Modelling Batteries in Hybrid Power Plants

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A hybrid power plant combines at least two different power plant types

Key drivers

1. Financial
   - Savings to fuel and maintenance costs
2. Environmental
   - Reduced fuel consumption → lower emissions
3. Reliability
   - Components complement each other
   - Careful system planning and operation required

Thermal power plant

Renewables

Battery energy storage system (BESS)

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Batteries enable renewables and help thermal units

Enabling renewables

1. Smoothing output
2. Peak shaving
3. Energy shifting

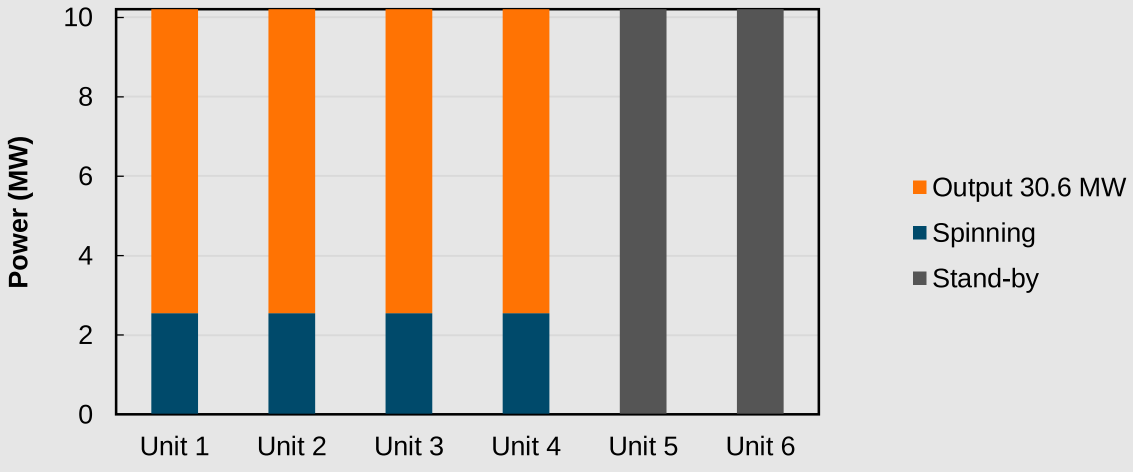
Reserve capacity

1. Thermal (spinning) reserve replacement
2. Renewable output reserve

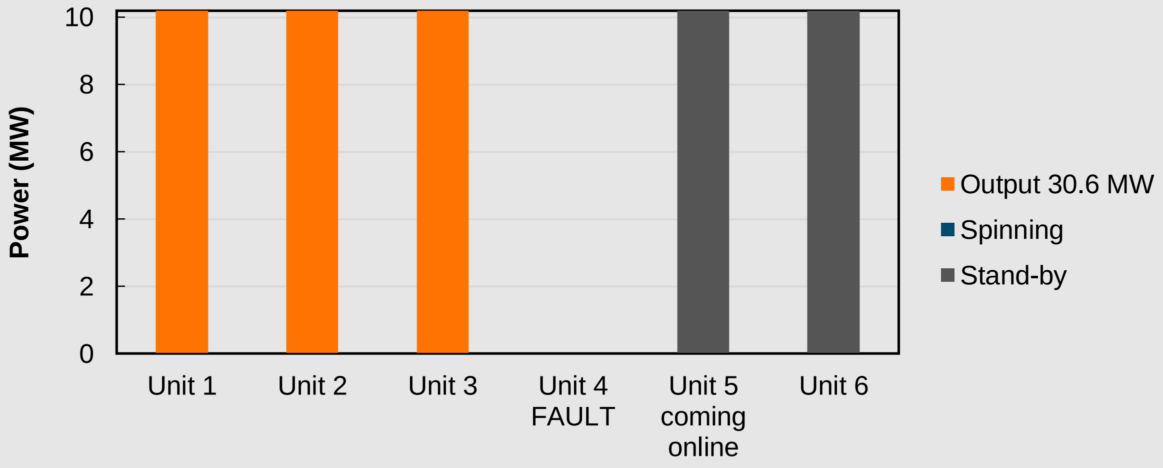
QUANTIFY VALUE
with a Plexos ®
power system model

NO BESS

Output and reserves: 4+2

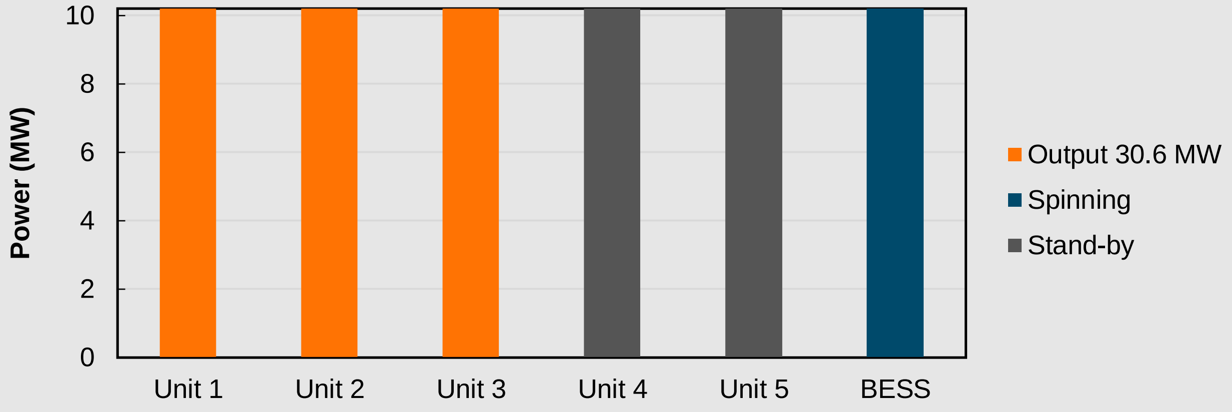


Output and reserves: 4+2 fault

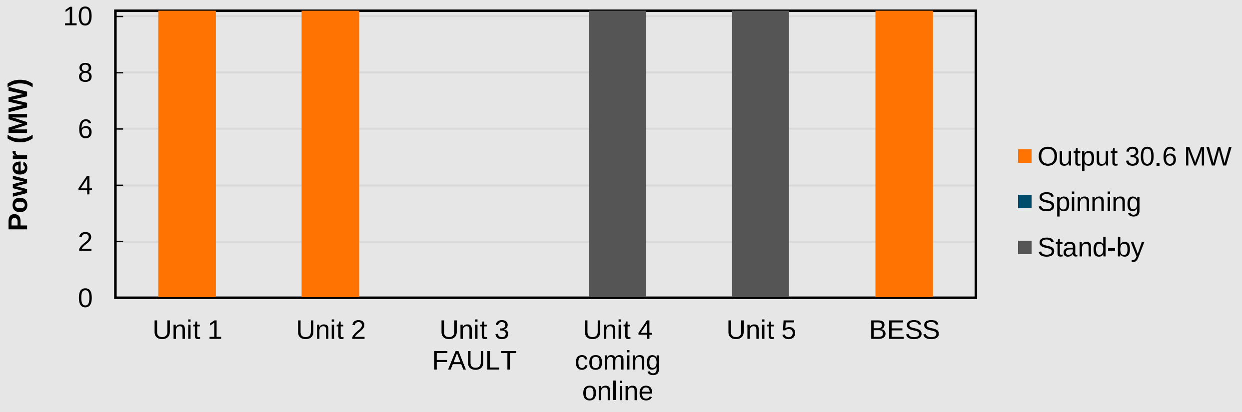


WITH BESS

Output and reserves with BESS: (3+BESS)+2



Output and reserves with BESS: (3+BESS)+2 fault



Model

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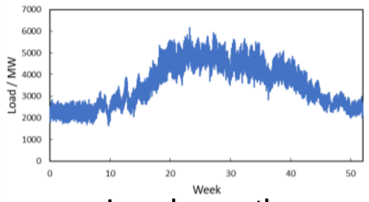
Demand

Load & Reliability

Spinning reserve
Load risk
Ren. forecast risk



Load growth

Supply

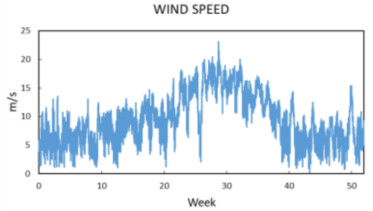
Existing capacity

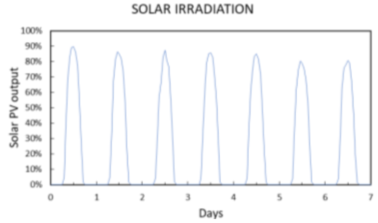
HYDRO

New build options

HYDRO

Profiles





Costs

Fuels
Gas, Coal, HFO, LFO prices

FO&M
VO&M
Start costs
Ramp costs

RE & ES CAPEX
Wind
Solar PV
Hydro
4 h Battery
30 min Battery
Price dev. from Bloomberg NEF

Thermal CAPEX
ICE
OCGT
CCGT
Coal ST

PLEXOS BY ENERGY EXEMPLAR

M O D E L

Techno-economic optimization: minimize costs, while meeting demand + technical constraints
Chronological dispatch

Cost optimal battery size and application

Only a few parameters needed for BESS

- Size: 1 MW / XX MWh
- **Costs:** CAPEX (USD/kW), OPEX (Fixed O&M)
- Round-trip efficiency 88% (95% charge/discharge, 98% inverter)
- If built, part of the storage capacity is reserved for spinning reserve (minimum SoC)

Then it is about how they are used in the model

- Different storage sizes have different costs & applications.
  - **Power battery** = 2C rating. Lowest cost per power, highest cost per energy. **For reserves only.**
  - **Energy battery** = 1C rating and below. **For energy shifting and reserves.**
- Technical constraints, e.g.
  - Short circuit protection requires several times nominal current to function
  - For this, BESS would have to be oversized: rule of thumb (1.2 * Max Load) for ½ hour
  - Typically not feasible with today's prices

Case example: Large mine in Africa

Isolated grid in a remote location

- independent electricity production
- liquid fuels
- expensive transportation

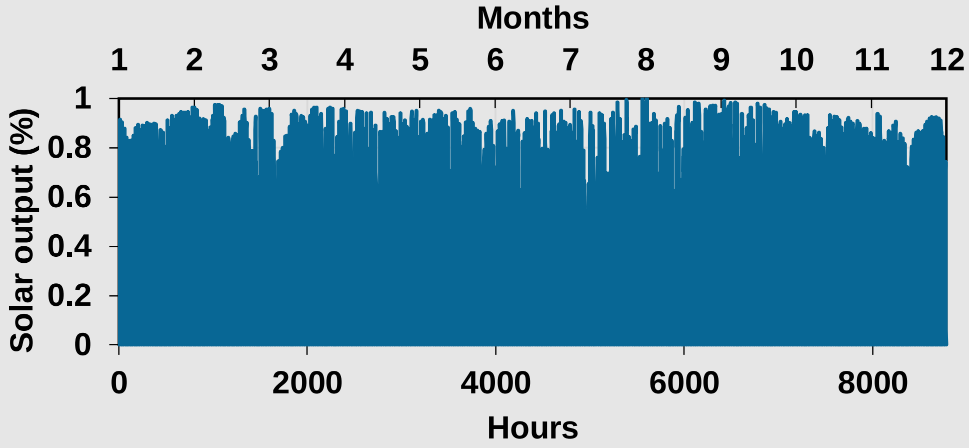
Good renewable resources

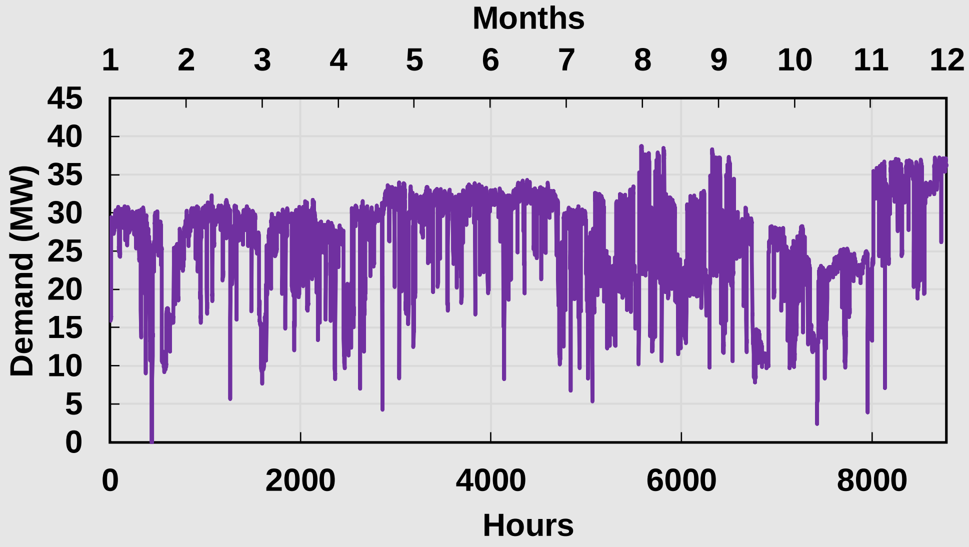
- stable solar output throughout year
- Capacity factor 28%

Demand profile

- Peak demand 39 MW
- Average demand 27 MW
- 63% of the time demand below 30 MW

Real case. Today’s realistic prices & performance.





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Chronological, hourly model, today's prices

Case 1: Full thermal

x 6

10.2 MW

Design principle n+2
Operating as n+1
1 unit as backup

Case 2: Thermal + BESS

x 5

10.2 MW

Optimized
= 8.2 MW / 4.1 MWh

Design principle n+1+BESS
Operating as n+BESS
1 unit as backup

Case 3: Thermal + BESS + PV

x 5

10.2 MW

Optimized
= 7.9 MW / 7.9 MWh

Optimized
= 32 MW

Design principle n+1+BESS
Operating as n+BESS
1 unit as backup

Technical constraints:
Short circuit current: 1 engine running at all times.
Spinning reserve requirement for 15 minutes.
Ability to operate without solar.

Lifecycle value of a hybrid: payback in 3 years, depends on fuel price

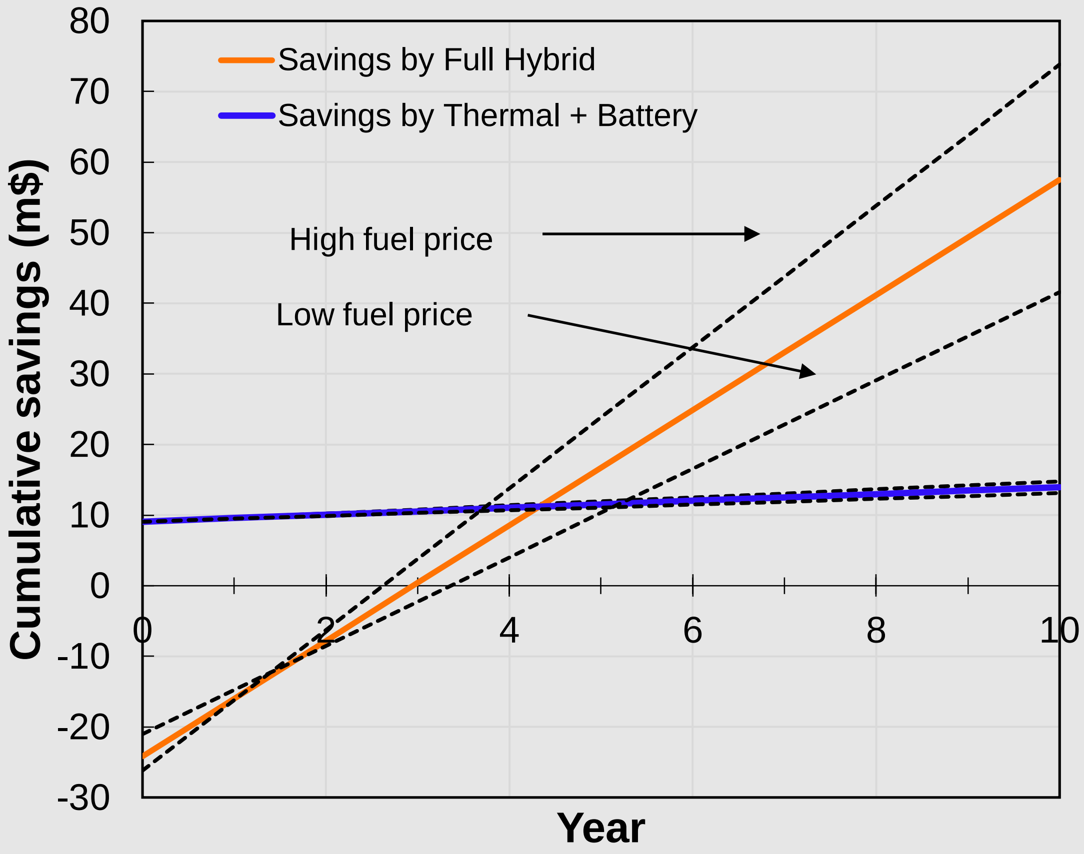


Figure shows cumulative savings against 100% thermal, achieved with Thermal + Battery (blue line) and Full Hybrid solution (yellow line).

The dashed lines represent the effect of ± 20% changes to the fuel price (13 ± 3 $/GJ). The higher the fuel price, the steeper the savings curve.

Savings of Full hybrid and Thermal + Battery against 100% Thermal

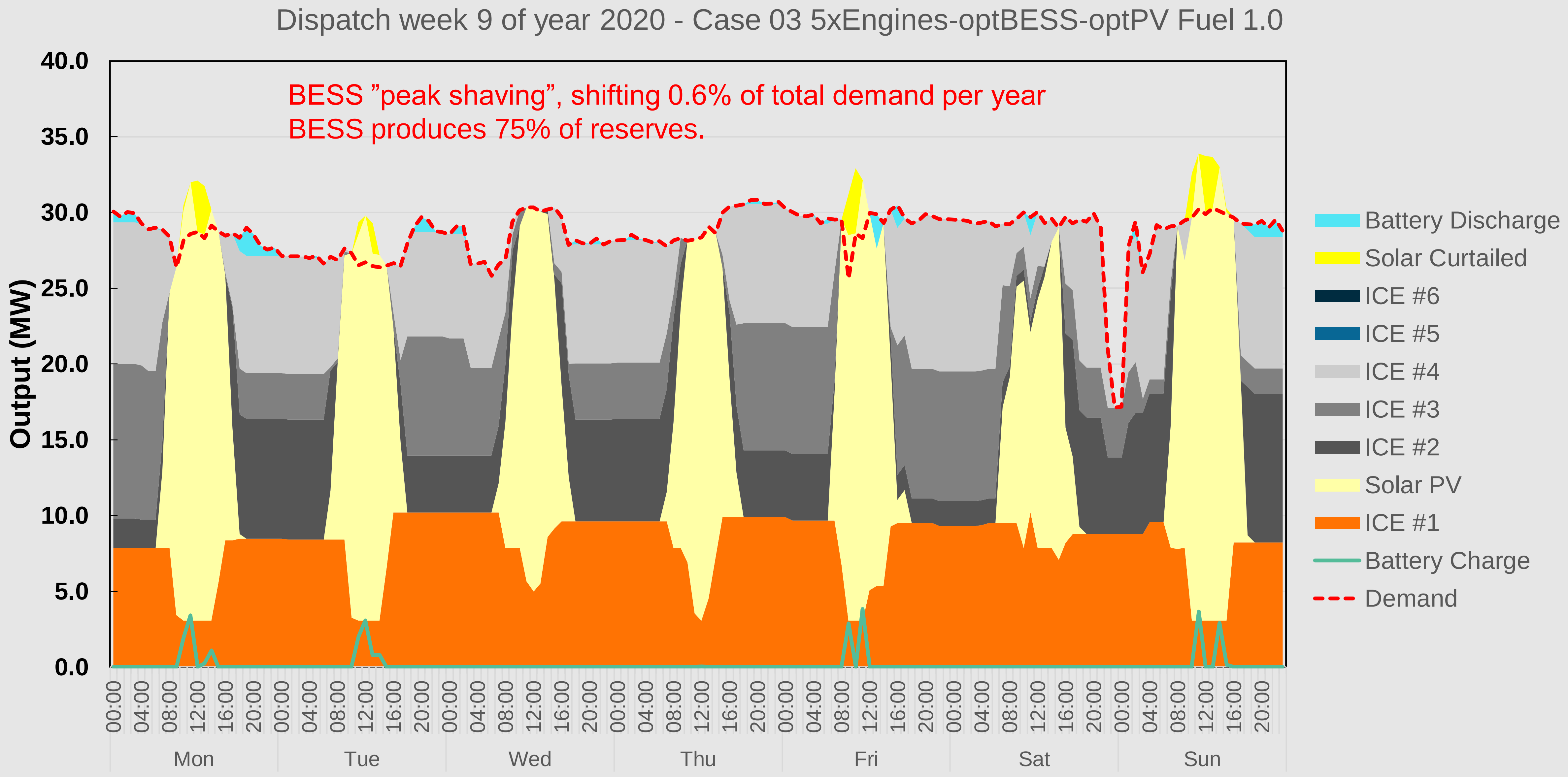
- The investment for 100% thermal plant stands at ca. $70m, and annual OPEX at ca. $30m (excluding CAPEX)

Thermal + Battery vs 100% Thermal:

- -$9m investment
- -$0.5m/year opex
- Insensitive to fuel price

Full Hybrid vs 100% Thermal:

- +$25m investment
- -$8m/year opex
- Sensitive to fuel price (note: optimal renewable penetration changes)


Dispatch week 9 of year 2020 - Case 03 5xEngines-optBESS-optPV Fuel 1.0
BESS ”peak shaving”, shifting 0.6% of total demand per year
BESS produces 75% of reserves.
Output (MW)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
00:00
04:00
08:00
12:00
16:00
20:00
Mon
Tue
Wed
Thu
Fri
Sat
Sun
Battery Discharge
Solar Curtailed
ICE #6
ICE #5
ICE #4
ICE #3
ICE #2
Solar PV
ICE #1
Battery Charge
Demand

Chronological, hourly model, ~~today's~~ 2028 prices

Case 1: Full thermal

x 6

10.2 MW

Design principle n+2
Operating as n+1
1 unit as backup

Case 2: Thermal + BESS

x 5

10.2 MW

Optimized
~~= 8.2 MW / 4.1 MWh~~
= 10.2 MW / 5.1 MWh

Design principle n+1+BESS
Operating as n+BESS
1 unit as backup

Case 3: Thermal + BESS + PV

x 5

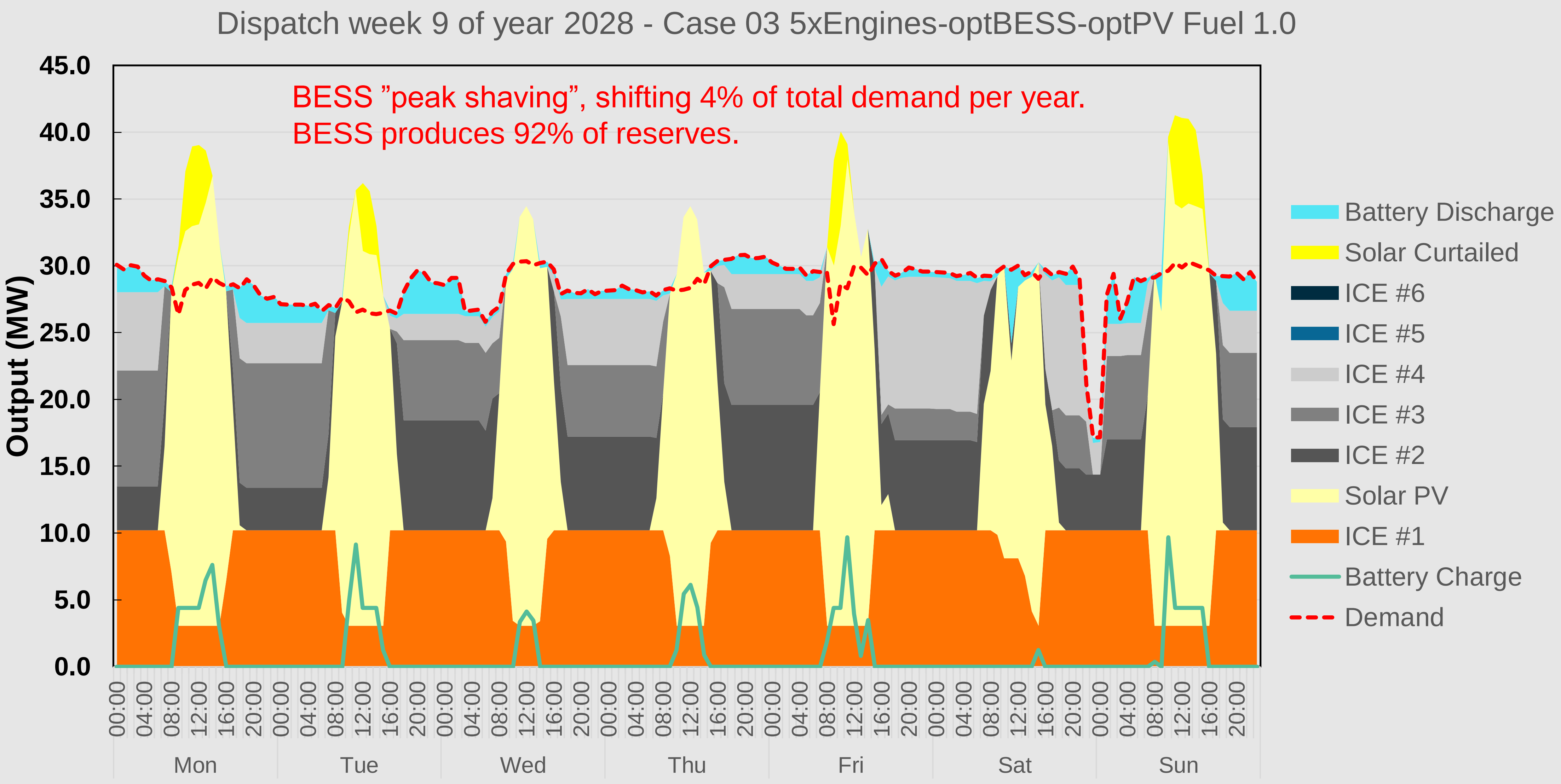
10.2 MW

Optimized
~~= 7.9 MW / 7.9MWh~~
= 10.6 MW / 41.4 MWh

Optimized
~~= 32 MW~~
= 40 MW

Design principle n+1+BESS
Operating as n+BESS
1 unit as backup

Technical constraints:
Short circuit current: 1 engine running at all times.
Spinning reserve requirement for 15 minutes.
Ability to operate without solar.



Dispatch week 9 of year 2028 - Case 03 5xEngines-optBESS-optPV Fuel 1.0
BESS ”peak shaving”, shifting 4% of total demand per year.
BESS produces 92% of reserves.
Output (MW)
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
00:00 04:00 08:00 12:00 16:00 20:00
Mon
Tue
Wed
Thu
Fri
Sat
Sun
Battery Discharge
Solar Curtailed
ICE #6
ICE #5
ICE #4
ICE #3
ICE #2
Solar PV
ICE #1
Battery Charge
Demand

Optimal buildout & savings achieved very sensitive to inputs.
Every project needs to be optimized individually.

BESS with thermal, 8 MW

One thermal unit replaced with 8.2 MW spinning reserve battery → **less upfront investment**

Spin. Res. with **BESS saves fuel**

- Thermal running on part-load is less efficient

No value in adding energy shifting batteries

8.2 MW BESS replaced 80% of spinning reserves. For 100% spinning reserve replacement, BESS needs to be cheaper and fuel more expensive.

BESS in full hybrid

- Cost of renewable energy + storage vs. cost of thermal dispatch
- Batteries enable more renewables
  - 30 MW without BESS, 32 MW with BESS
- Energy shifting now possible, but not economically favorable in large scale (today).

However, this is bound to change…

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