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Energy transition - Project





Outline

Technologies used

Electrical mix, first idea

Improvement idea

Weather and topography analysis

Mathematical model for a dam

Final electrical mix

Conclusion

Technologies



Photovoltaic panels



Wind turbine



Battery



But also :



Import



Export



PV panels

→ unlimited capacity

Efficiency of 20.5%

Lifetime of 35 years

Investment cost = 870 k€/MW

O&M fixed = 10.6 k€/MW/y

O&M variable = 10 €/MWh/y

Source: Danish Energy Agency ([Technology Data for Generation of Electricity and District Heating](#))



Wind turbine

→ unlimited capacity

Efficiency of 47%

Lifetime of 27 years

Investment cost = 1.11 M€/MW

O&M fixed = 16.4 k€/MW/y

O&M variable = 2 €/MWh/y

Source: Danish Energy Agency ([Technology Data for Generation of Electricity and District Heating](#))



Battery

Battery of 3 MW

During 4h

→ Maximal capacity of 12 MWh

Efficiency of 85 %

Lifetime = 25 years

State of charge $\in [0.2; 0.8]$

Investment cost = 500 k€/MWh

Source : Invinity data sheet (https://invinity.com/wp-content/uploads/2024/12/Invinity-ENDURIUM-Data-Sheet-MAR000020-2024-12.pdf?_gl=1*lgj6v*_up*MQ..*_gs*MQ..&gclid=CjwKCAiA65m7BhAwEiwAAgu4JFqYz_U4PtidA2i2jLRaFiS13FNLzbv9fz0VtaHFF2xsj7x1VRSZBoCTVQQAyD_BwE)



National grid

Import and Export

→ Unlimited capacity

Composed of 80 % of hydropower

→ import not expensive

Import price of 74 €/MWh

Export price of 20 €/MWh

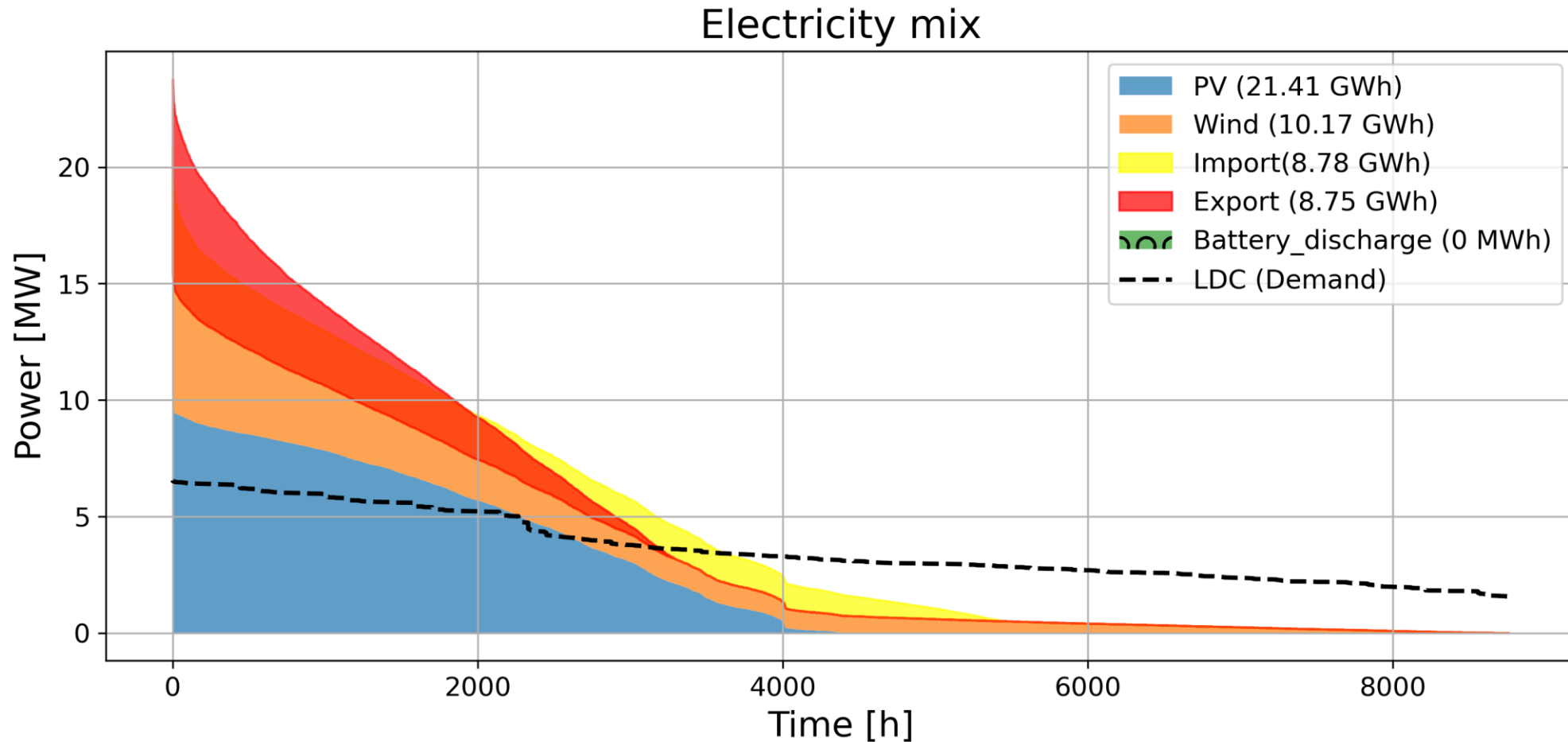
Demand

Electrical consumption of 31.6 GWh

Cooling produce with absorption chiller → solar panel and biomass, so no electrical consumption.

→ total demand of 31.6 GWh

Electrical mix – First version



➡ 7.1 MW of wind turbine

➡ 12.9 MW of PV

➡ 1.562 M€

LCOE = 49.40 €/MWh



Comparison with results of last semester



Last semester



This semester



LCOE = 60 €/MWh



LCOE = 49 €/MWh



PV = 4.4 MW



PV = 12.9 MW



Wind turbine = 4.9 MW



Wind turbine = 7.1 MW



Energy stored = 3.5
GWh



Energy stored = 0 GWh

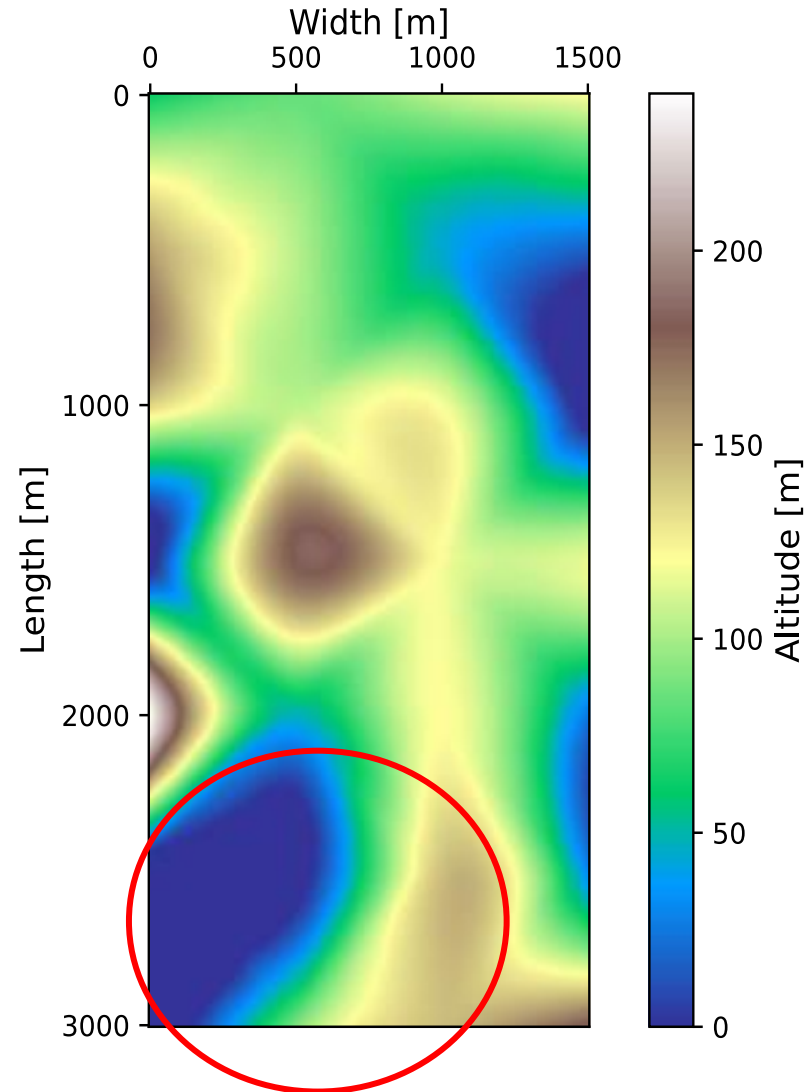
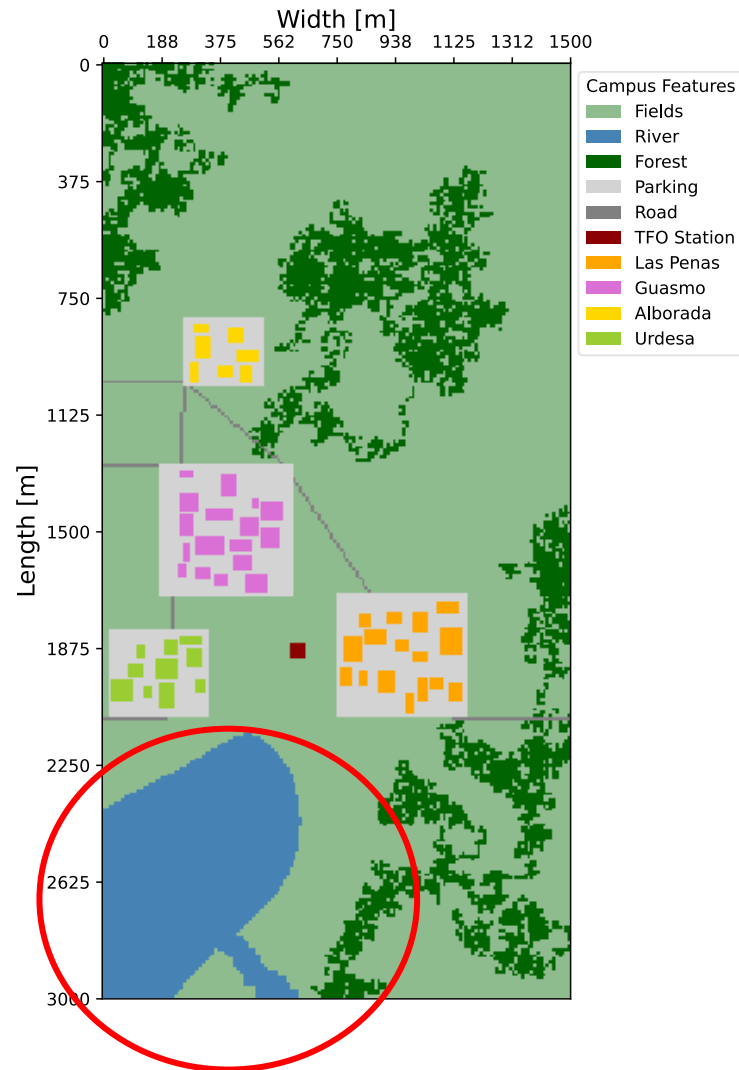
Same import and export price, but enhance of renewable energy and battery prices which were not accurate (particullary information about PV).

A step further



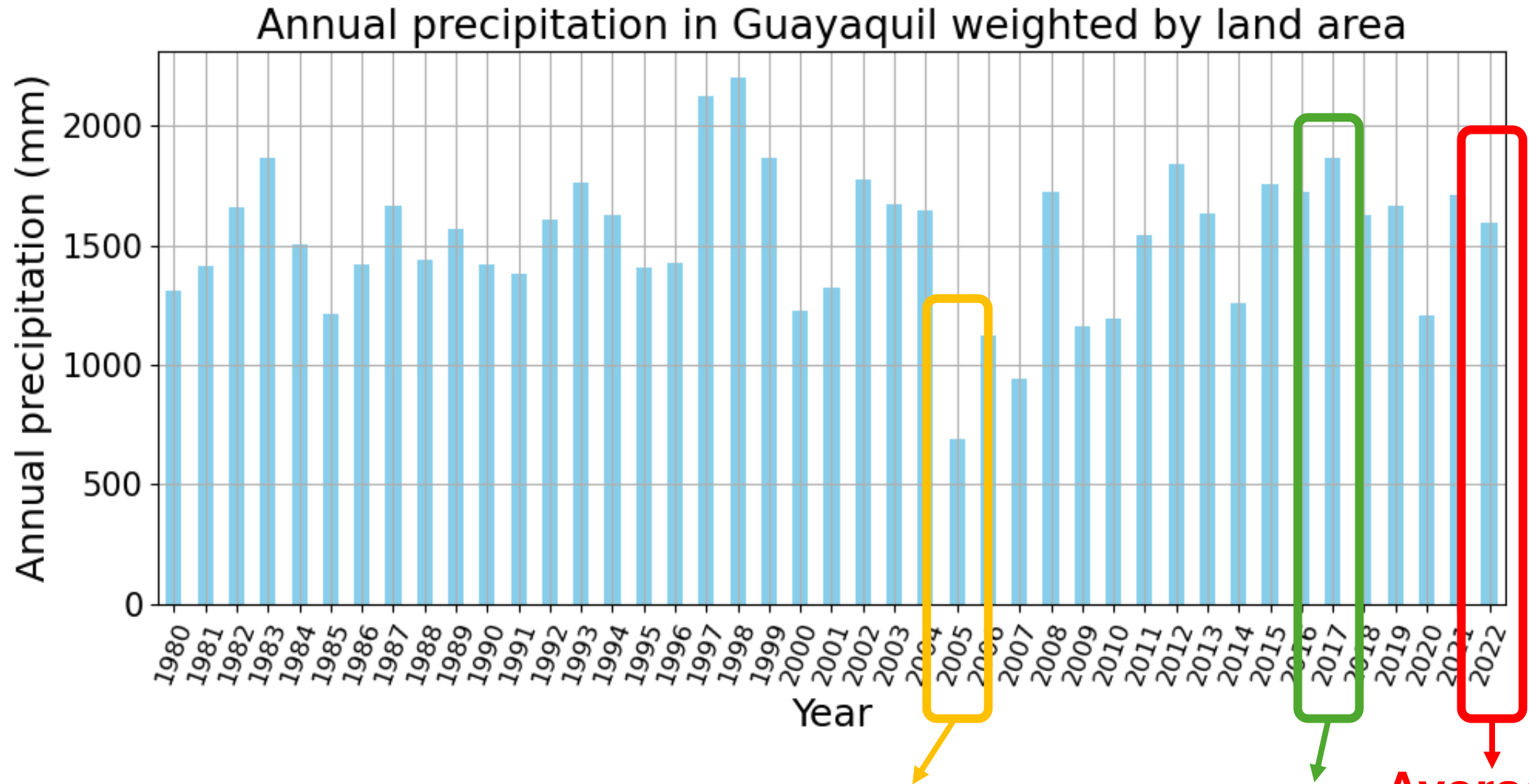
- The national energy mix contains 80% hydropower. However, hydropower prices vary significantly depending on rainfall.
- ➔ Design and implementation of a dam on campus, along with analysis over several weather years.

Topography analysis



- ➔ River available on the campus
- ➔ Head of 150m
- ➔ Installation of the dam there

Weather analysis



Source: Renewable ninja (<https://www.renewables.ninja>)

Dry year

Humid year

Average year

Precipitation translation

[MWh]



$$CF = \frac{\sum P_{inflow} \tau}{D_{max} \tau 8760} = 70\%$$

Dimensionalised using an average year (2022) as reference.

$$= \frac{\frac{\sum P_{inflow}}{D_{max}} \tau}{\frac{D_{max}}{D_{max}} \tau 8760}$$

$$\Leftrightarrow \frac{\sum P_{inflow}}{D_{max}} = 0.7 * 8760 = 6132 \text{ h}$$

Precipitation translation

$$\frac{\sum P_{inflow}}{D_{max}} = 0.7 * 8760 = 6132 \text{ [h]}$$

$$\alpha = \frac{\sum P_{inflow} [MW] (2022)}{\sum P_{inflow} \left[\frac{mm}{h} \right] (2022) D_{max}} \frac{1}{1} \\ = \frac{6132}{701.881} = 8.74$$

Constant converting all the precipitation in power

$$\Rightarrow \sum P_{inflow} [MW] (t) = \sum P_{inflow} \left[\frac{mm}{h} \right] (t) \times \frac{\alpha}{D_{max}}$$

➔ D_{max} is the variable representing the installed power of the power plant. The value of P_{inflow} is adimensionalised with D_{max} . It will be multiplied later by cap_{dam} , a variable representing the installed capacity.

Assumptions



Uncertainty is applied on the model



Probability of 60% of an average year, based on precipitation.



Probability of 20% for a dry year



Probability of 20% for a humid year.



Dam

Capacity stored : 100 MWh

Empty in 20h

Efficiency of 75%

Lifetime = 75 years

Assume already constructed

→ Investment price of 0 €/MWh

Dam storage equations

Balance :

$$e_{t+1} - e_t = \tau \cancel{\eta^c s c_t} - \tau \frac{sd_t}{\eta^d} + \tau (p_{inflow,t} - \cancel{P_{outflow,t}} - P_{spill,t})$$

Only power generation, no pumping.

No environmental
flow is considered

$\in [0; \infty]$


$$= P_{inflow,t} \times \frac{cap_{dam}}{DAM_{dT}}$$

Initial state :

$$e_{t=0} - e_{t=T} = -\tau sd_T - \tau P_{spill,T} + \tau P_{inflow,T}$$

Where T is the last time step

Capacity max :

$$cap_{dam} \leq 100 \text{ MWh}$$


This maximum capacity corresponds to a reservoir holding 326 200 m³ of water.

Discharge max :

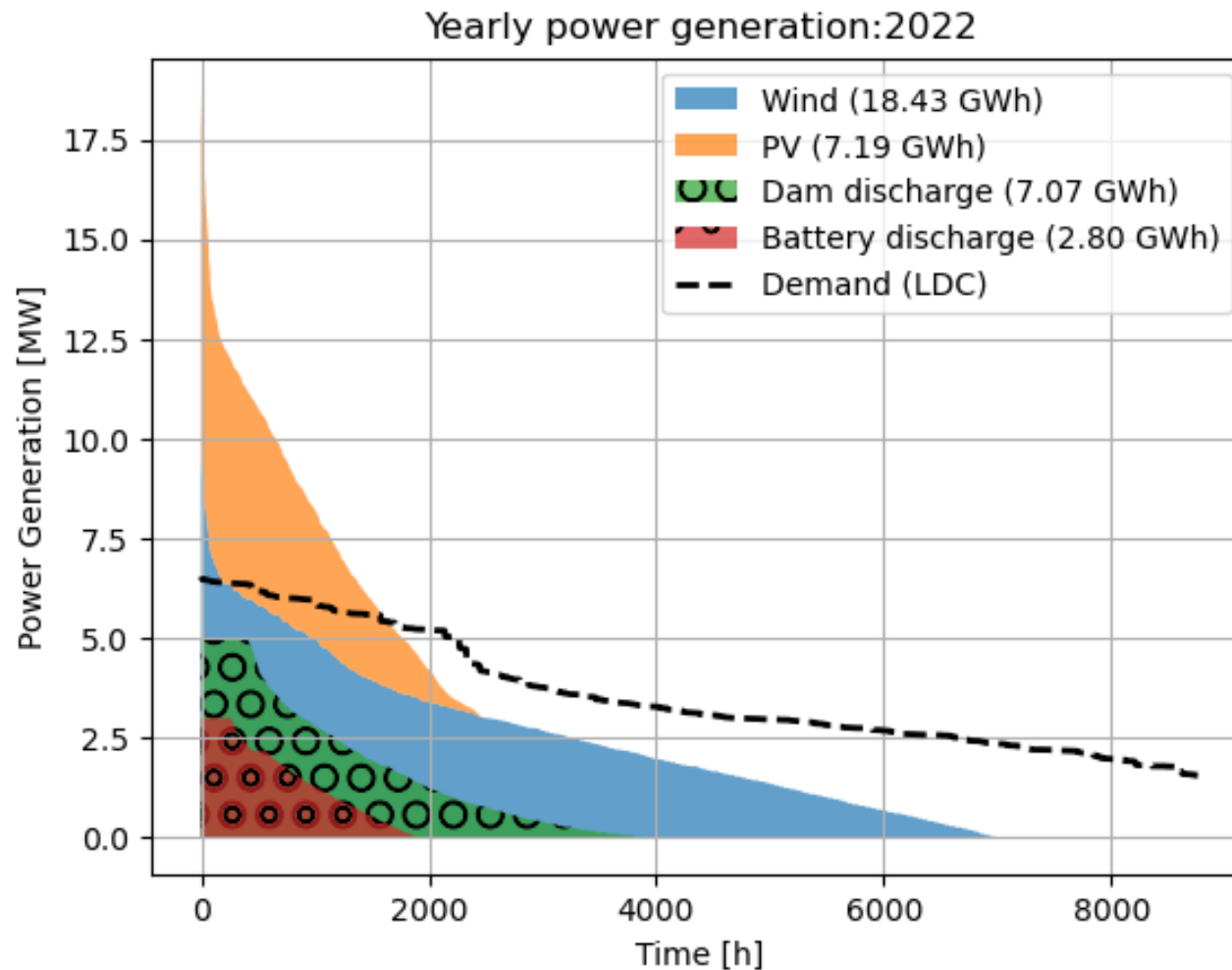
$$sd \leq \frac{cap_{dam}}{Dam_{dt}} = \frac{100 \text{ MWh}}{20 \text{ h}}$$

Energy stored range:

$$0 \leq se \leq cap_{dam}$$


There is no minimum water required in the reservoir

Final electrical mix



Power installed

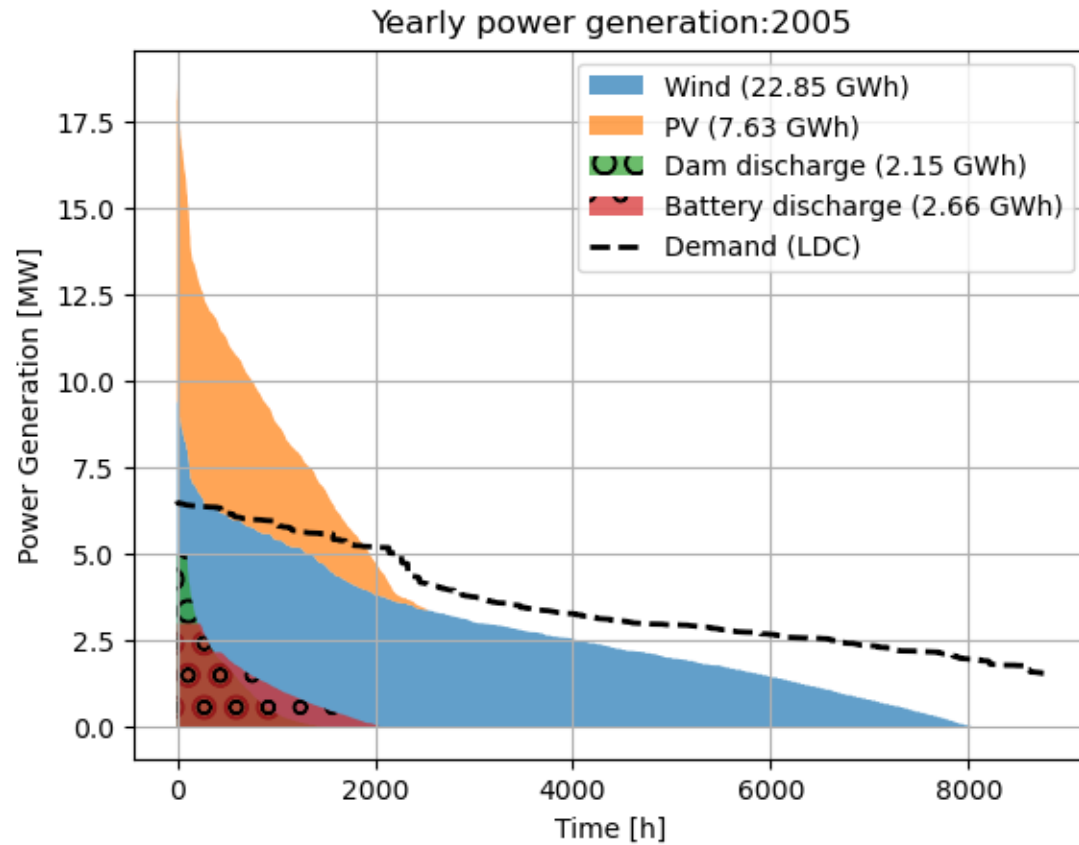
PV panels : 17.4 MW

Wind turbine : 32 MW

Dam : 5 MW (20h)

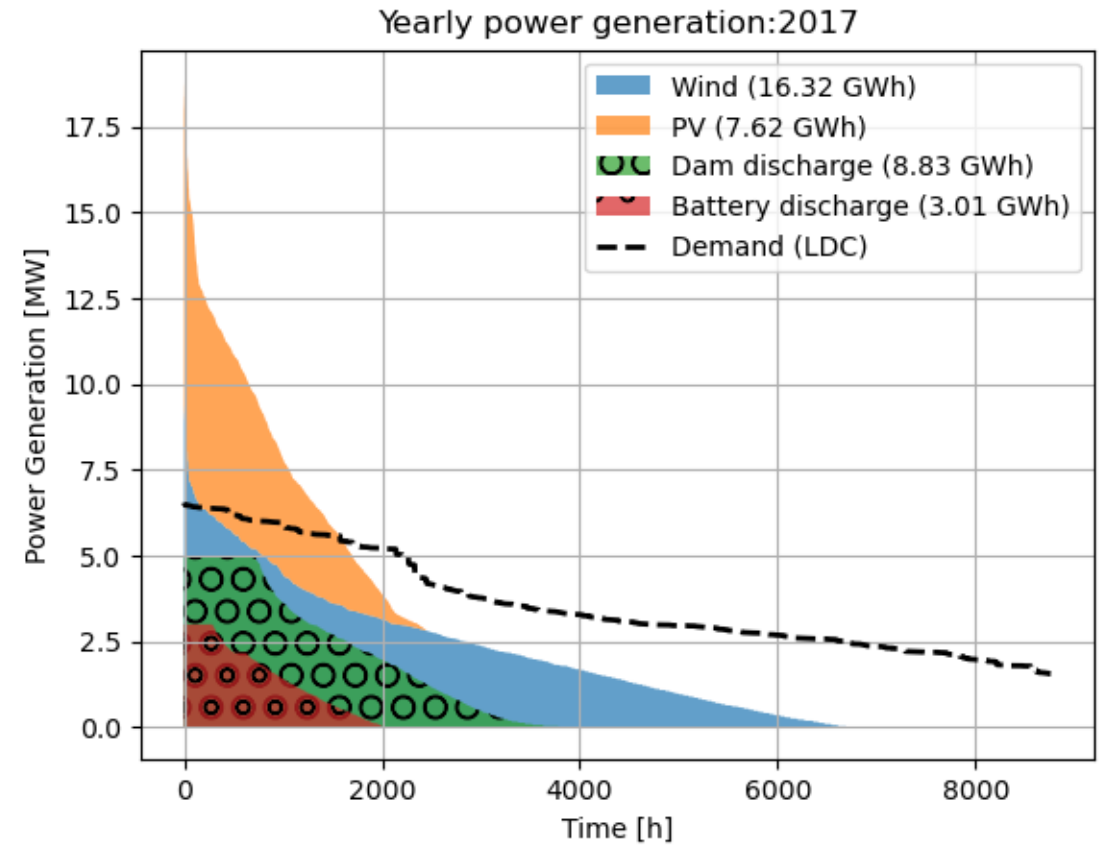
Battery : 3 MW (4h)

Dry year



Total cost : 3.4 M€

Humid year



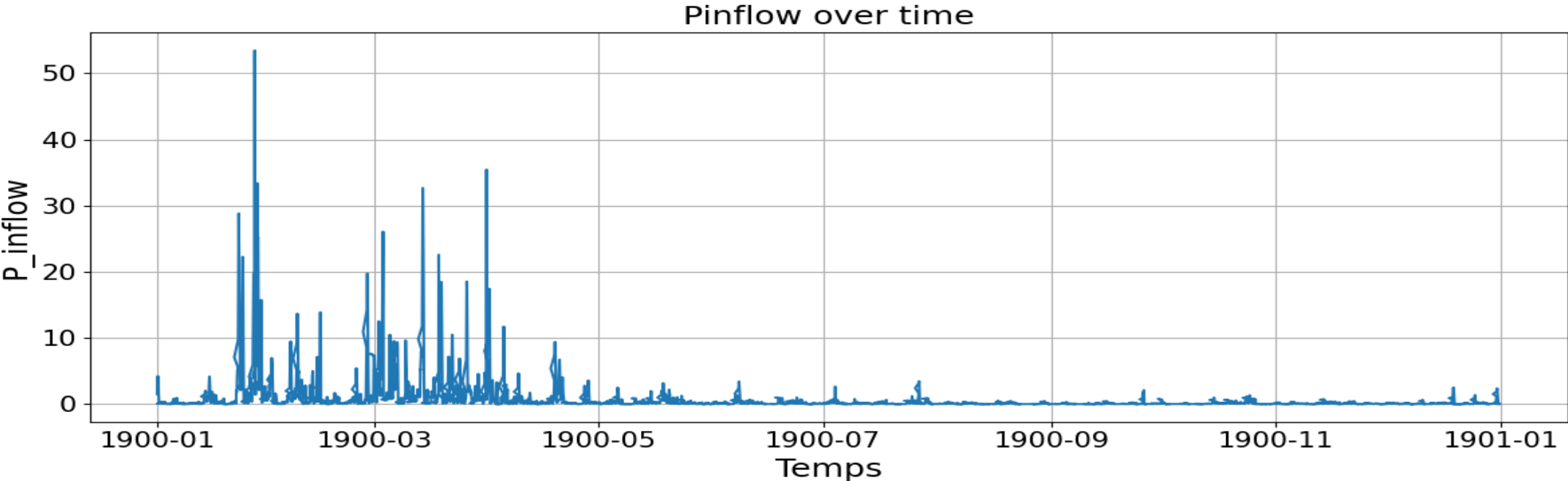
→ LCOE = 106.60 €/MWh



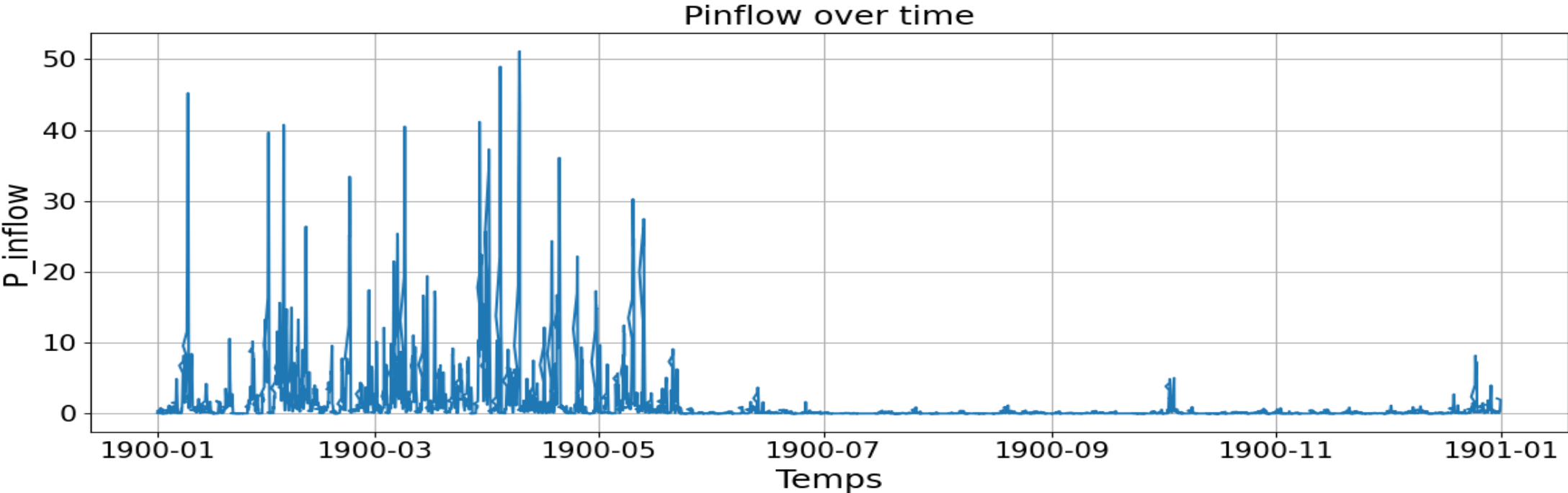
Why doesn't the dam store more ?

- There is a strong seasonal contrast between the humid and dry periods in Ecuador.
- There was more water in 2017 due to extrem rainfall.
- When extrem rainfall occurs, the reservoir is quickly full, so the excess water is spilled rather than stored. In 2017, 80 % of water was spilled from the dam.

2022



2017



Conclusion

- Integrating the dam on the campus allows to observe the variability of hydropower in Ecuador.
- These fluctuations cause variations in the cost of importing electricity from the national grid.
- The final Levelized cost of Electricity (LCOE) is much higher, since more renewable energy sources must be available to meet electricity demand, even when water supply is insufficient.

Thank you!

