The challenges of local pumped storage hydropower: modelling the equipment of the pumping-turbining cycle to improve the flexibility and efficiency of the plant

Dr. Laurent Smati Mhylab, Montcherand, Switzerland
Mr. Vincent Denis Mhylab, Montcherand, Switzerland
Dr. Ariel Waserhole Sun'R Smart Energy, ENSTA, Paris, France

SunHydro project :

Project background

- Clean energy goals and carbon emissions reductions
  - ⇨ share of renewable energies ⇗
    (prod. = non-predictable, intermittent and non-storable)
- PSP[1] is a traditional, efficient and proven energy storage but **most of these plants are large scale plants (>100 MW)**
- With ⇗ IRES[2] and their **geographic spread**, distributed and smaller PSP (<20 MW) could be an interesting way?
- Small PSP are easier to implement but cannot benefit from the economies of scale

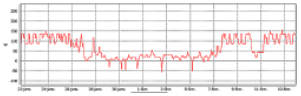
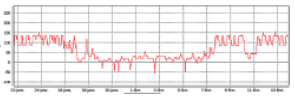
⇨ Finding **new** sources of income is imperative

⇨ And probably **one source will not be sufficient**

[1]: *PSP* = Pumped Storage Plant

[2]: *IRES = Intermittent Renewable Energy Sources*

SunHydrO's project strategies to improve the profitability of small PSP – Part 1

- Using incomes issued **from several markets**[1] [day-ahead, intraday, balancing mechanism, imbalance settlement and secondary reserve (ancillary services)]
- Optim. **b/w various markets** with price forecasts 
- **Aggregating** IRES prod. and storage assets in a **Virtual Power Plant** (VPP)
- Optim. VPP profits with **weather and price forecasts**  

Optim. are performed within an **Aggregated Storage Energy Optimizer (ASEO)**

[1]: *highly variable according to the different power exchange area*

SunHydrO's project strategies to improve the profitability of small PSP – Part 2

- This strategy requires very **high op. flexibility** of the PSP

- But **flexibility is very expensive** and should not be requested <u>without suitable justifications</u>

> ⇨ **Optim. of the flexibility level of the PSP**
>
> during **site survey** or during the **eng. studies** of a specific site
>
> *Optim. of PSP op. flex. ≈ electro-mechanical equipment*

- Operational and plant design optim. are closely linked
  - ⇨ Same tool (ASEO) is used for both but with 2 versions: an operational tool to pilot the storage syst. and a study tool for design optim.

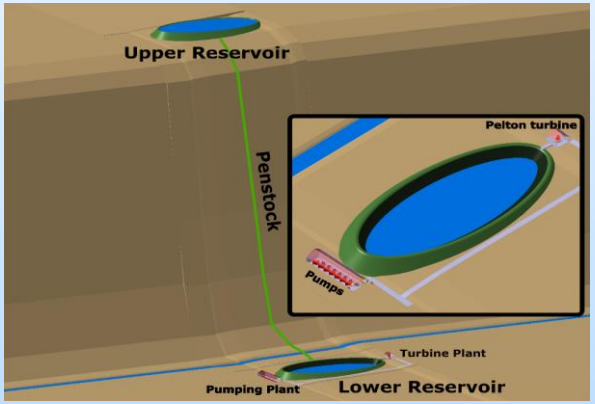
Plant design optimization

- Usually, with a set of rigid and detailed specifications, eng. studies analyze **few altn scenarios** and use a **rather simple economic model** to select the best scenario

- Here, specs. are reduced to the min. (to keep deg. of freedom) and the **altn scenarios are introduced in the ASEO study tool** which takes into account **multiple sources of incomes**

- Specs. of the EM equipment are adjusted with the results of the ASEO simulation, and a study of new scenarios start again

At the end, the optimum b/w CAPEX and OPEX is found



Pumped Storage Plant study under gross head of 770m

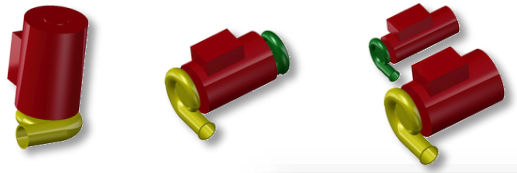
Plant input/output Electrical Power: 17MW

6 pumps (3MW) & 1 Pelton Turbine (17.7 MW)

Location in Alpine Mountain area

PSP overall efficiency modeling

- Several options of types of turbine are possible:

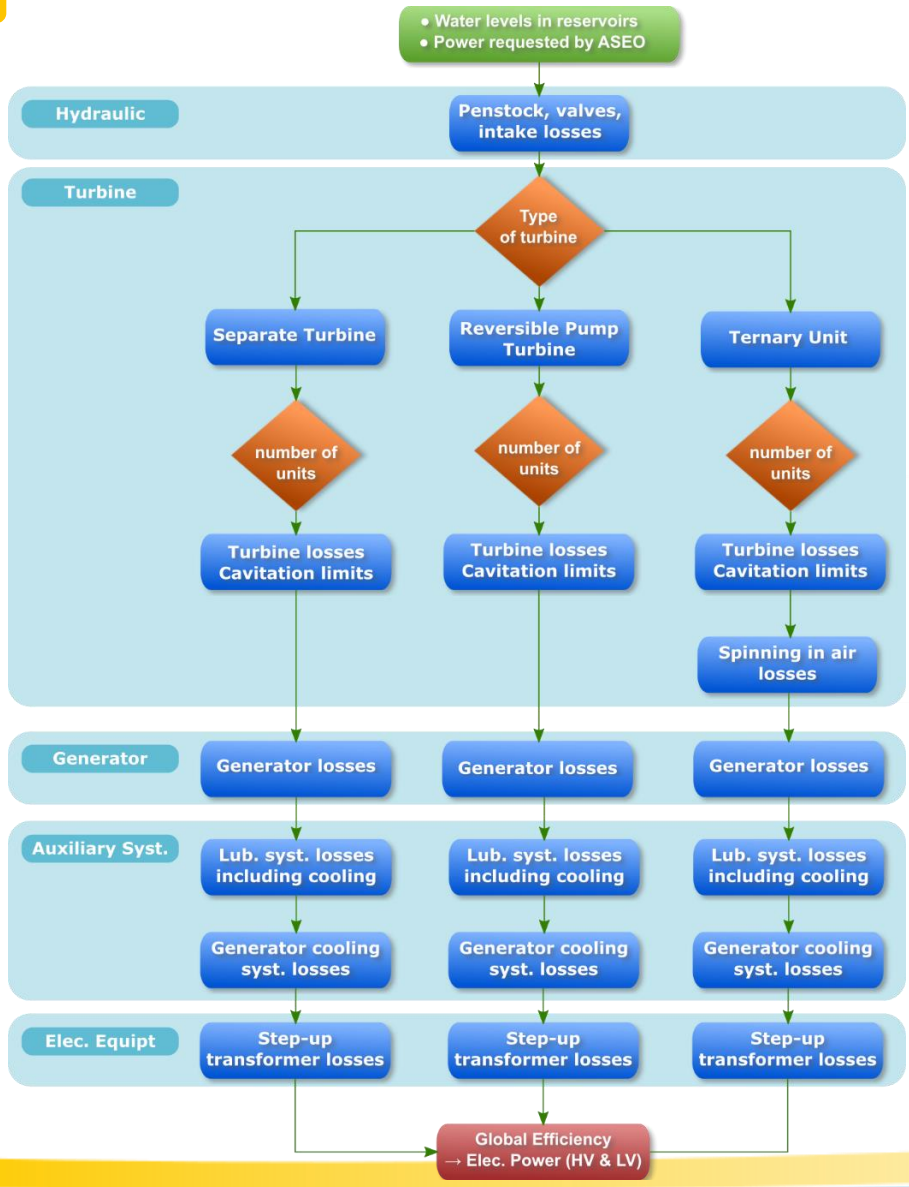


- **Cavitation limits** affects CAPEX & OPEX (op. range ⇘)
  Best compromise = ASEO computation ⇨ P&T setting depth

- **ASEO limits op. period in critical zone** if market price is not high enough
- Accurate ASEO optim. requires accurate data of the EM equipment
- Efficiency of one type of equipment can be jeopardized by high losses in **spinning in air losses** or in an auxiliary system, as **cooling**, lubrication

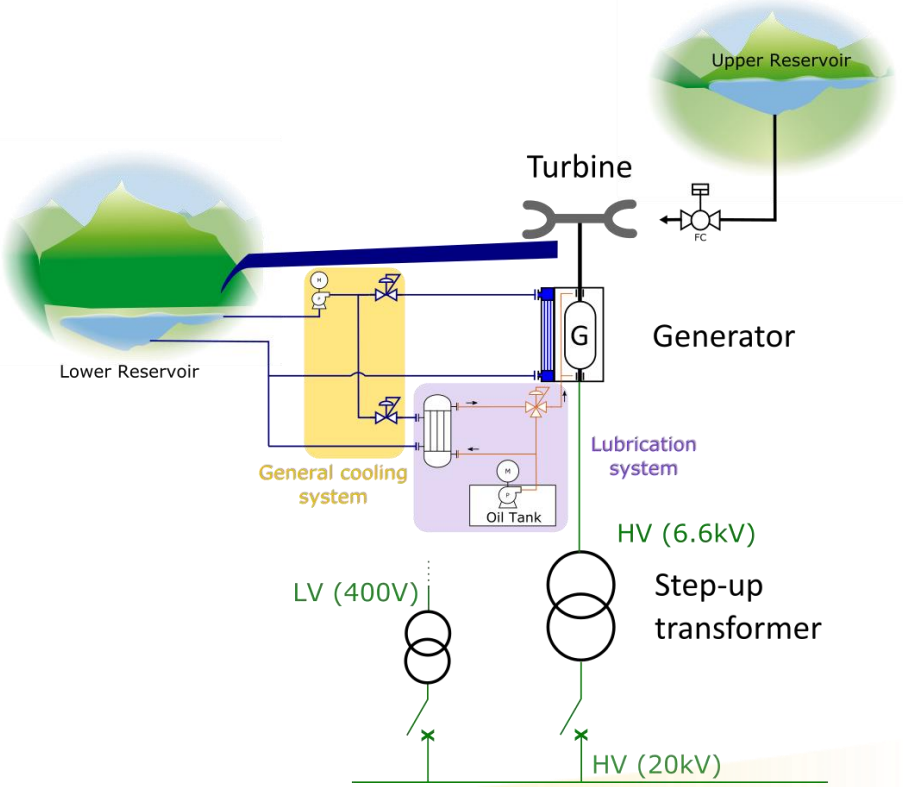
⇨ **overall efficiency** of the PSP, **including all auxiliary systems**, is modeled and introduced into the ASEO simulator

Turbine mode modeling

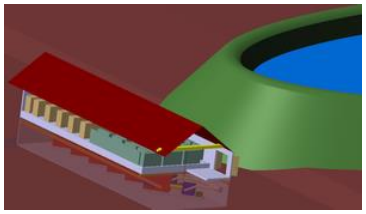


Main and auxiliary equipment are different for pump and turbine units

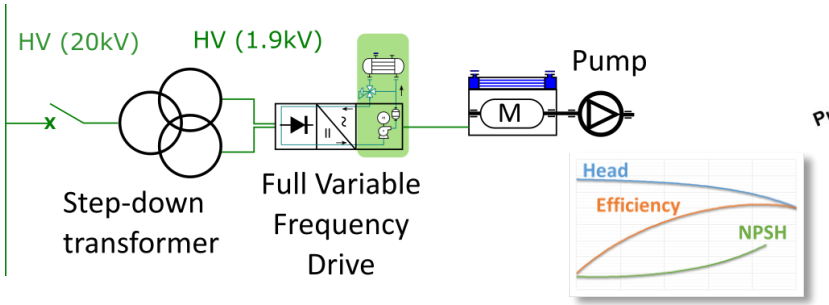
⇨ 2 different subroutines

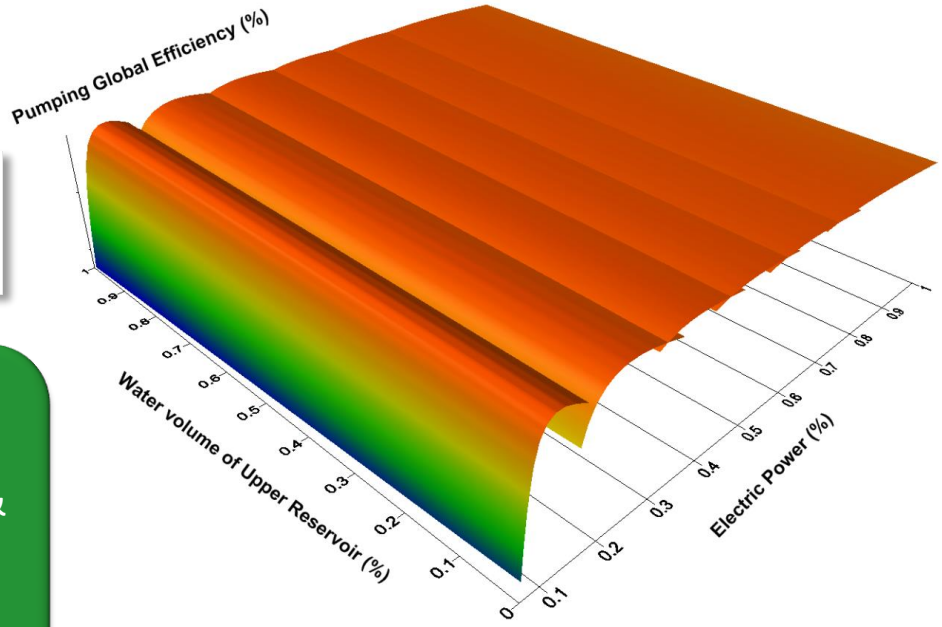


Pumping overall efficiency



- **Ancillary service is a key source of profits** and requires **high op. flexibility**
  - ⇨ Variable Frequency Drives (VFD) are used for speed adjustment
- Unit power of pumps is small ⇨ **full medium voltage VFD**

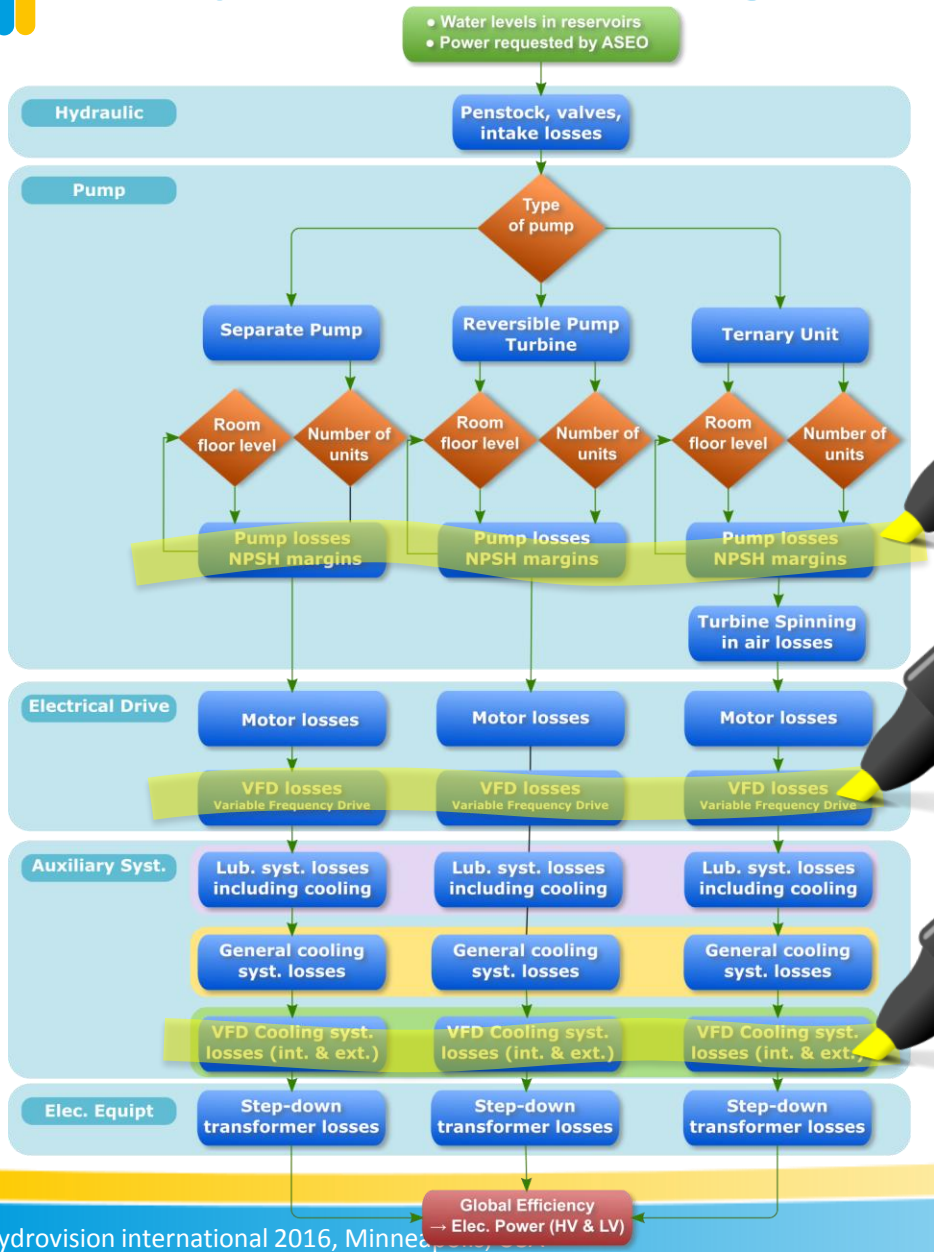


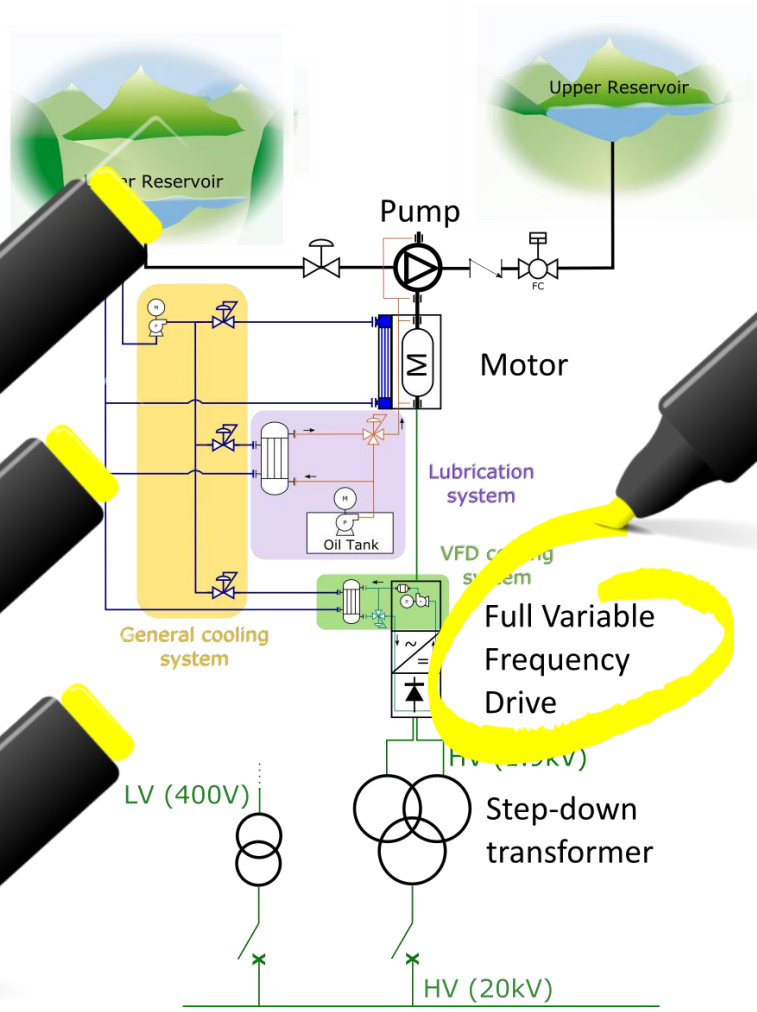


Key point of the pumping computation =

- VFD efficiency including cooling syst. & stepdown transformer
- Cavitation limits

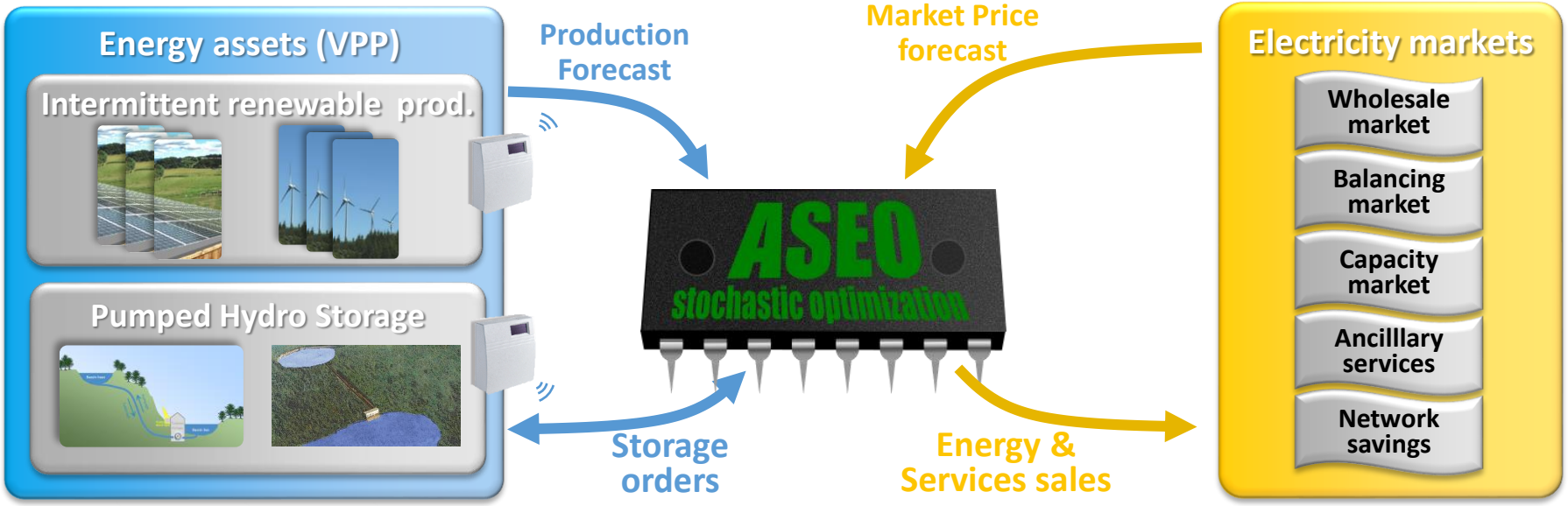
Pump mode modelling

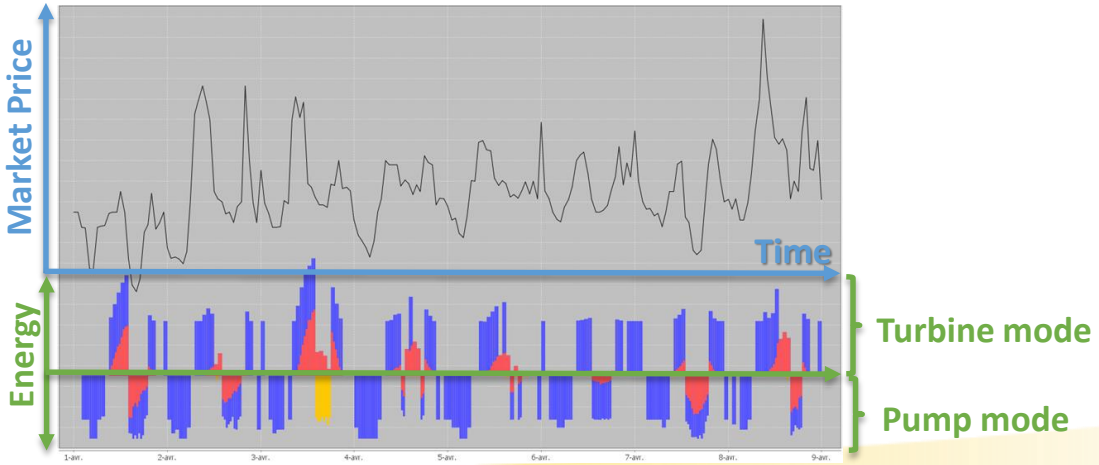




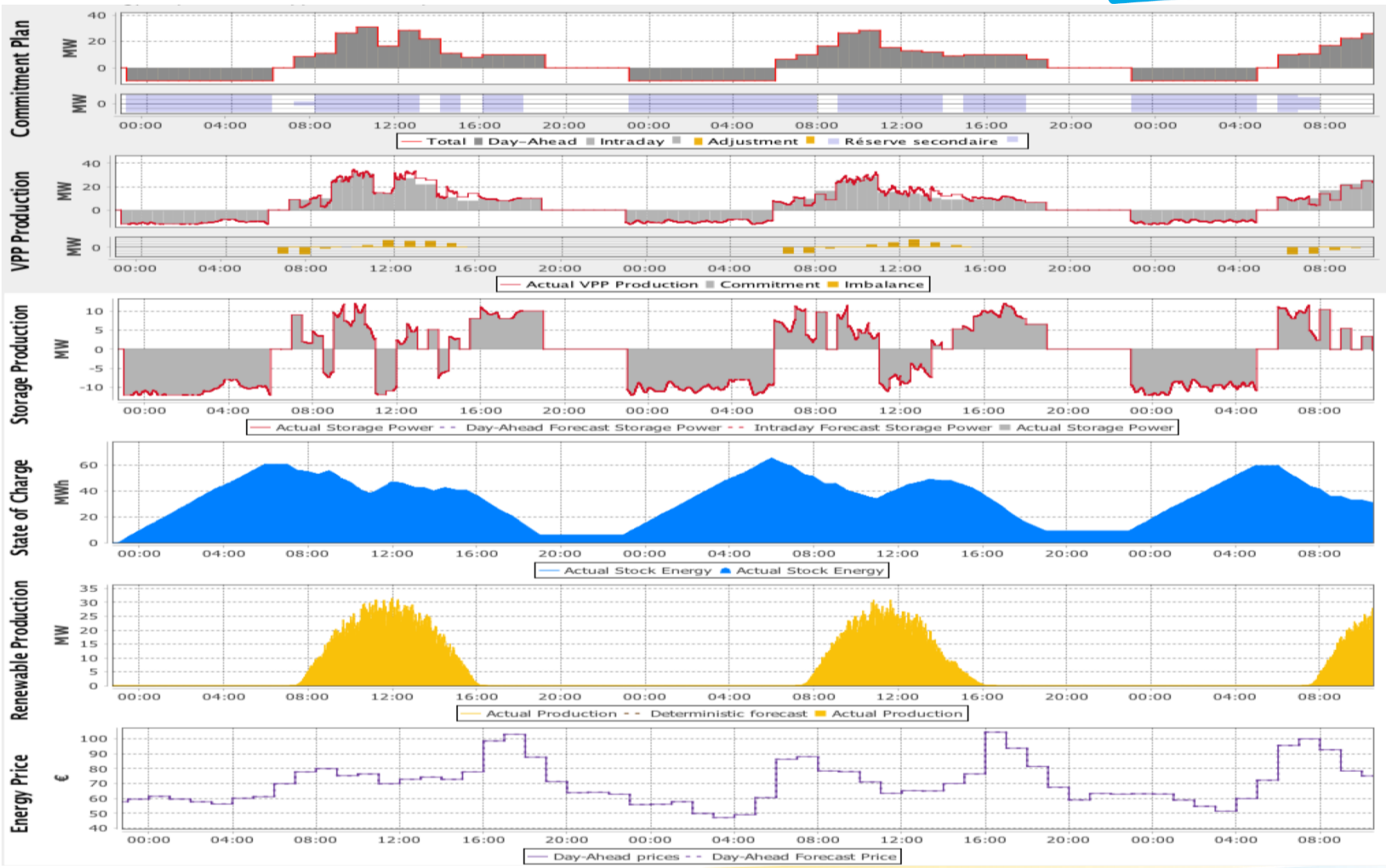
Optim. pump mode is the backbone of success :
flex and efficient just as necessary !

ASEO: Aggregated Storage Energy Optimizer



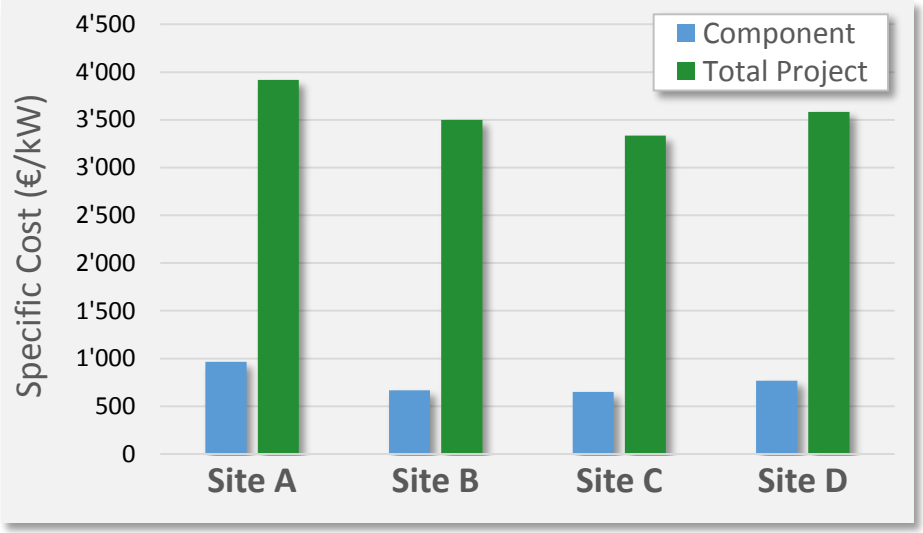


ASEO Software Dashboard



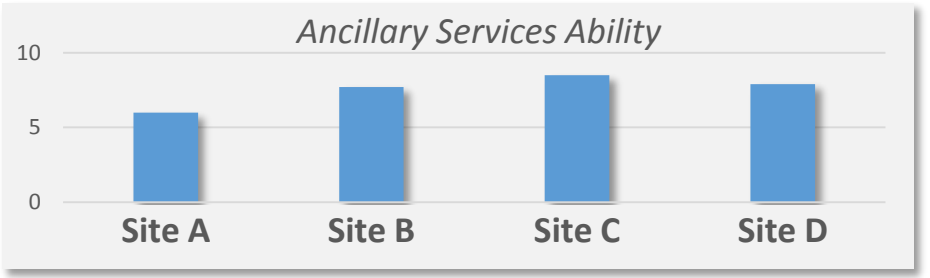
Site survey

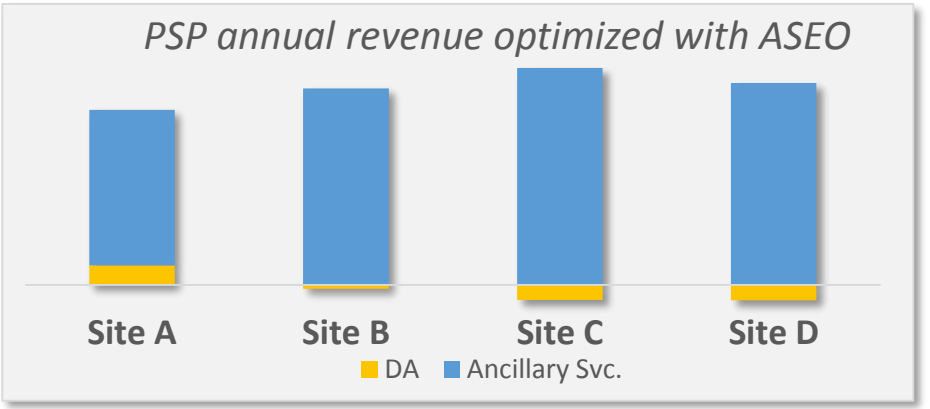
	Site A	Site B	Site C	Site D
Plant Power (MW)	12	12	12	12
Static Head (m)	155	400	770	860
Nber of pumps	2	4	4	5
Min. Cont. Op. Range (MW)	6	7.7	8.5	7.9

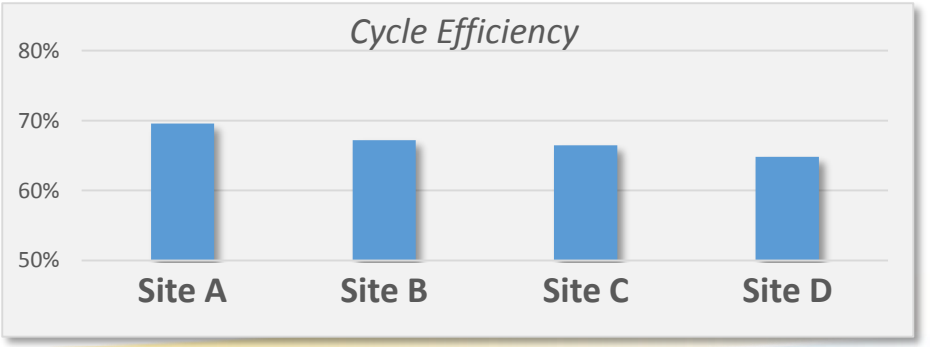


- High head is beneficial (CAPEX ⇘)
- Flexibility improve annual income but could also ⇗ Cost
- **When it is necessary ASEO ⇘ Efficiency to ⇗ profits**

- Site A = Eliminated
- Best site = Site C (next Site B)





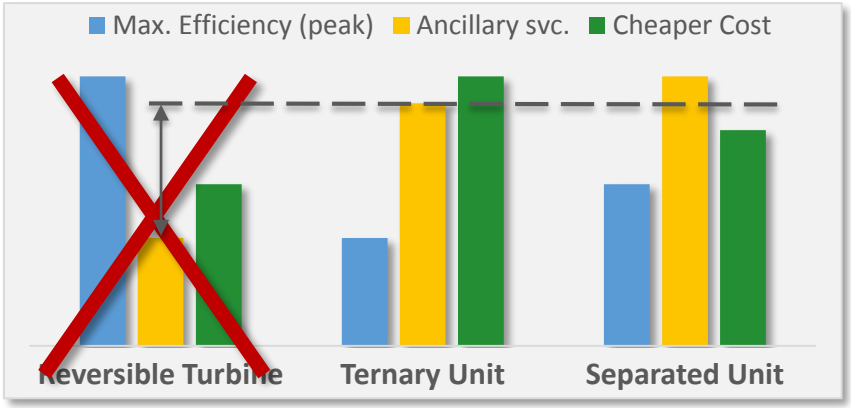


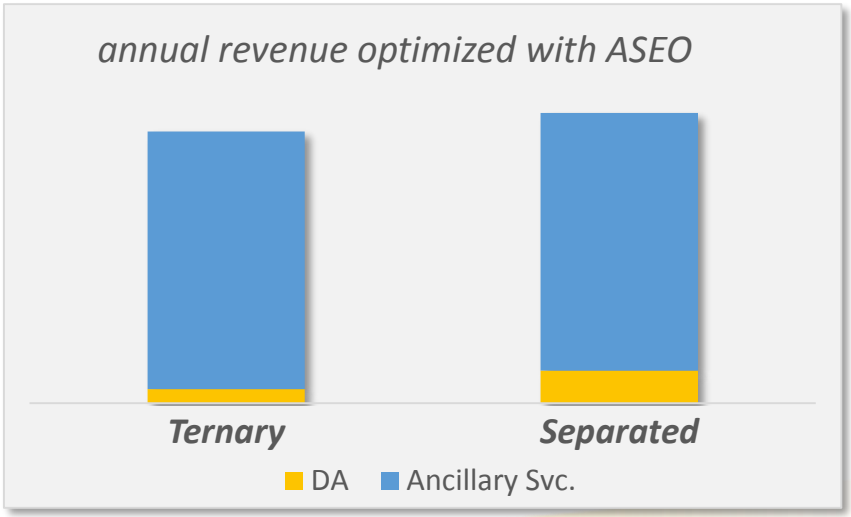
Pump-turbine technology?

Site A : Gross head = 155m & Plant Electrical Power = 12MW

- Reversible turbine : Anc. Svc. too low
- Using multistage pumps & double eye impeller ⇨ increase operating range
- Ternary group less efficient (spinning in air losses) but less expensive
  - ⇨ increase Day Ahead
  - ⇨ increase Ancillary Svc.

⇨ Separated Pump and Turbine

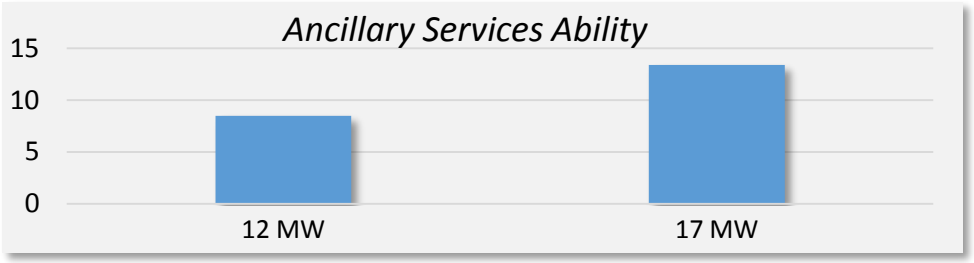


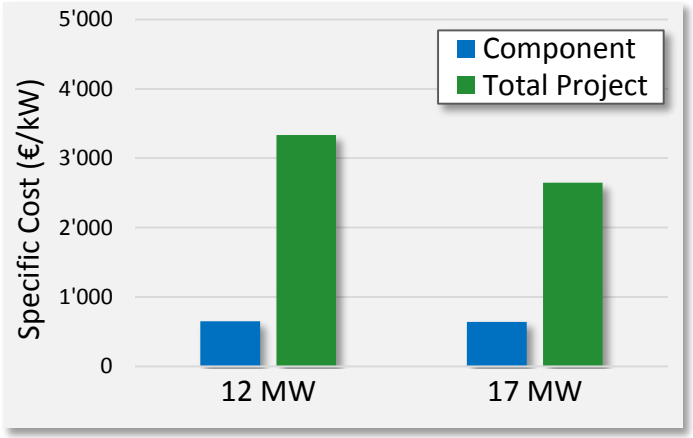


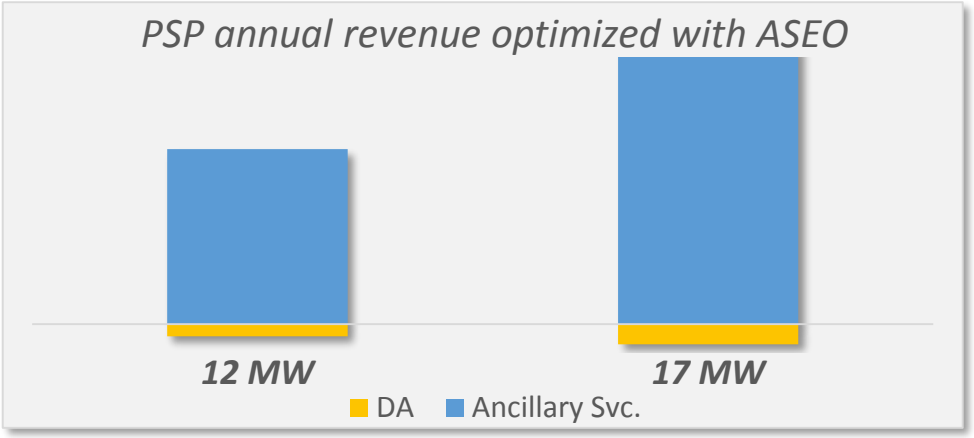
Improve flexibility and profitability

PSP flexibility is a key point of profits

	Site C	Site C
Static Head (m)	770	770
Plant Power (MW)	12 MW	17 MW
Nber of pumps	4	6
Min. Cont. Op. Range (MW)	8.5	13.4



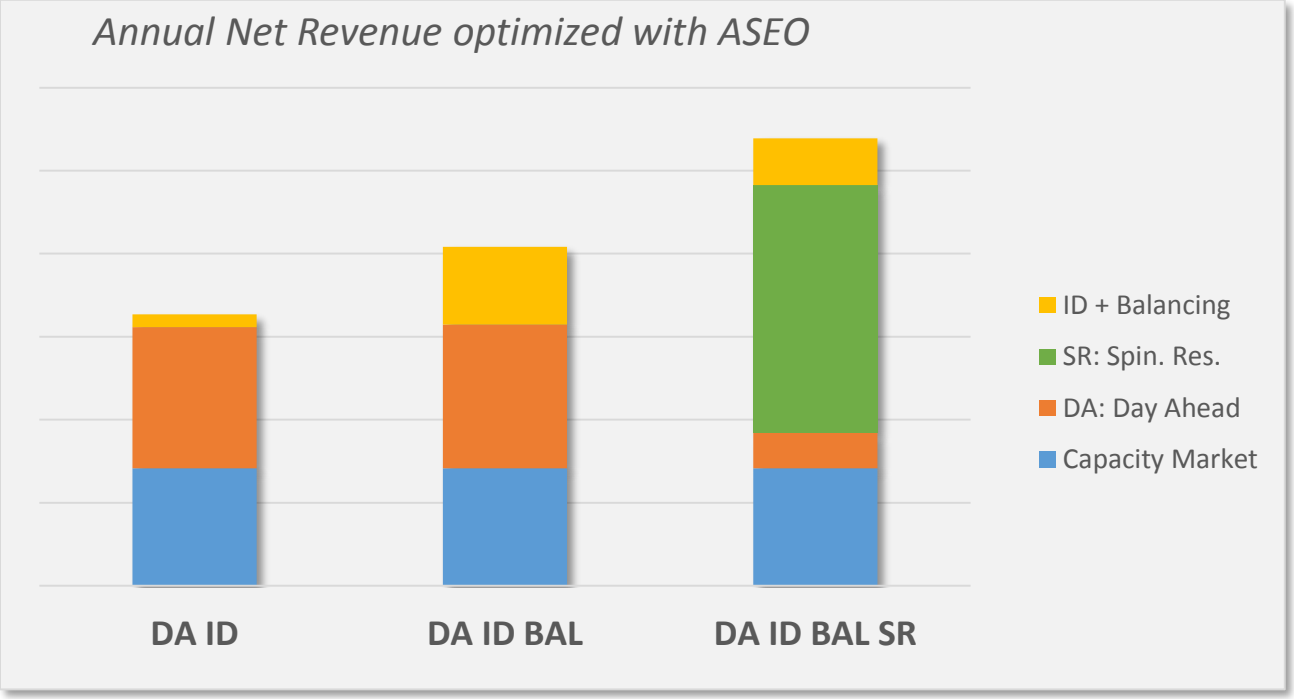




Increase number of pumps ⇨ operating range ⇗
- Project Specific Cost ⇘
- Income ⇗

Use and Optimize all possible sources of revenues

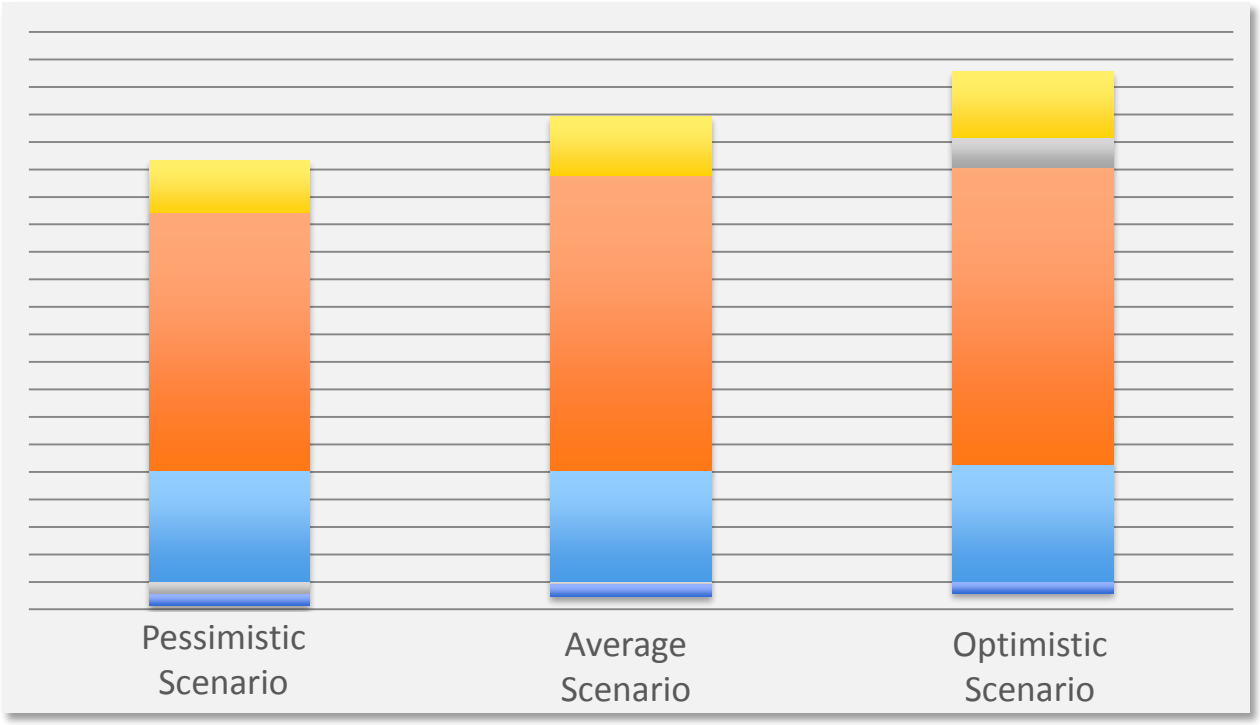
- Price forecast ⇨ ASEO operational tool optimize revenues b/w different markets



- Spin. Reserve is the key source of revenue
- Optim. all mechanisms improves a little more ANR : Decisive for small PSP

Reduce risks of energy market development

- Analysis of the influence of three scenarios of market development on Annual Net Revenue:



⇨ Consolidate PSP characteristics (especially Level of flexibility)

Conclusions
Improvement of small PSP viability

- Without the benefit of the economies of scale, **optim. of energy mix and ancillary svc. is essential** to max. revenue of a **small PSP**
- ∃ large nber of cycle scenarios ⇨ **Stochastic optim. methods of ASEO**
- Arbitration b/w various energy and ancillary svc. requires an **accurate and realistic model of the P&T global cycle efficiency**
- ASEO :
  - ⇨ **Optim. the annual net revenue**
  - ⇨ **Optim. PSP characs. (specs. of EM equipment)**
  - ⇨ Improvement of the viability of projects, and a **risk reduction**

    (current context = quick changes of the energy market)
- ASEO can also used during **site survey** (major role in project viability)

THANK YOU FOR YOUR ATTENTION!

Dr. Laurent Smati	Mhylab, Montcherand, Switzerland
Mr. Vincent Denis	Mhylab, Montcherand, Switzerland
Dr. Ariel Waserhole	Sun'R Smart Energy, ENSTA, Paris, France

To know more : info@mhylab.com www.mhylab.com contact@sunr-sme.fr www.sunr-sme.fr

SunHydro project :