

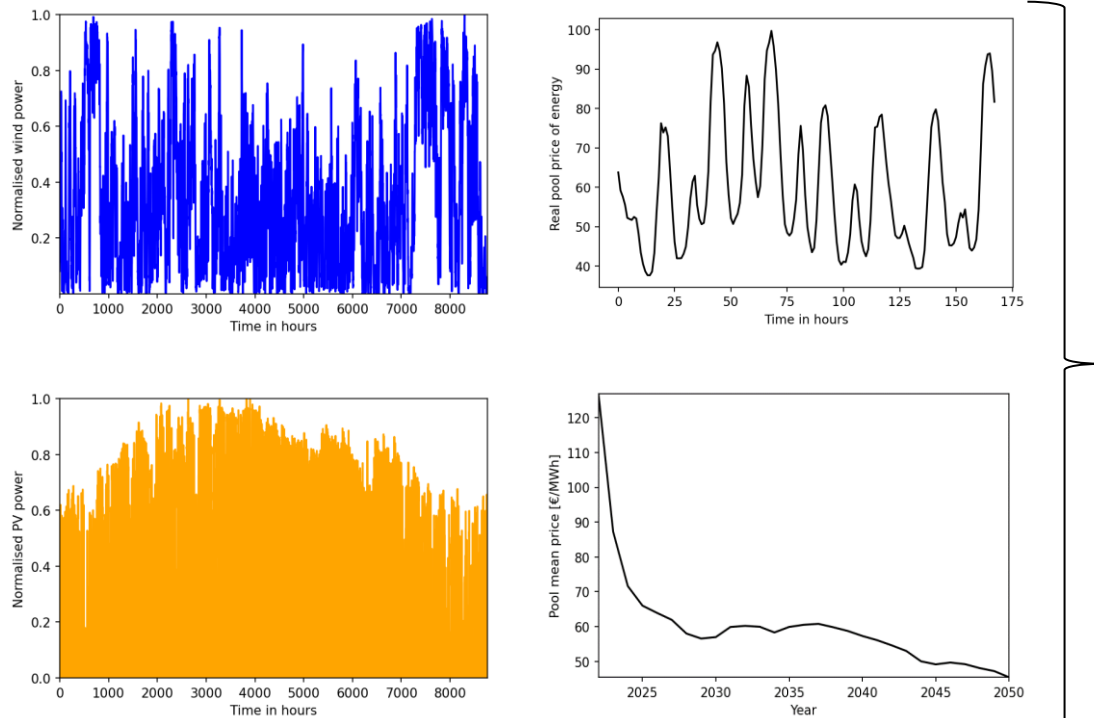
**ADVANCED  
RENEWABLE  
ENERGY  
OPTIMIZATION**

**EN E R G Y**

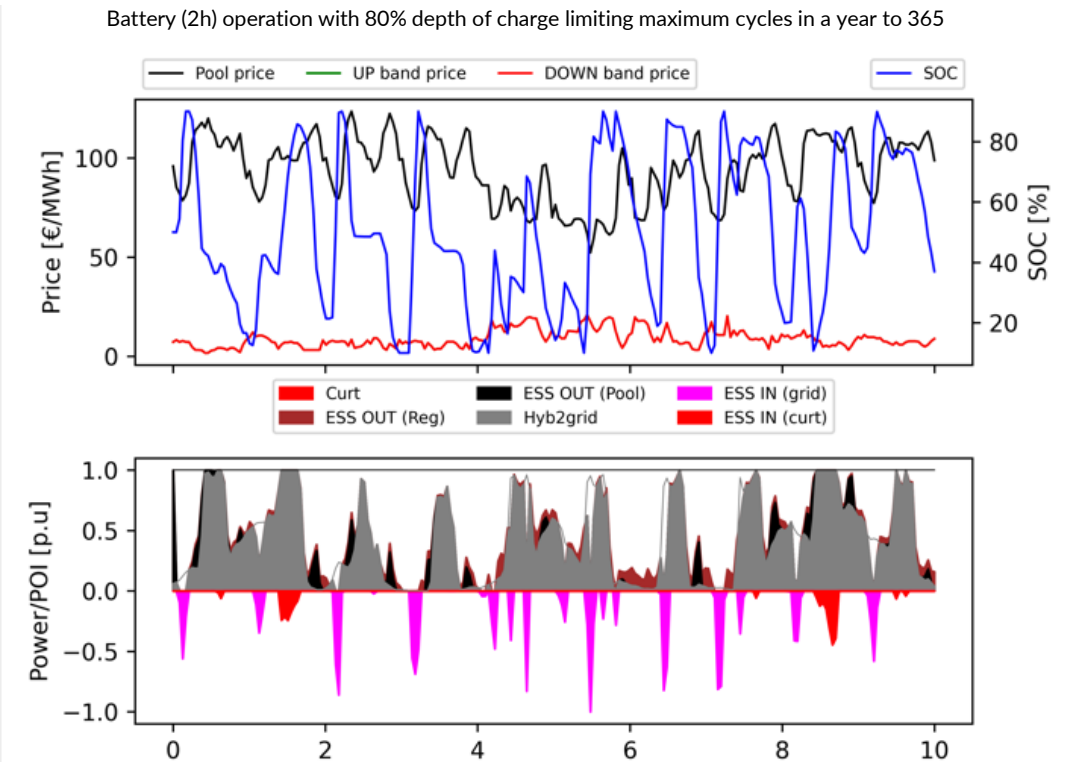
# Clear defined objective

AREO uses its own cutting-edge software that provides optimal sizing and operation of a renewable energy system through accurate mathematical models .

We find the optimal operation of the energy storage system according to mixed markets at once: spot / PPA / other contracts for a broad variety of energy storage technologies.



Wind & PV time series + Electricity Market Prices

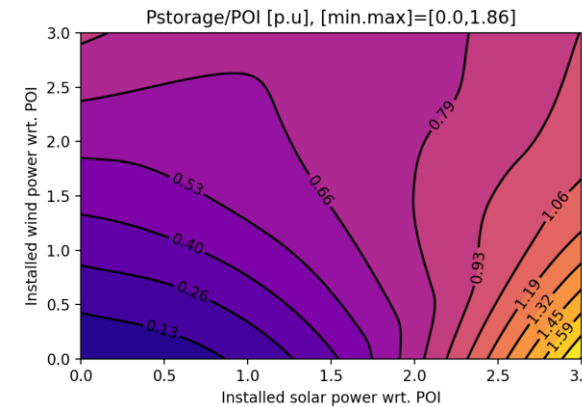
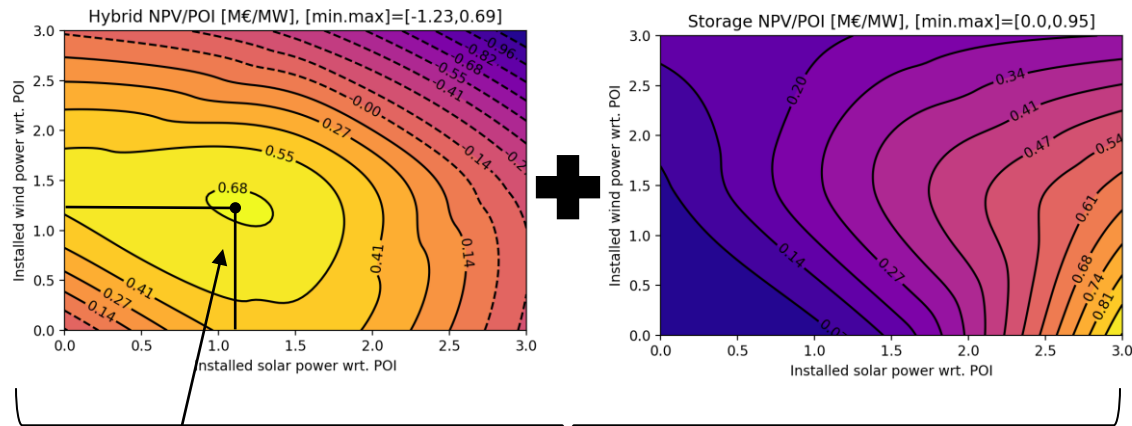


Total input /output power of the optimized power system

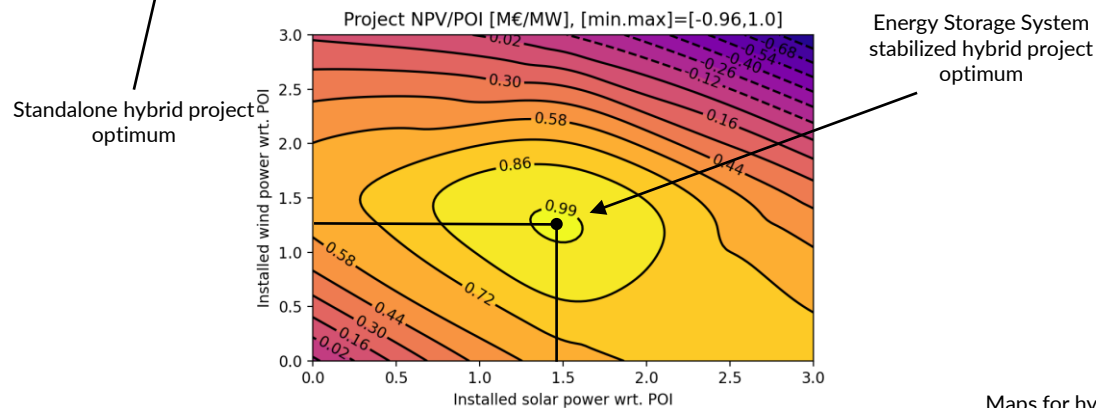
# Attractive visual results

We **optimise the project** in terms of any chosen objective function e.g. **NPV, IRR, LCOE, NEH ...** this obviously leads to a very convenient **strategic position**.

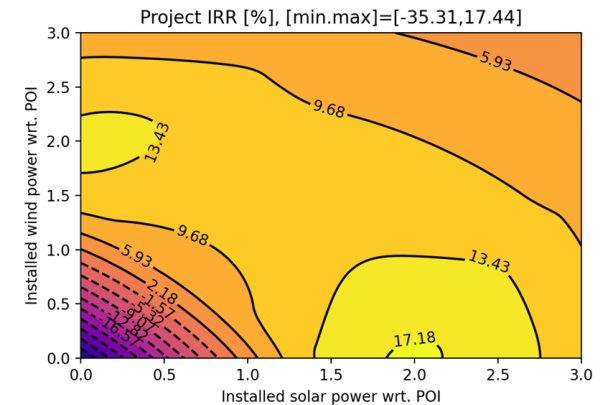
As a result, an **optimal mixing of renewable systems** is found within an **attractive visual frame** that gathers an infinite variety of optimal combinations.



From these maps, any convenient optimum combination can be chosen **at first sight**.



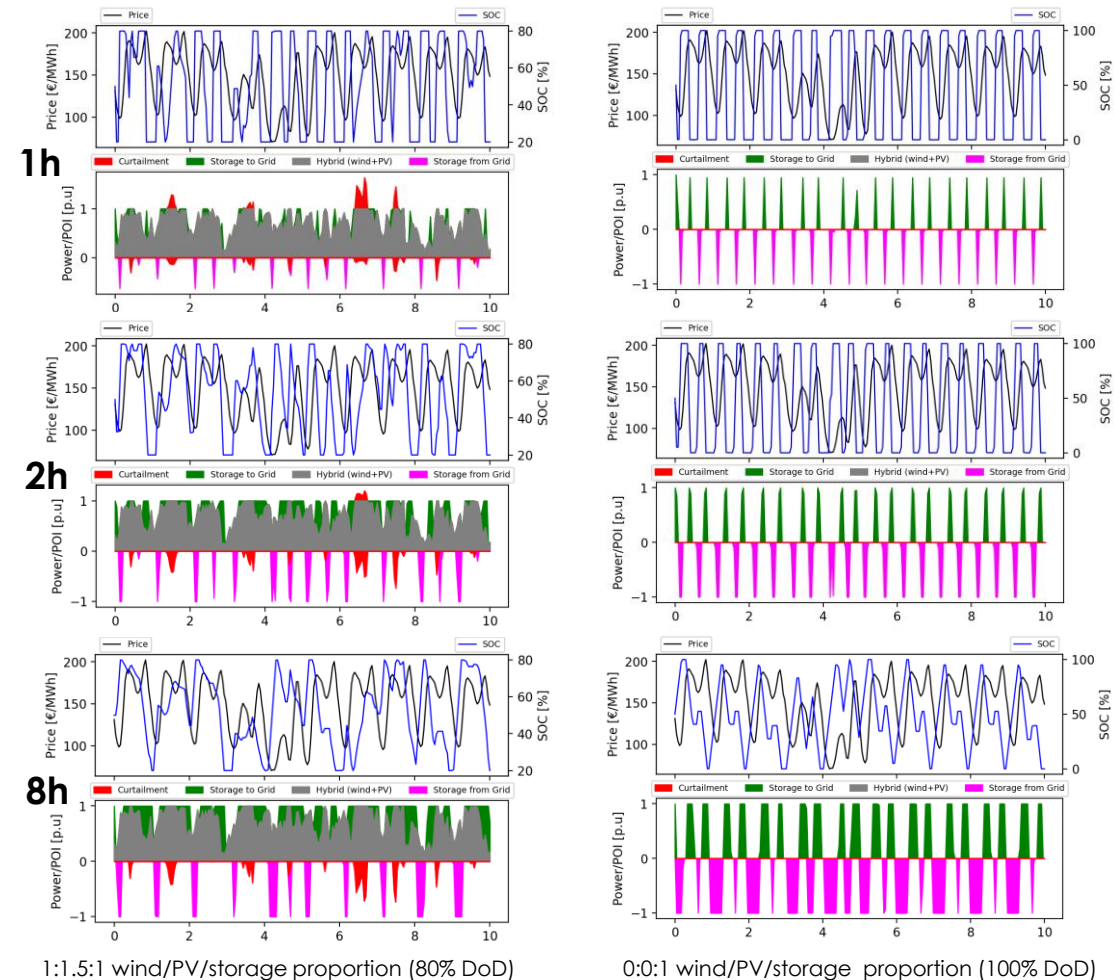
**Constraints** (technical, economic...) can be set **visually** with the aid of **advanced compact graphics**.



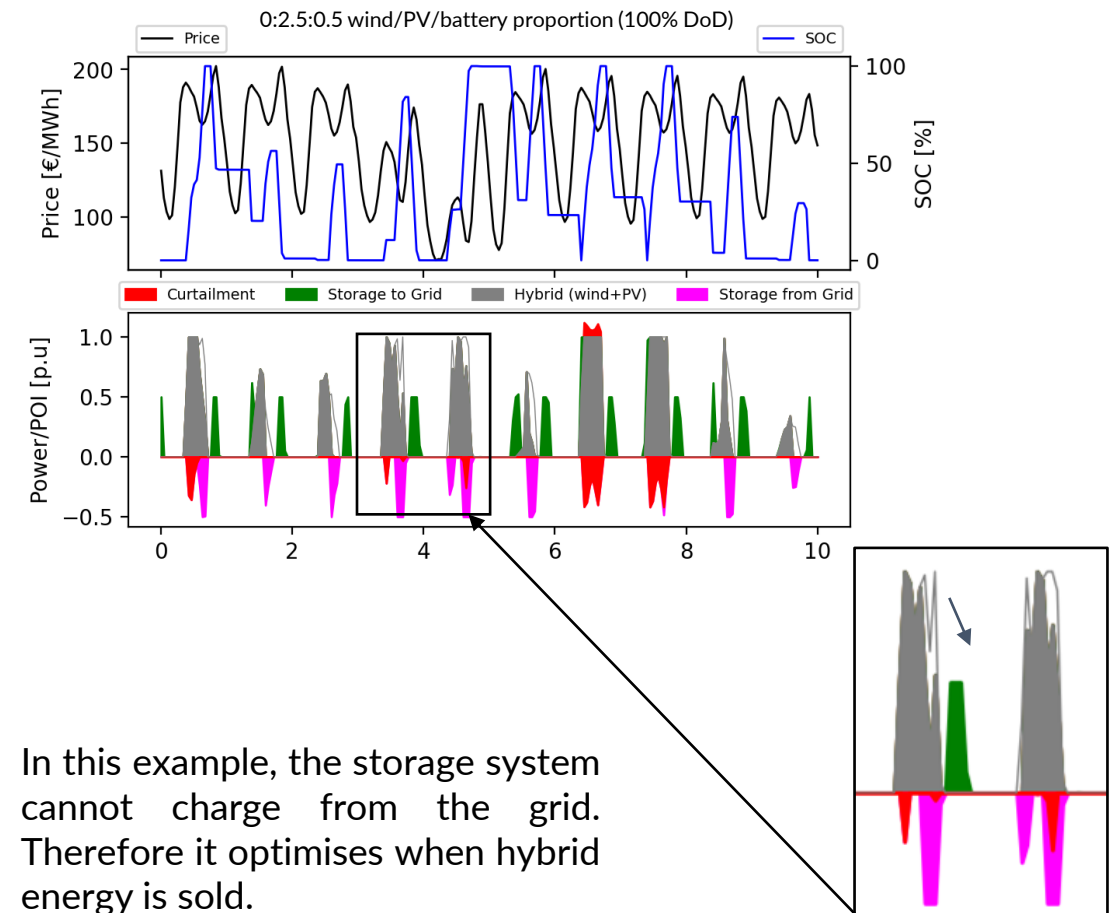
Maps for hydro project with 8h of storage

# Cutting-edge mathematical model

We can model any type of storage system and incorporate every market at once with any timestep.

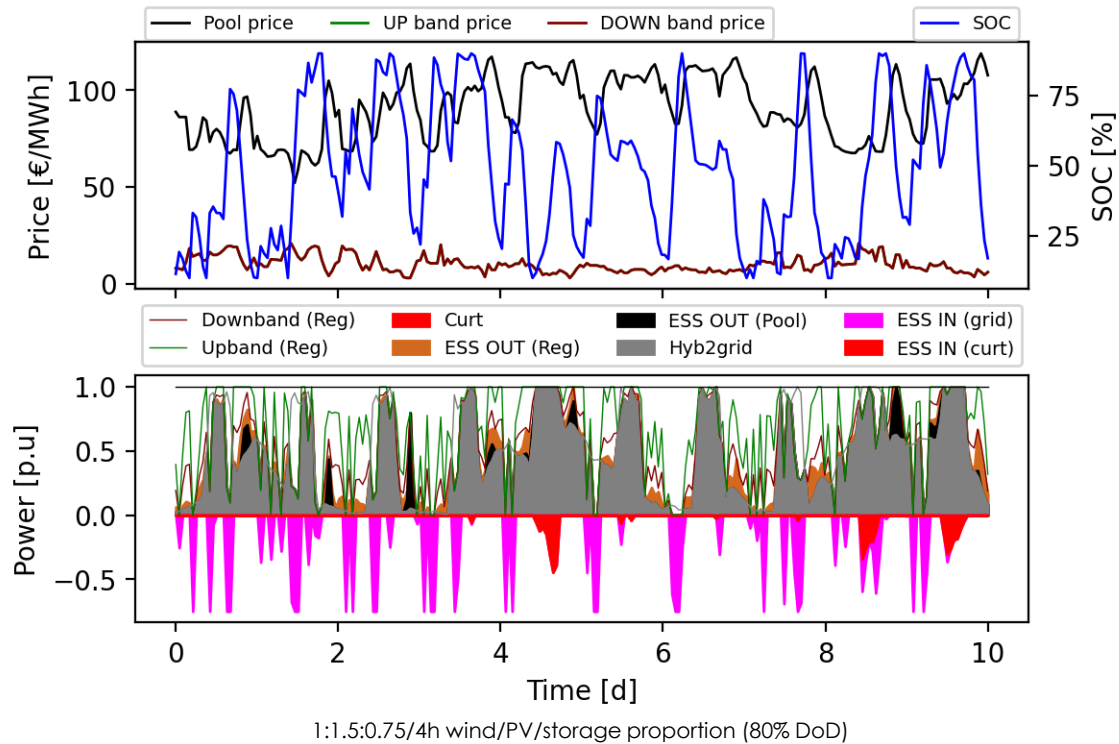


We do the unintuitive work with energy shift from price valleys to price peaks. This can be seen when grid consumption is prohibited (avoiding grid taxes).



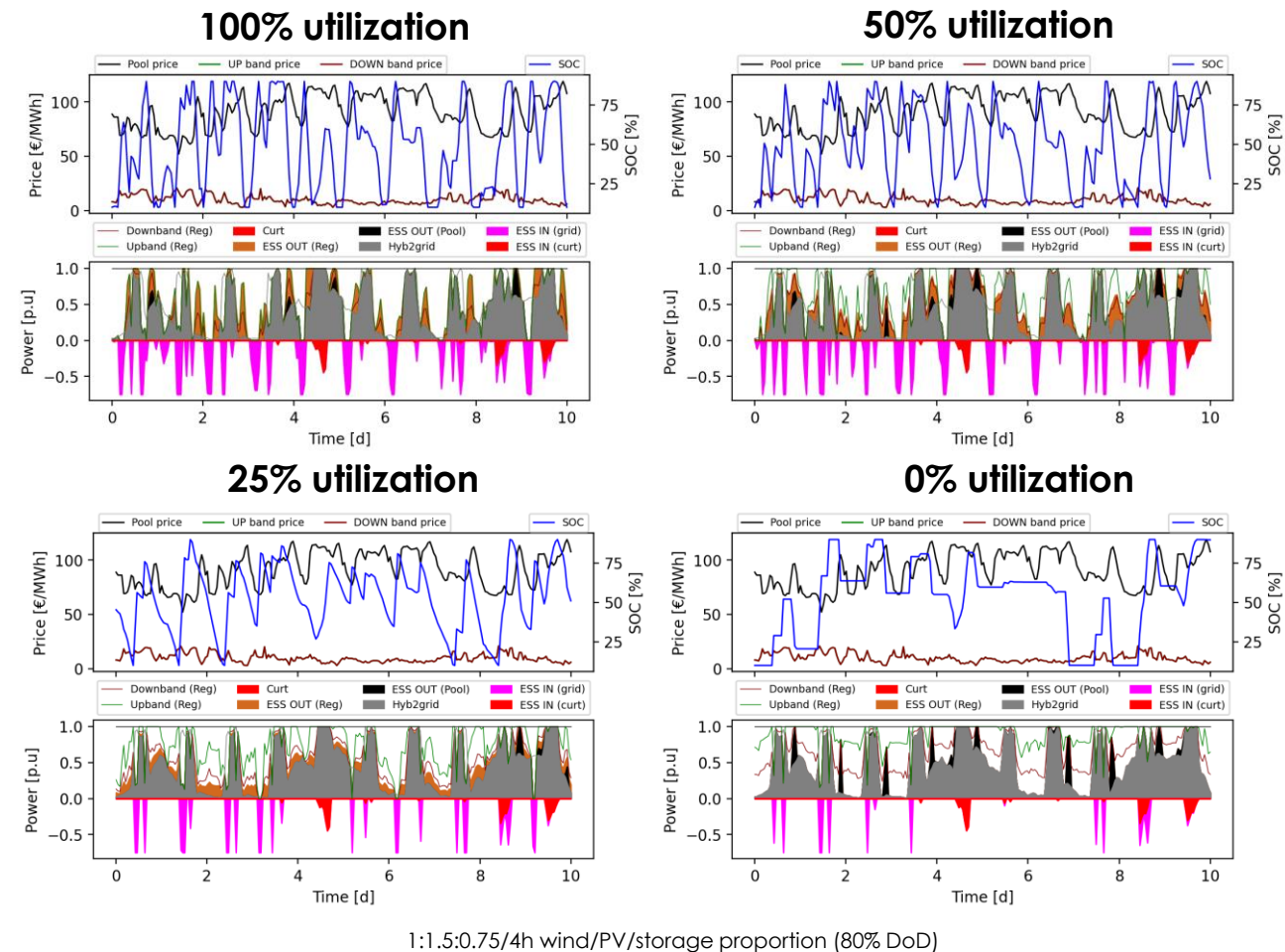
# Secondary regulation market example

We can model any type of market that can be described by a price curve. Secondary market modeling is shown below:



The cleared secondary power quantity has been randomly set between 0% and 100% of the total secondary band according to the SO requirements depicted in the plot. The battery can charge either from the hybrid power plant, from the grid or from both at the same time. Further constraints in this regard as grid restrictions can be applied.

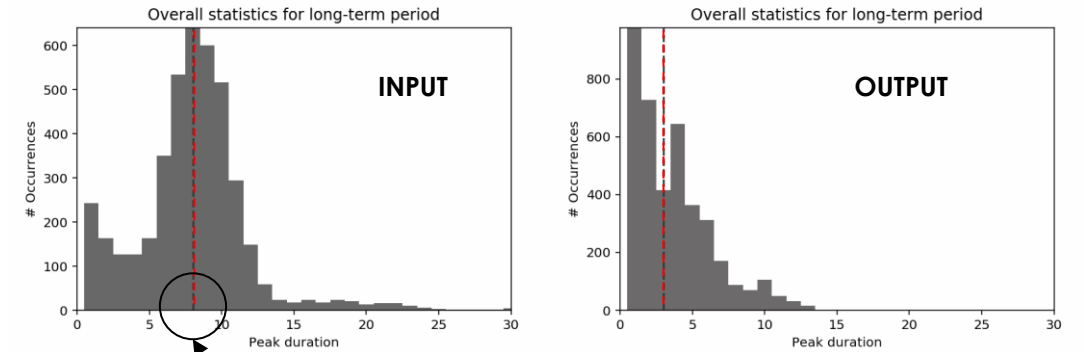
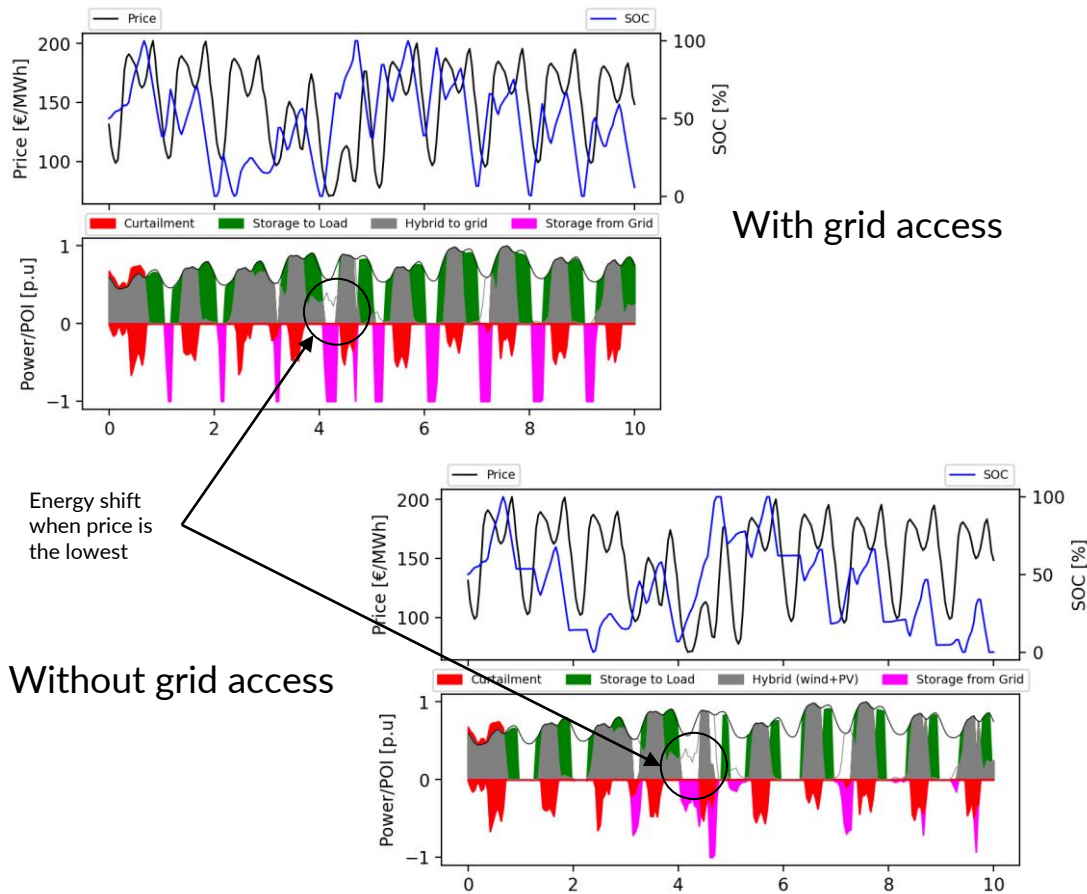
If we vary the percentage of the cleared secondary power (utilization) maintaining it constant in time with same simulation parameters we can obtain the market incomes thresholds and when the different markets become more or less dominant w.r.t. others.



# Infinite possibilities

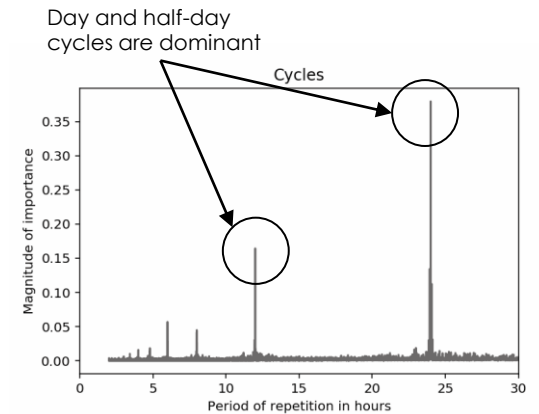
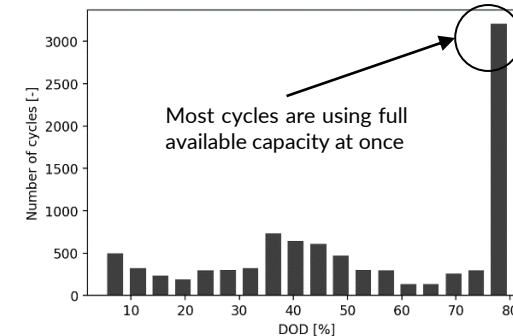
We also solve the **load following problem**, e.g. when prices are higher (or any other rule) and buying/applying energy shifting when low giving **maximising the load matching**.

We provide **valuable information** from data **post processing** to determine and understand any hidden behaviour by **statistical analysis**.



Storage input/output length periods histograms.

8h storage charge period repeatedly occurs



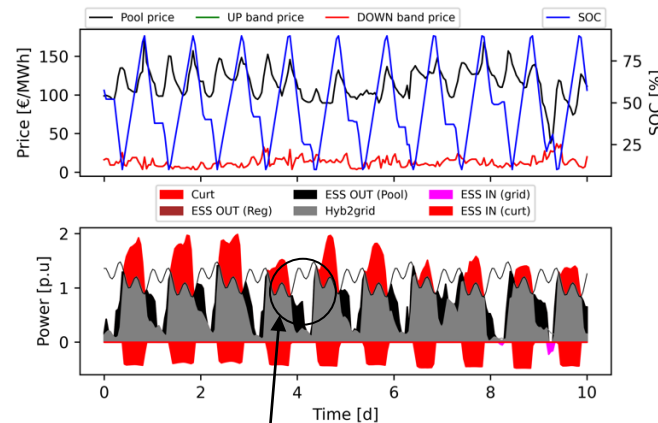
Fourier and reflow analysis to determine relevant storage cycles

1:2:1 wind/PV/storage proportion (100% DoD, 8h)

# Advanced electrolyzer model

For projects in which a **demand of chemical product** must be fulfilled, AREO offers an advanced electrolyzer model to precisely obtain a **demand coerture** at a **minimum production price**.

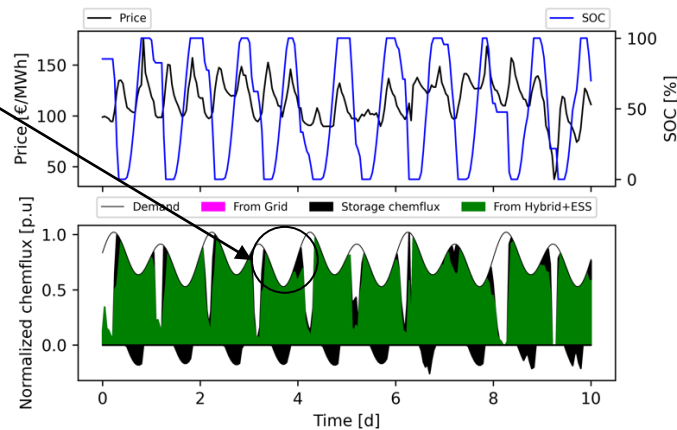
After the **optimization of the operation** has been performed, the sheet of results offers a **simplified gathered data** for an easy verification of the **financial performance**.



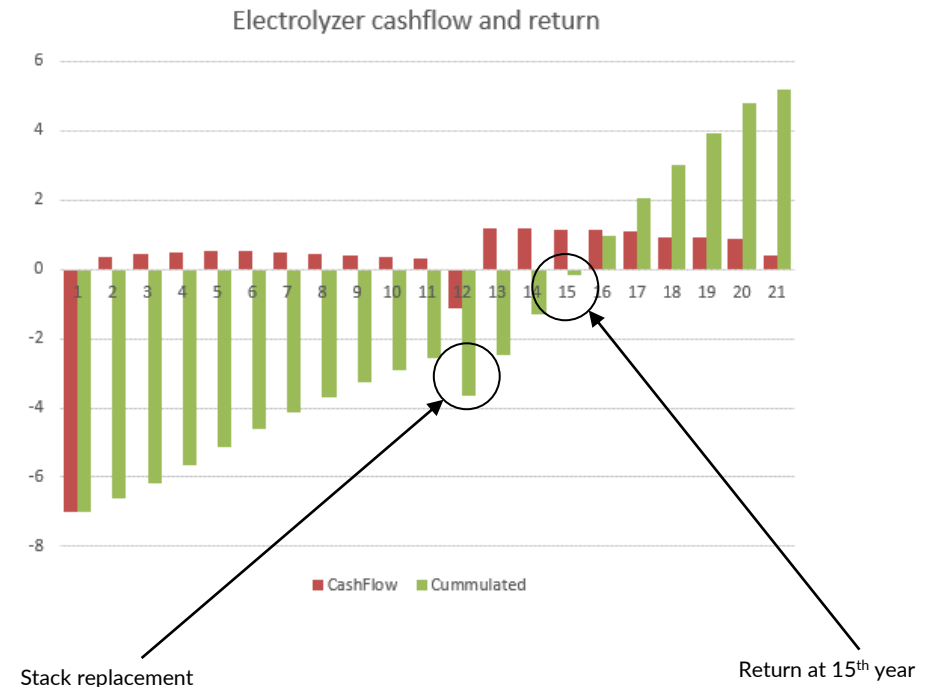
Without grid access, exposure to market is minimized

The energy storage system optimizes both: the power sell and the price of the chemical that is being produced

The chemical tank serves as a reserve to fill peak prices.



1.5:2:0.5 wind/PV/storage proportion w.r.t. electrolyzer(80% DoD, 10h). Ammonia tank of 115 kg

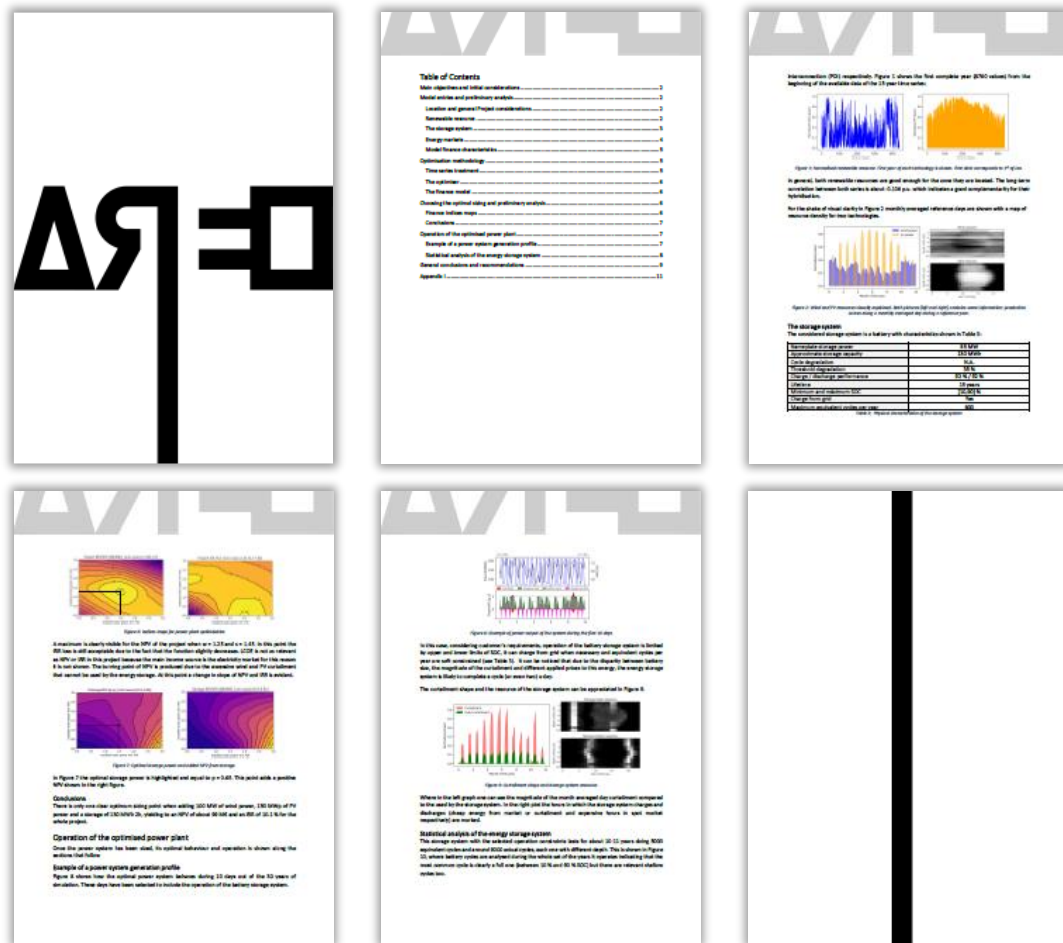




# High quality report

We deliver our clients **high-tech, clear and easy-to-read reports**, that combined with the output datasheet is **fully traceable and auditable**. The minimum essential report length is 14 pages.

Computed data series as well as the **economical analysis** from the optimized case are presented through the five sheets of the output excel sheet of AREO.



|    | A                | B                    | C                     | D                       | E                            | F                             | G                                    | H                              | I   | J   | K               | L |
|----|------------------|----------------------|-----------------------|-------------------------|------------------------------|-------------------------------|--------------------------------------|--------------------------------|---|---|-----------------|---|
|    | Date             | Price Series [€/MWh] | Price UP band [€/MWh] | Price DOWN band [€/MWh] | Hybrid power production [MW] | Storage grid input power [MW] | Storage curtailment input power [MW] | Storage grid output power [MW] | Storage grid output secondary regulation power [MW] | Storage grid output secondary regulation UP/DOWN power ratio [p.u.] | Storage SOC [%] |   |
| 1  |                  |                      |                       |                         |                              |                               |                                      |                                |   |   |                 |   |
| 2  | 2022-01-01 00:00 | 95.86916             | 7.205136              | 7.205136                | 0.598353143                  | 3.90928E-06                   | 2.61211E-06                          | 9.40142063                     | 0.249306416   | 1.4   | 50              |   |
| 3  | 2022-01-01 01:00 | 85.29684             | 8.19387               | 8.19387                 | 0.710415418                  | 1.53343E-05                   | 4.29192E-06                          | 0.001429775                    | 1.311172677   | 1   | 43.0917         |   |
| 4  | 2022-01-01 02:00 | 82.04209             | 7.205136              | 7.205136                | 0.896638617                  | 2.10947E-05                   | 4.50155E-06                          | 0.000711812                    | 0.866000037   | 1.25  | 38.5301         |   |
| 5  | 2022-01-01 03:00 | 78.56288             | 7.773132              | 7.773132                | 1.225534644                  | 9.08927631                    | 5.08527E-06                          | 4.42717E-06                    | 1.9798E-06  | 1.25  | 80.5907         |   |
| 6  | 2022-01-01 04:00 | 81.25646             | 7.205136              | 7.205136                | 1.545822129                  | 2.031714713                   | 5.08817E-06                          | 1.95117E-05                    | 8.88145E-06   | 1.25  | 89.9924         |   |
| 7  | 2022-01-01 05:00 | 87.29458             | 7.205136              | 7.205136                | 1.752837605                  | 0.007037544                   | 5.09296E-06                          | 0.000718967                    | 0.00497928  | 1.25  | 89.995          |   |
| 8  | 2022-01-01 06:00 | 107.923              | 4.628117              | 4.628117                | 1.927751965                  | 2.92109E-05                   | 4.69044E-06                          | 0.002112646                    | 0.482928336   | 1.8   | 87.4423         |   |
| 9  | 2022-01-01 07:00 | 113.8937             | 3.155534              | 3.155534                | 1.870894537                  | 1.29163E-05                   | 4.17867E-06                          | 2.121271279                    | 0.399530294   | 1.4   | 74.175          |   |
| 10 | 2022-01-01 08:00 | 115.7119             | 3.155534              | 3.155534                | 1.894019946                  | 9.89901E-06                   | 3.9163E-06                           | 3.045535801                    | 0.352640339   | 1.8   | 56.2899         |   |
| 11 | 2022-01-01 09:00 | 117.8443             | 3.05035               | 3.05035                 | 4.558149507                  | 8.60116E-06                   | 3.75662E-06                          | 4.041149862                    | 0.252831029   | 1.4   | 33.6901         |   |
| 12 | 2022-01-01 10:00 | 115.2405             | 1.661915              | 1.661915                | 9.710194555                  | 0.000113799                   | 5.01528E-06                          | 0.283703271                    | 0.008345752   | 1   | 32.1535         |   |
| 13 | 2022-01-01 11:00 | 119.9992             | 1.682952              | 1.682952                | 9.828809618                  | 0.00016128                    | 5.05278E-06                          | 0.169466632                    | 0.00487034  | 1   | 31.2367         |   |
| 14 | 2022-01-01 12:00 | 114.1631             | 2.930991              | 2.930991                | 9.451753228                  | 6.67227E-05                   | 4.93662E-06                          | 0.50202514                     | 0.027196914   | 1   | 28.4517         |   |
| 15 | 2022-01-01 13:00 | 111.7164             | 3.155534              | 3.155534                | 9.425697747                  | 0.000189492                   | 5.05498E-06                          | 0.104660591                    | 0.03118772  | 1   | 27.7376         |   |
| 16 | 2022-01-01 14:00 | 105.7681             | 4.207379              | 4.207379                | 10.09207812                  | 0.001888749                   | 0.091972755                          | 4.9627E-06                     | 5.06292E-06   | 1   | 28.1719         |   |
| 17 | 2022-01-01 15:00 | 105.4987             | 4.228416              | 4.228416                | 10.59830875                  | 0.001975462                   | 0.598203258                          | 4.80607E-06                    | 4.73789E-06   | 1   | 30.9492         |   |
| 18 | 2022-01-01 16:00 | 109.0453             | 3.891825              | 3.891825                | 8.777996237                  | 0.000205585                   | 5.05758E-06                          | 0.002620626                    | 0.080498582   | 1   | 30.5127         |   |
| 19 | 2022-01-01 17:00 | 110.5941             | 3.155534              | 3.155534                | 3.773133796                  | 3.34753E-05                   | 4.74732E-06                          | 0.443245856                    | 0.358479094   | 1   | 26.2932         |   |
| 20 | 2022-01-01 18:00 | 107.8107             | 4.207379              | 4.207379                | 2.795859199                  | 3.7406E-05                    | 4.78329E-06                          | 0.002068016                    | 0.524783362   | 1   | 23.5205         |   |
| 21 | 2022-01-01 19:00 | 103.6806             | 4.186342              | 4.186342                | 3.550753948                  | 7.41023E-05                   | 4.9439E-06                           | 0.00137888                     | 0.260867536   | 1   | 22.1416         |   |

|    | A    | B                 | C               | D              | E                   | F                  | G                | H               | I                    |
|----|------|-------------------|-----------------|----------------|---------------------|--------------------|------------------|-----------------|----------------------|
|    | Year | Hybrid investment | Hybrid expenses | Hybrid profits | Hybrid amortisation | Storage investment | Storage expenses | Storage profits | Storage amortisation |
| 1  |      |                   |                 |                |                     |                    |                  |                 |                      |
| 2  | 2021 | 19750000          | 0               | 0              | 0                   | 8380000            | 0                | 0               | 0                    |
| 3  | 2022 | 0                 | 568080          | 6470128        | 1975000             | 0                  | 31560            | 781944.3        | 838000               |
| 4  | 2023 | 0                 | 590803.2        | 4626437        | 1975000             | 0                  | 32822.4          | 568078.8        | 838000               |
| 5  | 2024 | 0                 | 611481.3        | 3927899        | 1975000             | 0                  | 33971.8          | 489213.1        | 838000               |
| 6  | 2025 | 0                 | 624933.9        | 3697400        | 1975000             | 0                  | 34718.55         | 458670.3        | 838000               |
| 7  | 2026 | 0                 | 635557.8        | 3638751        | 1975000             | 0                  | 35308.77         | 445440.9        | 838000               |
| 8  | 2027 | 0                 | 646362.3        | 3584192        | 1975000             | 0                  | 35909.01         | 432222.1        | 838000               |
| 9  | 2028 | 0                 | 657350.4        | 3411606        | 1975000             | 0                  | 36519.47         | 409717.9        | 838000               |
| 10 | 2029 | 0                 | 668525.4        | 3381819        | 1975000             | 0                  | 37140.3          | 399011          | 838000               |
| 11 | 2030 | 0                 | 679890.3        | 3462303        | 1975000             | 0                  | 37771.68         | 397669.3        | 838000               |
| 12 | 2031 | 0                 | 691448.4        | 3699364        | 1975000             | 0                  | 38413.8          | 404422.1        | 838000               |
| 13 | 2032 | 0                 | 703203.1        | 3780751        | 0                   | 0                  | 39066.84         | 256780.2        | 0                    |
| 14 | 2033 | 0                 | 715157.5        | 3826785        | 0                   | -2882304.4         | 0                | 0               | 0                    |
| 15 | 2034 | 0                 | 727315.2        | 3782795        | 0                   | 0                  | 0                | 0               | 0                    |
| 16 | 2035 | 0                 | 739679.6        | 3949964        | 0                   | 0                  | 0                | 0               | 0                    |
| 17 | 2036 | 0                 | 752254.1        | 4056331        | 0                   | 0                  | 0                | 0               | 0                    |
| 18 | 2037 | 0                 | 765042.4        | 4141700        | 0                   | 0                  | 0                | 0               | 0                    |
| 19 | 2038 | 0                 | 778048.1        | 4143386        | 0                   | 0                  | 0                | 0               | 0                    |
| 20 | 2039 | 0                 | 791275          | 4135444        | 0                   | 0                  | 0                | 0               | 0                    |
| 21 | 2040 | 0                 | 804726.6        | 4100136        | 0                   | 0                  | 0                | 0               | 0                    |
| 22 | 2041 | 0                 | 818407          | 4079731        | 0                   | 0                  | 0                | 0               | 0                    |
| 23 |      |                   |                 |                |                     |                    |                  |                 |                      |

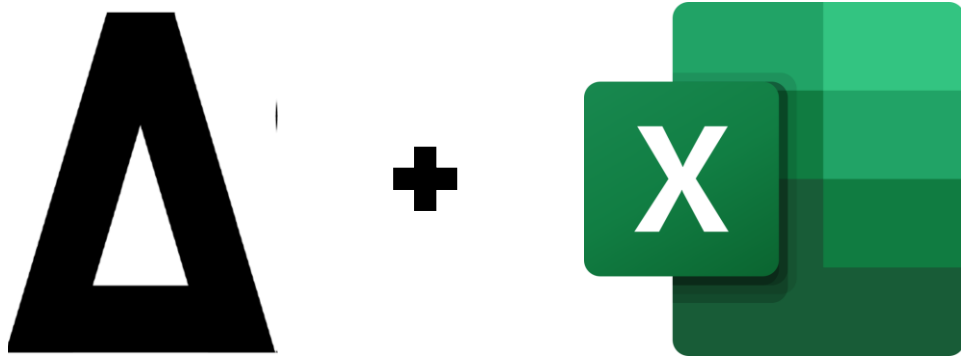
All data series used to build the final report's optimization result is here.

Balance sheet can be fully accomplished by using the data presented in the rest of the sheets.

# Strengths and key points

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This methodology is **extremely compatible with any software** and **can be adapted with ease** e.g. to use any financial excel sheet to calculate any economic indices.



**AREO can be used in any computer by any customer** that want to calculate a complete financial analysis for a portfolio once a **personalized license of use** is given.

```
C:\Users\AREO.exe
The provided user license is valid.

Optimisation begins:
Iteration NPV: 0.0265, Residue:97.5015
Iteration NPV: 0.0455, Residue:35.4221
```

The only work that user is asked to fulfill is to gather all necessary data to fill some excel templates and double-click on the executable **▲ AREO.exe**

Some **key points** are:

- **Results are clear and trustable** if provided data is so. There are no hidden or non traceable information that clients cannot check by their own.
- The solution is **designed for a full adaptability** to the client, i.e. it is the core for an ad-hoc designed methodology which **can combine any already used software** for e.g. data acquisition, data processing, financial and risk analysis... among others. Therefore **any variable can be optimised**.
- We can also **provide parametric studies**: e.g. how much the NVP varies w.r.t. certain parameters of interest (most commonly considered are financial but **infinite possibilities** can fit into the frame of parameterisation).
- System **degradation, efficiencies and other parameters** are taken into account along the project lifetime. **Reposition of components (augmentation)** can be also set.
- **Running a full case** for 20 years of 8760 data each one, should not take more than **several minutes in a basic laptop**. This time extends a little bit when **restricting the maximum number of cycles the storage can perform** for every year.

# Contact Us

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