with widely disparate average power requirements. Global average deficit from renewable sources.
 - Massive storage facilities to compensate both deficit and intermittence of renewable sources and loads.
 - Overall technical, economic and environmental balance unfavorable to energy storage, and very unfavorable to the H2 vector with that case study and requirements.
- Other types of storage such as STEPs could be considered, but this would require CERN to have control over the management of pumped storage, given the difference between renewable production and intermittency.
- The addition of storage in general, and H2 in particular, needs to be re-examined in greater detail and in a different way. For example, selling the H2 stored by electrolysis during the shut-down phase when ENRs are in surplus would avoid seasonal storage.

Thank you for your attention

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