CLEANHORIZON

The Energy Storage Experts

CRE-STORE:
Helping you size energy storage

A service by Clean Horizon

The energy storage experts

CRE-STORE is a solution commercialized since 2015 to help optimally size energy storage

Based on its initial success in the French Islands, Clean Horizon has developed CRE-STORE, a customized Matlab®-based tool dedicated to finding the optimal energy storage sizing for specific applications

Who is this service for?

- Grid and Off-grid customers looking to optimize their energy bill/ energy sourcing
- PV and wind developers looking to serve customers with storage
- Battery and PCS vendors who are looking to address customers in new applications / geographies

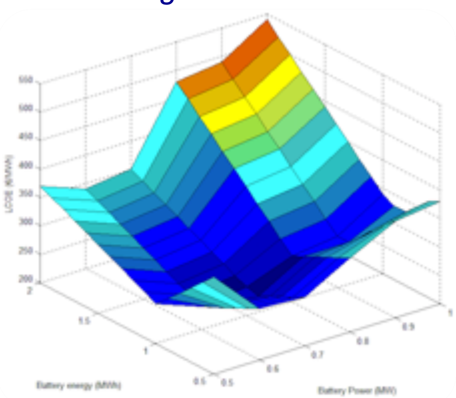
What value does CRE-STORE deliver?

1. **Optimal sizing of the storage component of your project**
2. **Business plan of the overall project containing storage**
3. **Detailed view of energy flows in the project to compute performance ratios**

Our references since 2015

From storage optimal sizing

Sizing vizualisation



To procurement

- Technical specifications
- Administration of RFP
- Selection of vendors
- Contract negotiation

As of March 2018

Energy storage systems designed	Projects designed around the world
225 MWh*	36

*71% of these MWh are built or in the process of being financed

Clean Horizon's CRE-STORE 3-Step process to optimize the sizing of energy storage

STEP 1
Inputs on specific project

STEP 2
Input on energy storage technology

STEP 3
Computation process

You tell us about your project

We add our technical inputs

We compute this data in our proprietary software

Output:

Clean Horizon provides you the optimal storage size for your project

Clean Horizon's CRE-STORE 3-Step process to optimize the sizing of energy storage

STEP 1
Inputs on specific project

Determine use case
- PV smoothing/ramping
- Demand charge management
- Offgrid customers / self consumption
- Diesel replacement / Island power generation
- Frequency regulation
- Other

Desired optimization criteria:
- Payback time, IRR, NPV, energy bill reduction, lowest PPA tariff, LCOE…

Acquisition of customer data
- PV/Wind data
- Load data
- Diesel engines data
- Specific constraints
- Financing

STEP 2
Input on energy storage technology

Energy storage technical data
- Either standard data provided by Clean Horizon or project specific data if available

Energy storage features:
- Power capacity
- Usable Energy
- Ageing (cycling & calendar)
- Efficiency

Energy storage prices
- Present prices (CAPEX, OPEX)
- Balance of Plan
- Future replacement prices

STEP 3
Computation process

Computation of duty cycle of the battery based on rule-based simulations
- Each minute, CRE-STORE computes the energy actually sent to the grid

Free Cash flow
- The free cash flow is computed, taking into account the turnover and all costs of the past year as well loan reimbursement and as corporate tax applicable in selected country

Change of battery
- Every year, the remaining SOH of the battery is calculated and a change of battery is made if necessary

Outputs

Optimal battery sizing
- The computation process is iterated until the optimal battery size is obtained (for instance, providing highest IRR or shortest payback)

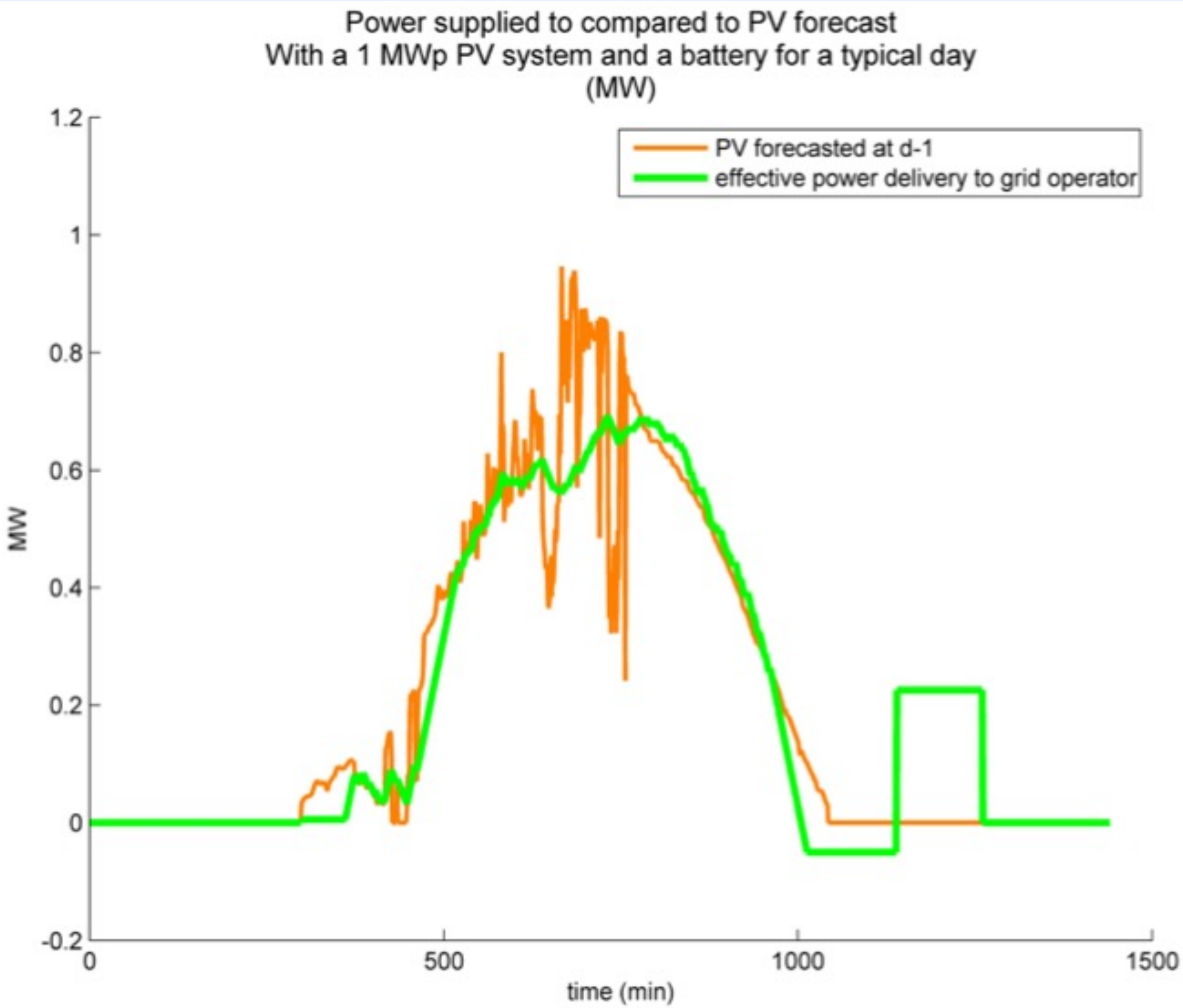
Battery duty cycle
- The charge and discharge pattern of the battery for one given year is provided

Business plan over the lifetime of the project
- Based on previous computations iterated for each year of the project, the complete business case including revenues, OPEX, CAPEX with hardware replacement and taxes is presented in an Excel format

Sensitivity analyses
- Sensitivity analyses can be provided upon customer request

Use-case 1: PV + storage tender in the French islands

CRE-STORE allows to simulate specific client constraints: example of French Island 2015 tender



CRE-STORE Step 3 for this specific example consisted in simulating the grid injection (in green) of a PV plus battery facility following the constraints of a tender

Typical (example) output 1/2: energy cost as a function of storage sizing to decide optimal storage size

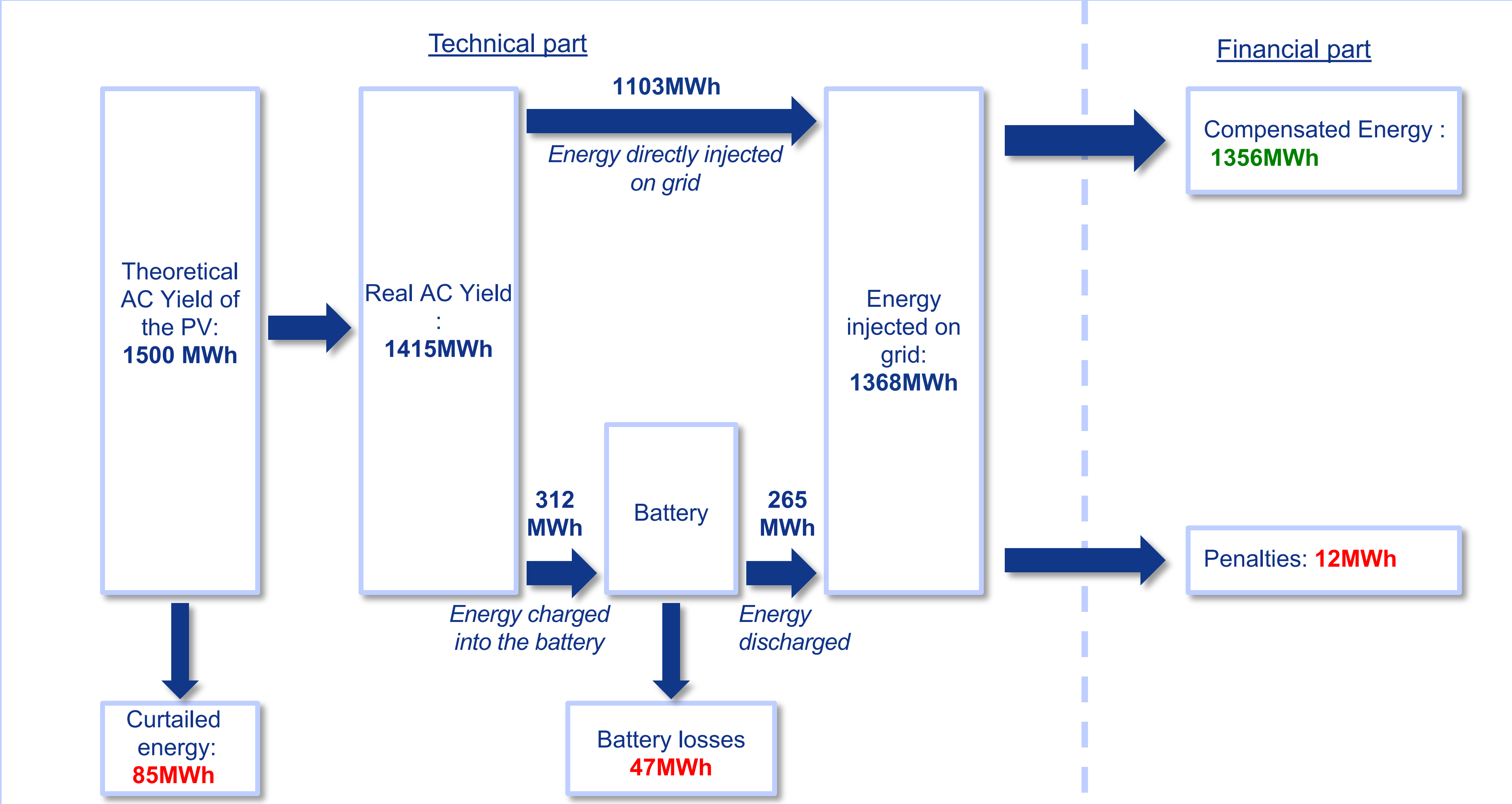
The optimal size of the storage system for this (example) location is 0.8MW / 2MWh

Energy cost (LCOE) of a 1MWp PV plant as a function of the battery power capacity and energy

LCOE in $/MWh	1 MWh	2 MWh	3 MWh	4 MWh
0.5 MW	220	210	225	240
0.6 MW	215	205	220	235
0.7 MW	210	200	215	230
0.8 MW	205	**195**	210	225
0.9 MW	210	200	215	230
1 MW	215	205	220	235
1.1 MW	220	210	225	240
1.2 MW	225	215	230	245
1.3 MW	230	220	235	250
1.4 MW	235	225	240	255
1.5 MW	240	230	245	260
1.6 MW	245	235	250	265
1.7 MW	250	240	255	270
1.8 MW	255	245	260	275
1.9 MW	260	250	265	280
2 MW	265	255	270	285

Typical (example) output 2/2: energy flow diagram for a 1MWp PV plant with storage

Aggregated energy flows over 1 year for example project

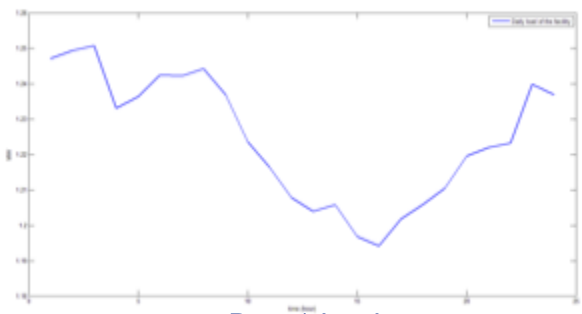


Use-case 2: end-customer energy bill optimization

Energy bill optimization – economic inputs to the model

Inputs:

Load data:
One year of load data from a commercial facility and with a one hour time step is entered into the model.



Day 1 load

Tarification structure:
The following tariff structure is implemented into the model:

	On-peak	Off-peak	Demand charge
Winter tariffs	45€/MWh	34€/MWh	0,77€/kW/month
Summer tariffs	55€/MWh	40€/MWh	0,77€/kW/month

Battery specifications and costs
The following battery specifications are used in the model.
Cost of the power component of the battery: 10€/kW (Volontarily unrealistic in order to reach a positive NPV in this specific case)
Cost of the energy component of the battery: 10€/kWh
Clean Horizon also assumes that the battery can withstand 4500 cycles at 80% DoD

- **These data are used to simulate the usage of batteries of different sizes and assess the economic gains (in this case the savings made) and expenses (capex and opex) for each of these batteries.**
- **The battery that returns the highest spread between gains and losses (aka the NPV) is then chosen.**

Output (1/3) : the optimal sizing is the one that guarantees the highest NPV.

The optimal size of the storage system for this consumer is 80kW / 160kWh (nominal rating), as it is the system reaching the highest NPV. These data are obtained through the constitution of a full business model implemented in the modelling tool.

NPV of the installation of the battery, as a function of the battery power capacity and energy, over 20 years

Expected NPV in €	0.02MWh	0.04MWh	0.06MWh	0.08MWh	0.1MWh	0.12MWh	0.14MWh	0.16MWh	0.18MWh	0.2MWh
0.02 MW	344.94	562.64	615.24	672.98	649.61	600.97	541.57	532.88	315.09	148.48
0.04 MW	95.65	587.43	811.19	828.83	893.14	915.20	875.62	834.17	808.94	807.62
0.06 MW	-164.18	339.04	694.57	955.07	1044.95	1113.55	1057.66	1093.35	1020.90	997.66
0.08 MW	-429.64	83.01	447.42	763.83	1023.87	1098.95	1188.16	**1197.78**	1164.02	857.33
0.1 MW	-695.11	-174.01	198.17	514.21	778.59	918.40	1038.36	1131.02	1169.12	1057.30
0.12 MW	-960.57	-432.26	-60.08	261.16	537.54	679.05	848.27	588.01	504.17	533.93
0.14 MW	-1226.03	-689.46	-317.09	14.46	288.43	442.44	620.13	762.95	711.18	740.27
0.16 MW	-1491.50	-948.87	-574.12	-245.97	31.90	207.69	371.56	509.48	476.93	544.73
0.18 MW	-1756.96	-1209.34	-832.36	-501.63	-224.70	-29.04	129.14	280.62	242.64	302.98
0.2 MW	-2022.42	-1473.41	-1089.37	-747.01	-470.32	-276.02	-113.85	26.21	-2.49	60.32

Output (2/3): energy flows and financial gains and losses can be precisely assessed

Aggregated energy flows and costs over 1 year for the example project – all years are then assumed to be identical

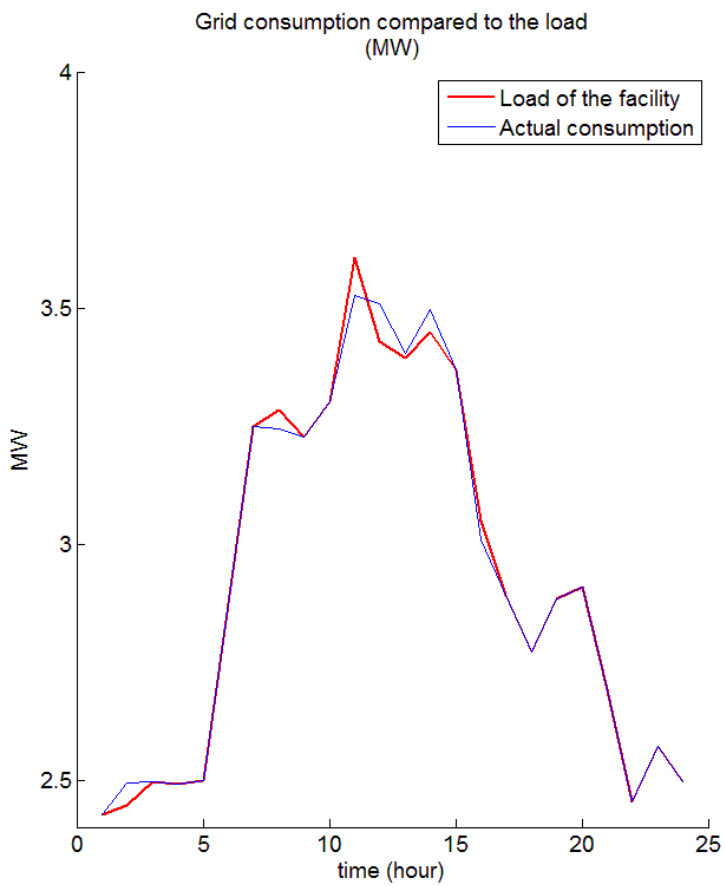
After the installation of the battery		Before the installation of the battery:		Gain or Loss:
Off-peak consumption: 6308MWh *(233,030€)*	−	Off-peak consumption: 6289MWh *(232,360€)*	=	Difference in off-peak consumption: **+19MWh** ***(- 670€)***
On-peak consumption: 13489MWh *(674,640€)*	−	On-peak consumption: 13505MWh *(675,390€)*	=	Difference in on-peak consumption: **-16MWh** ***(+ 750€)***
Average monthly power peak 3393kW *(31,355€)*	−	Average monthly power peak 3455kW *(31,920€)*	=	Difference in demand charge: **-62kW** ***(+565€)***

Energy bill reduction:

645€/year

Output(3/3): Precise view of the operation of the battery – here the time step is 1 hour but lower resolution is possible if the input data is precise enough

The battery mostly operates to shave the load peaks; It then recharges, even on peak hours, as it is not assumed that the future load is fully known in order to be more realistic. Some on-peak / off-peak arbitrage is also realized with battery capacity not used for demand charge management.

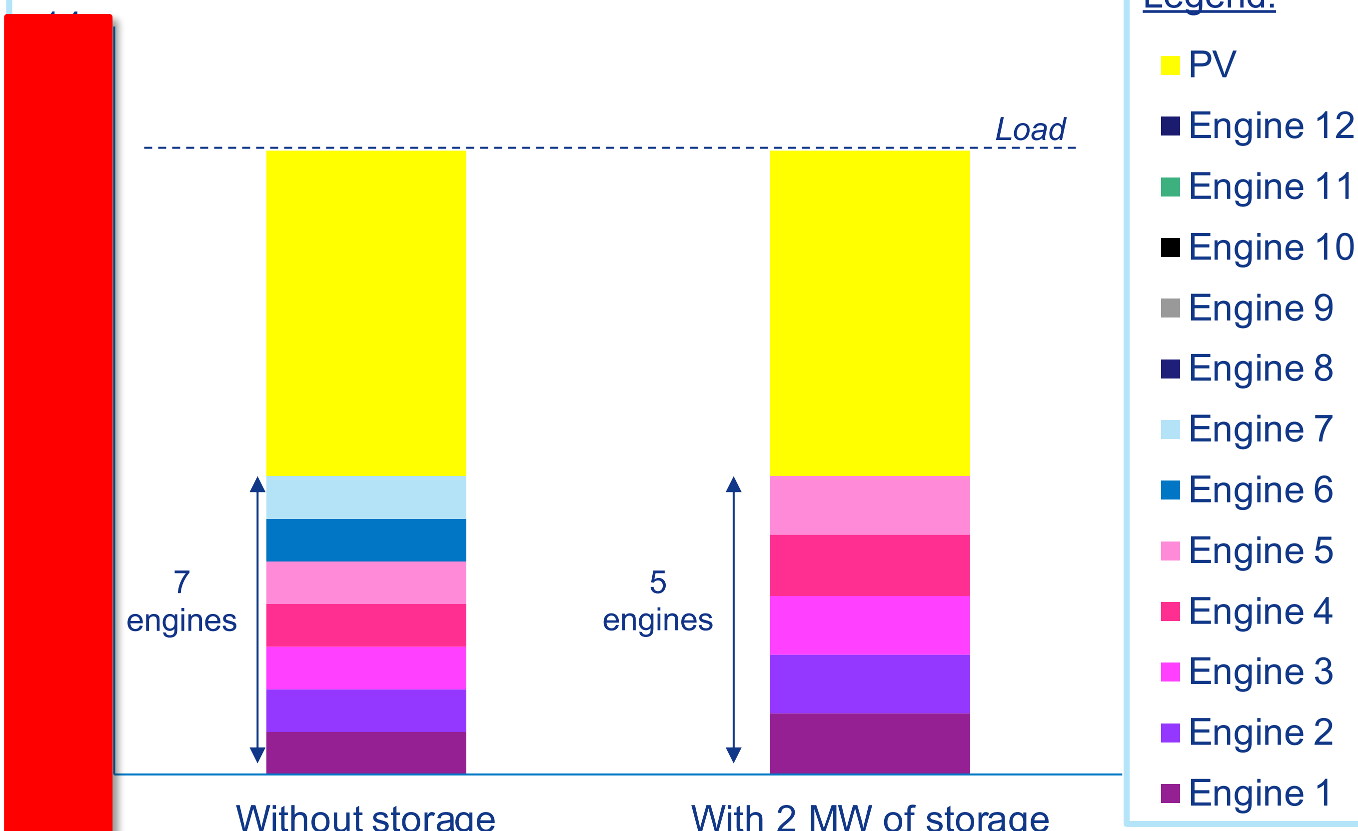


Use-case 3: PV + storage + diesel hybrid power plant

The energy storage system is primarily used to provide additional spinning reserve

The storage system allows to reduce the number of running engines necessary to ensure that a sufficient amount of reserve is available

<u>Example of operation with and without energy storage providing reserve (at XXX am on day 1)</u>
(in MW)

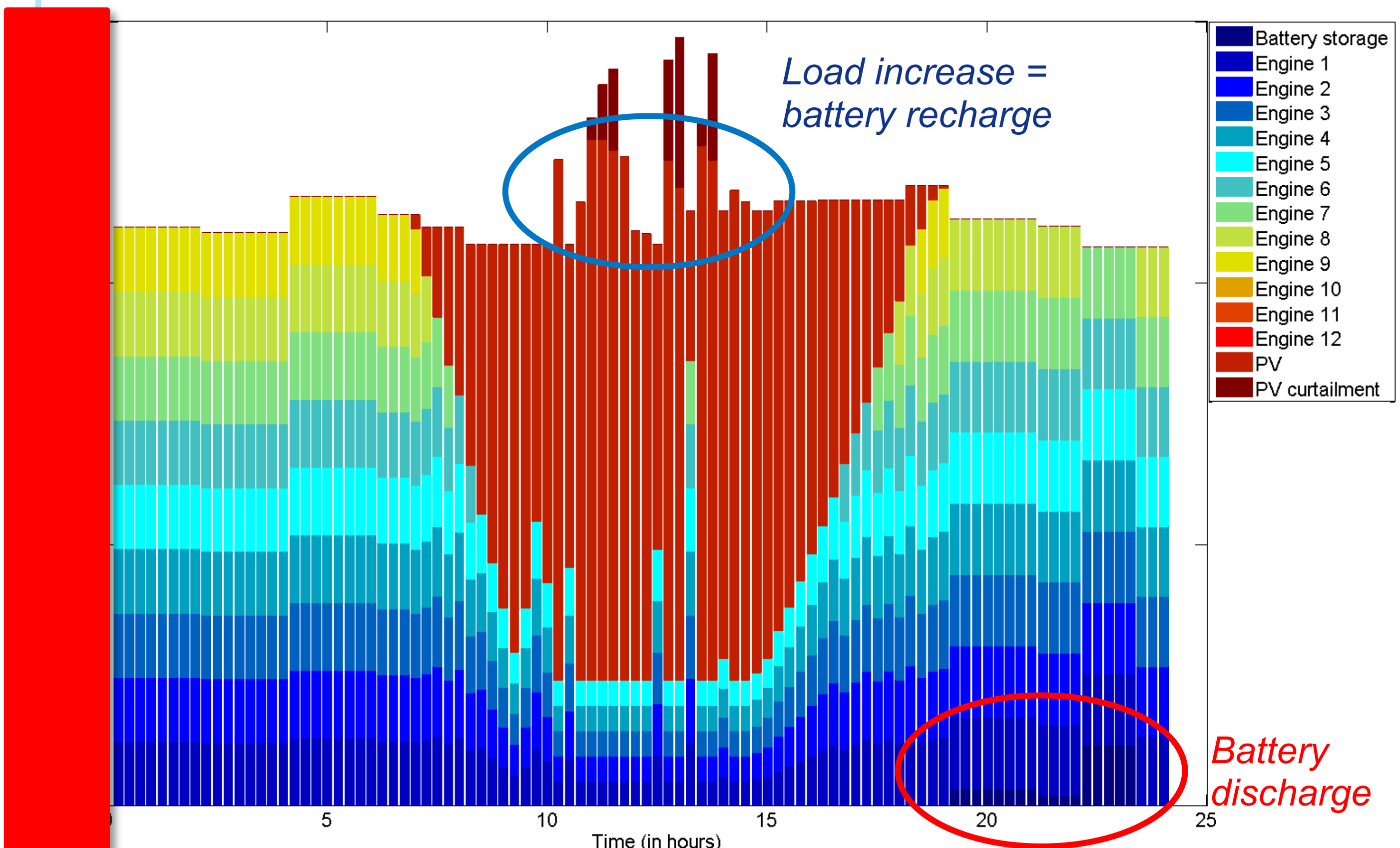


The provision of spinning reserve is considered the primary use of the energy storage system as it allows to optimize the dispatch of the engines and reduce the amount of PV curtailed without requiring a long duration storage system and heavy cycling.

Alternatively, when not used for reserve, the storage system attempts to reduce the amount of PV power being curtailed

The storage system allows to make use for the PV energy that is otherwise curtailed due to the constraints that apply to the system

Example of operation with a XXX MW / XXX MWh used to avoid PV curtailment (with a XXX MW PV system) *(in MW)*



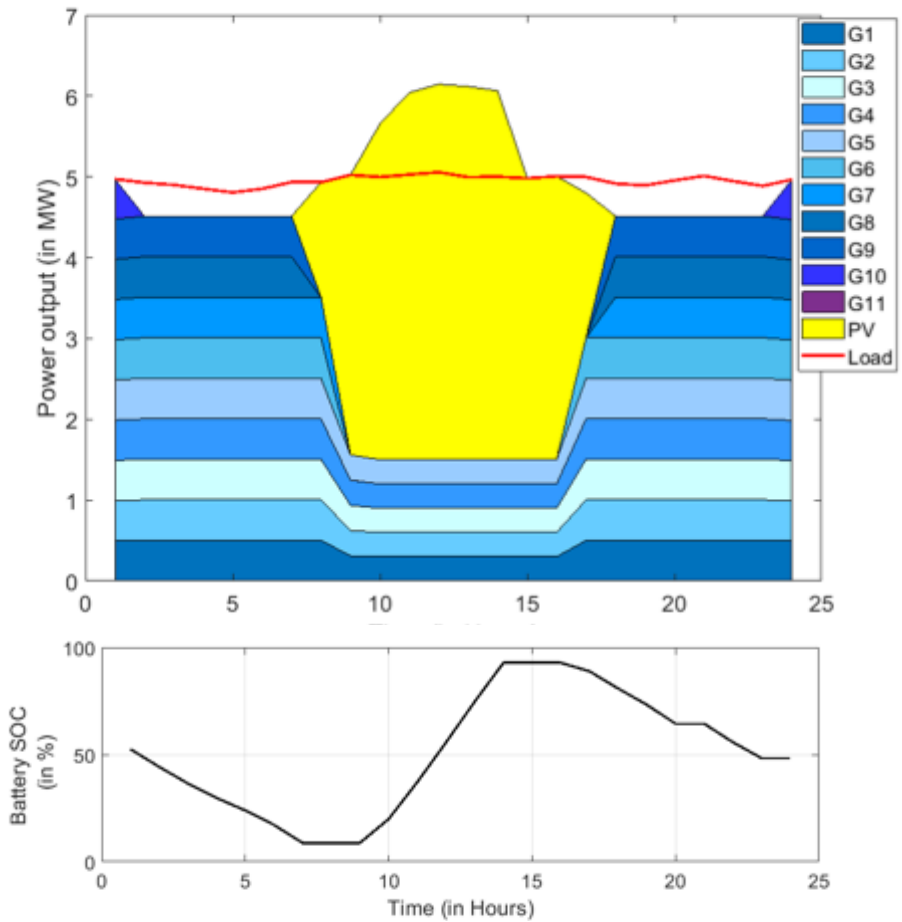
In combination with the provision of reserve, such operation of the energy storage system ensures that the engines run at a high efficiency and as little available PV energy as possible is lost

Another example

The storage system allows to make use for the PV energy that is otherwise curtailed due to the constraints that apply to the system

Example of operation of a PV plus diesel plus storage power plant, as simulated on Clean Horizon's CRE-STORE tool

in MW



In combination with the provision of reserve, such operation of the energy storage system ensures that the engines run at a high efficiency and reduce the PV curtailment.

In summary, what do you get from CRE-STORE?

The values brought by CRE-STORE:

1. **Optimal sizing of the storage component of your project**
2. **Business plan of the overall project containing storage**
3. **Detailed view of energy flows in the project to compute performance ratios**

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