

KYOS Energy Analytics

# Green gains: Hydrogen business cases

Luis Carlos A. Torres Sánchez  
Lisbon - April 18<sup>th</sup>, 2024



# KYOS Energy Analytics

- Headquarters in the Netherlands. A team of 40+ people.
- International client base across Europe, plus Americas and Japan.
- More than 100 corporate clients.



# KYOS services and products in a nutshell



Software for energy valuation & optimization



Software for multi-commodity exposures



Consultancy



Price data

- Financial models combined with years of experience in the energy markets to value and optimize assets and contracts.
- Models developed over the past 20 years by an experienced team of quantitative analysts.
- KYOS is at the forefront of new developments, understanding the market's needs.
- Continuous feedback from our clients helps us stay ahead.



# KYOS and market insights

- Some (free!) publications:



Available every quarter at:  
<https://www.kyos.com/knowledge-center/>

Follow us on LinkedIn! We publish weekly market updates.








# Green hydrogen business cases

# When is hydrogen green?



The colors of hydrogen based on its origin

-  Grey: produced from fossil fuels, no CCUS.
-  Blue: produced from fossil fuels, with CCUS.
-  Pink: produced from nuclear energy.
-  Green: produced from renewable energy.
-  White: found in nature.

*When is the sourced energy officially renewable?*

EU Commission Delegated Act from February 2023:

- Direct line between RE asset and electrolyser.
- Electrolyser is in a market with 90% renewable integration.
- Hydrogen production matches the RE production hour by hour (from 2030).
- Day-ahead price below 20 €/MWh **OR** below **0.36 \*** **CO<sub>2</sub> price.**



# Why care about green hydrogen?

- Compliance targets: the industry and transport sectors are required to use a growing share of green hydrogen.
- EU Hydrogen Bank:
  - 800 MEUR of fixed premium in EUR/kg over 10 years.
  - First auction: closed in Feb. 2024, 132 bids from 17 European countries (in total, 8.5 GWe). Results are not available yet.
  - More auctions to follow. Second round before the end of 2024.
  - Additional voluntary national support ('auctions as a service'): e.g. Germany: 350 MEUR.
- Targeted national programs:
  - E.g. H2 Pioneers programme in Spain. 2 auctions, 300 MEUR in subsidies, 31 hydrogen projects.

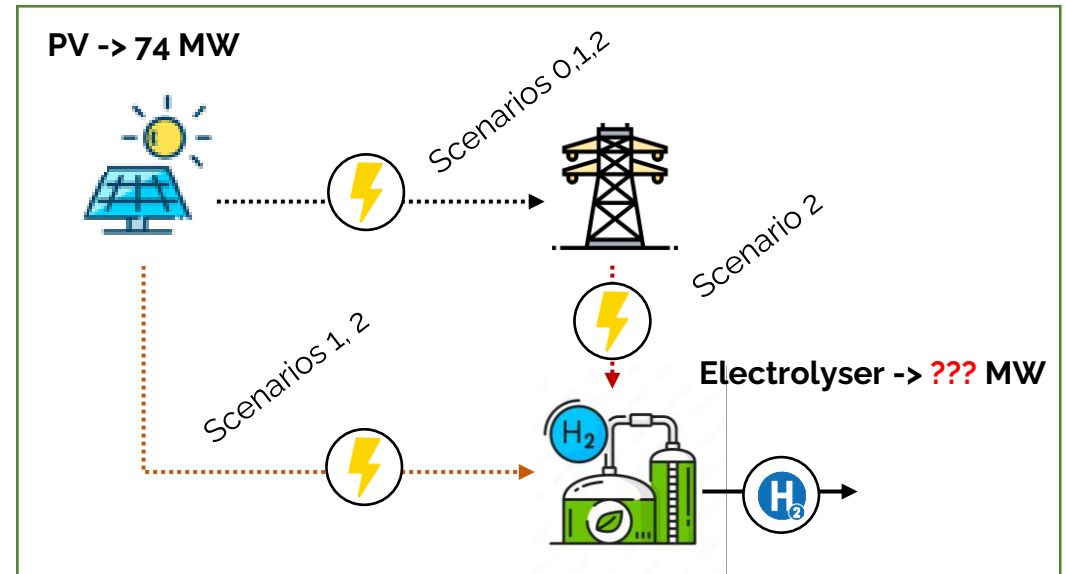


# When to invest in green H2 production?

Consider we want to build a 74 MW solar farm and possibly an electrolyser in Spain:

## Scenarios

- Scenario 0: PV production to the grid.
- Scenario 1: PV production to the electrolyser or the grid.
- Scenario 2: In addition, buy green power from the grid to increase hydrogen output.



- What is the scenario with the most value (e.g. highest NPV)?
- For what electrolyser size?



# KYOS valuation: A simulation approach



- Thousands of Monte-Carlo price and volume simulations.
- Market price volatility and weather patterns considered.
- Price and volume simulations negatively correlated to take cannibalization into account.

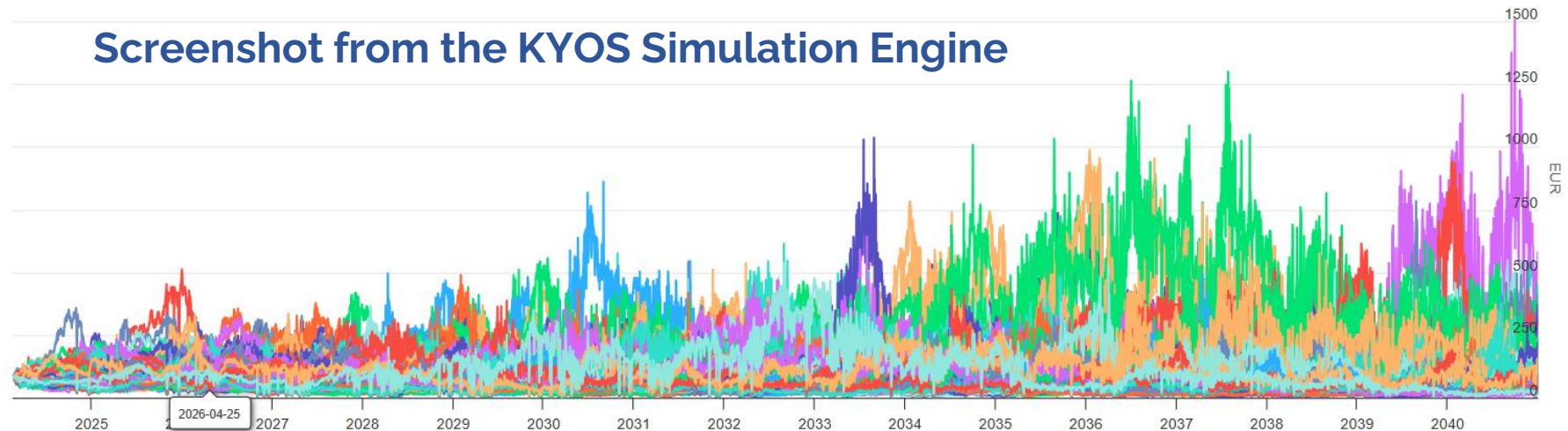


All comes together to find the fair value of an asset, and ... the risks.

Zoom 1m 3m 6m YTD 1y All

17 Feb 2024 → 31 Dec 2040

## Screenshot from the KYOS Simulation Engine



# Scenario 0 – only PV

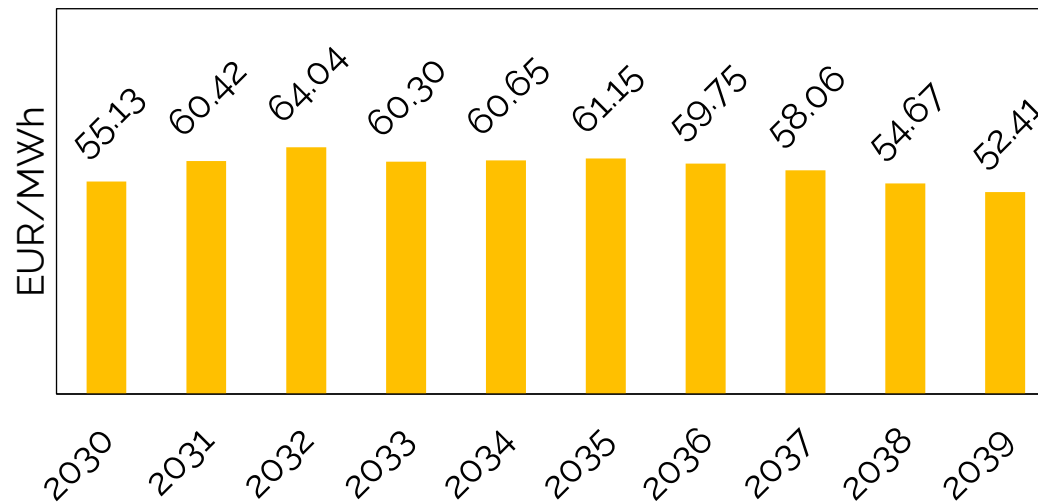


**Solar farm**  
Size: 74 MW  
CAPEX: 900 EUR/kW



**Valuation**  
Period: 2030 – 2039  
Discount rate: 3%

Nominal PV capture prices (Scenario 0 - only PV)



Decreasing capture prices due to:

- Falling baseload prices.
- Falling solar capture rates.

**The NPV for Scenario 0 is 1.85 MEUR.**

# Scenario 1 – PV to electrolyser and grid



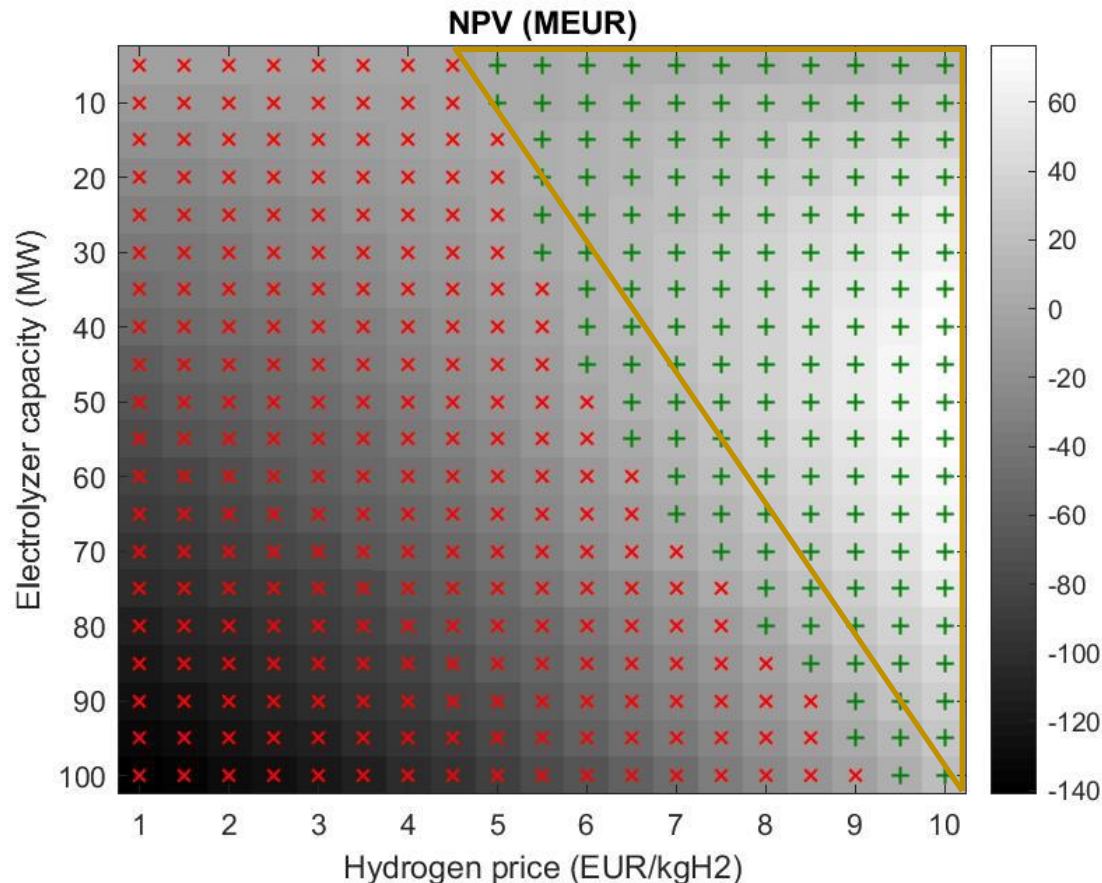
## Electrolyser

CAPEX: 1500 EUR/kW

OPEX: 0.3 EUR/kgH<sub>2</sub>

Consumption: 50 kWh/kg

- + Greater NPV than Scenario 0
- x Smaller NPV than Scenario 0



- At 5 EUR/kgH<sub>2</sub>, it makes sense to build either a 5 MW or a 10 MW electrolyser.
- 5MW is better due to lower capital costs.
- At low hydrogen prices, low revenues do not justify capital costs of (even) small electrolysers.
- At high hydrogen prices, building any electrolyser is reasonable.

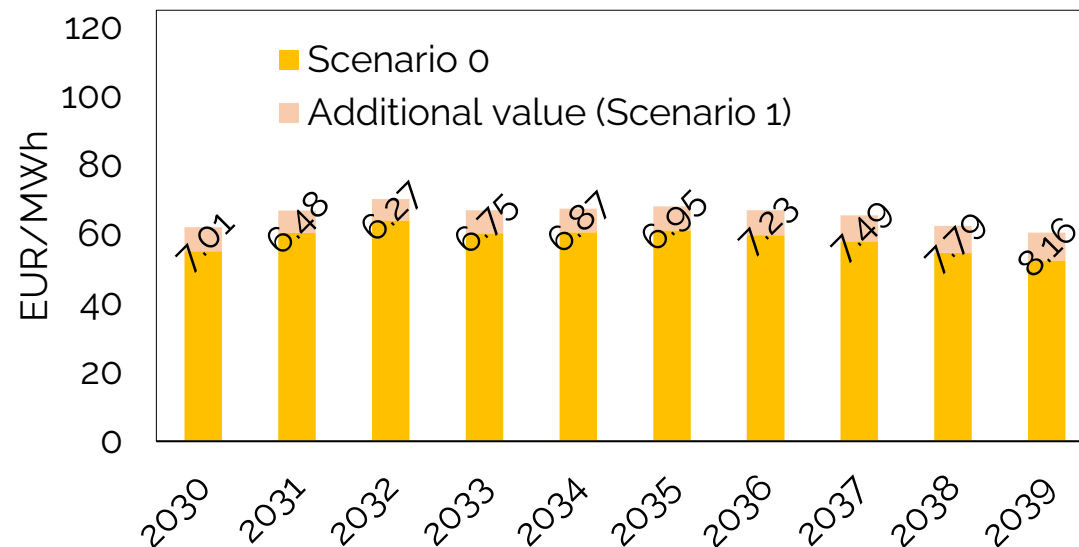
# Scenario 1 – Comparison to Scenario 0



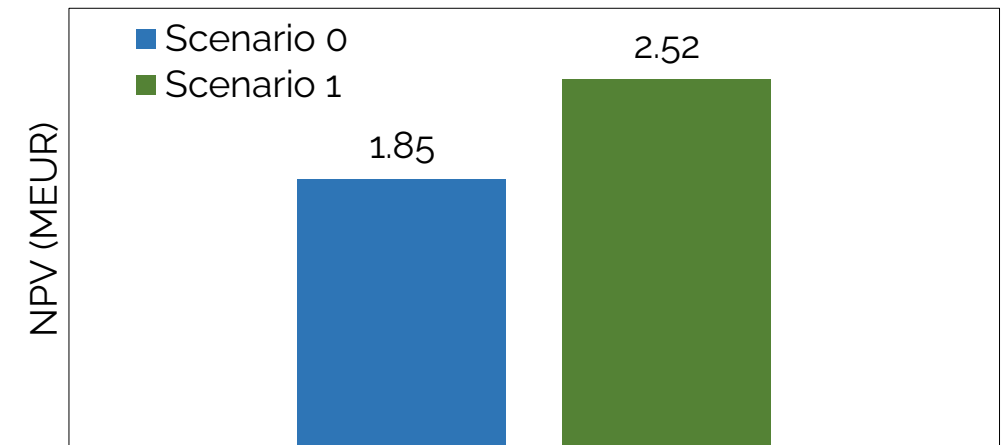
Assume the hydrogen price reaches 5 EUR/kgH<sub>2</sub>. It thus makes sense for us to build a 5 MW electrolyser.

- Selling hydrogen provides 7.10 EUR/MWh per year (on average) more than the PV capture price.
- Hydrogen sales make up for the lower electricity sales in later years (e.g. 2039).
- Having the 5 MW electrolyser in the portfolio increases the NPV by 0.68 MEUR.

PV capture price: Scenario 0 vs Scenario 1



NPV: Scenario 0 vs Scenario 1



# Scenario 2 – buy power from the grid too



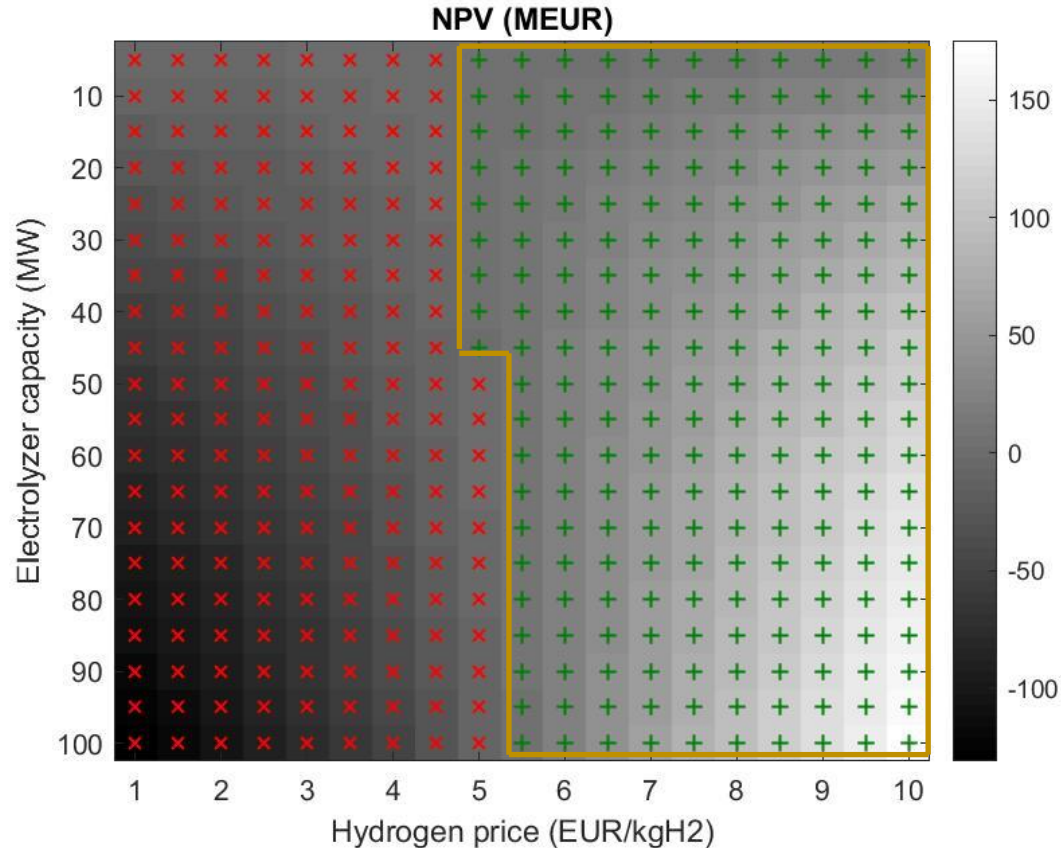
## Electrolyser

CAPEX: 1500 EUR/kW

OPEX: 0.3 EUR/kgH<sub>2</sub>

Consumption: 50 kWh/kg

- + Greater NPV than Scenario 0
- × Smaller NPV than Scenario 0



- At 5 EUR/kgH<sub>2</sub>, up to 45 MW electrolyzers have a business case.
- The optimal size is 20 MW, because of a high utilization of the green power from the grid and a relatively low capital cost.
- Much higher maximum NPV values are reached, because green power from the grid increases hydrogen sales.

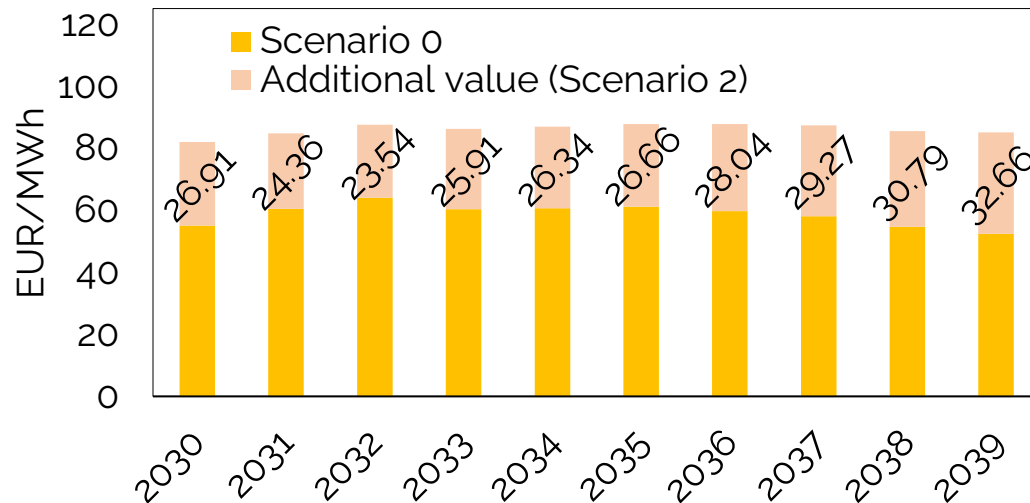
# Scenario 2 – Comparison to Scenario 0



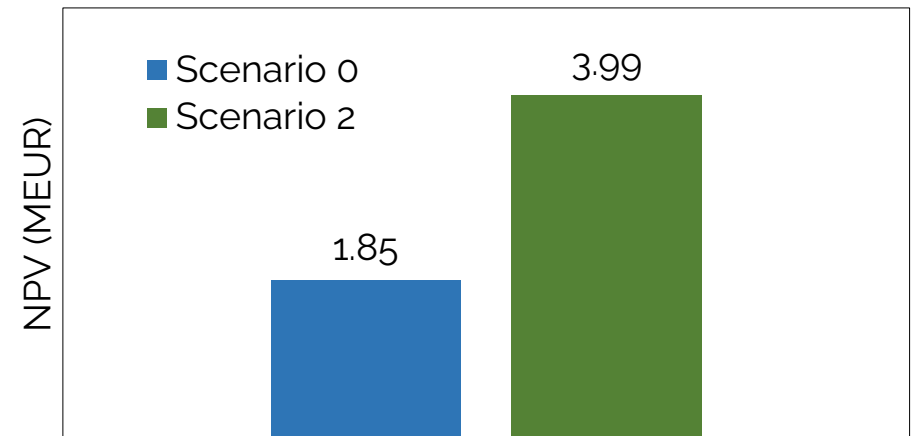
Assume the hydrogen price reaches 5 EUR/kgH<sub>2</sub>. It thus makes sense for us to build a 20 MW electrolyser, if we also want to buy power from the grid.

- Selling hydrogen provides 27.45 EUR/MWh per year (on average) more than the PV capture price.
- Having the 20 MW electrolyser in the portfolio increases the NPV by 2.15 MEUR.

PV capture price: Scenario 0 vs Scenario 2



NPV: Scenario 0 vs Scenario 2



# Scenario 2 – Reason for greater NPV



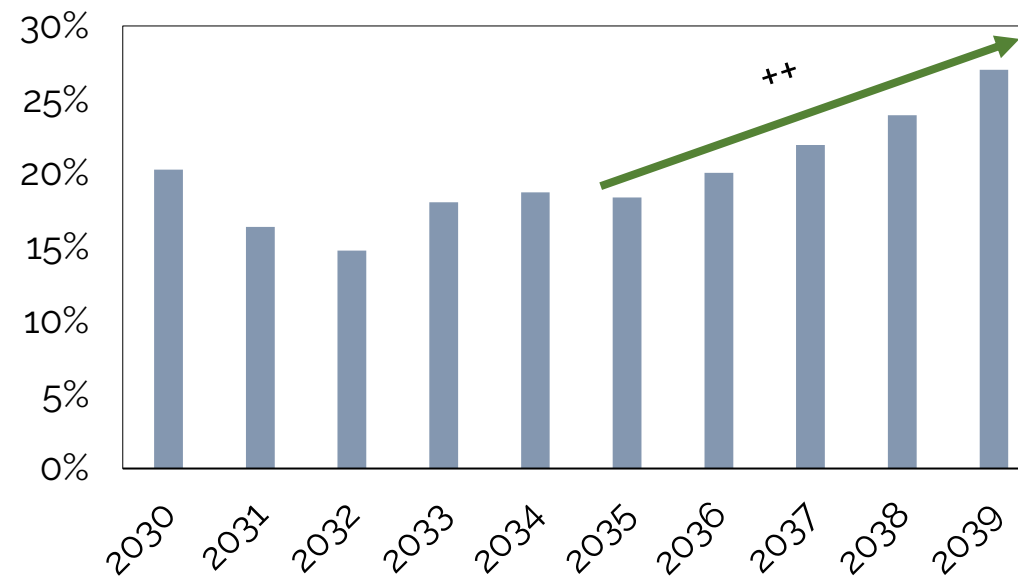
Buying green power from the grid increases the NPV, because:

- Capital costs remain the same, but...
- Several MWh's can be bought from the grid and resold at a higher hydrogen price.

A high share of renewable production expected in Spain in later years results in more green hours.

Green hours = Day-ahead price below 20 €/MWh **OR** below  $0.36 * CO_2$  price.

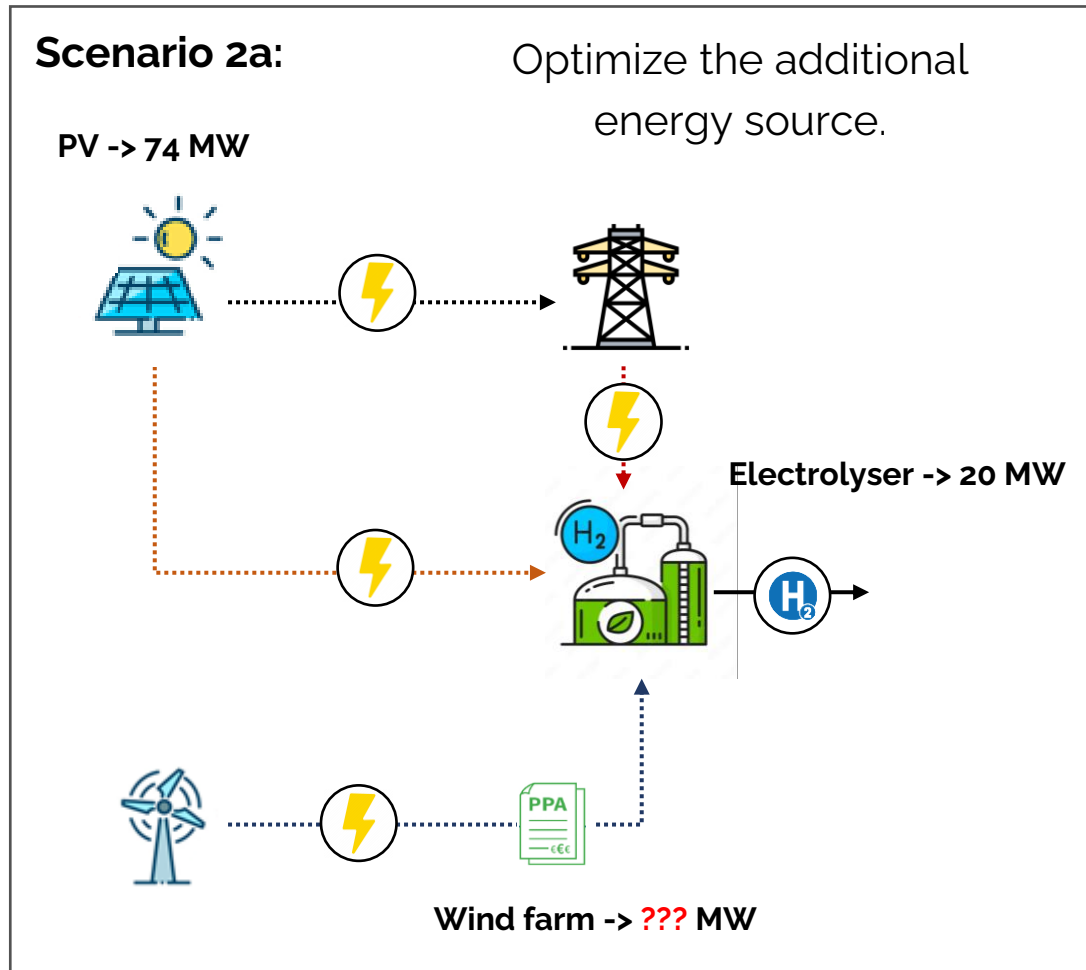
Portion of green energy hours in Spain



Capacity factor of electrolyzers increases, justifying the construction of larger electrolyzers.

# Additional value from the electrolyser

Assume the hydrogen price is at 5 EUR/kgH<sub>2</sub>, and we thus build a 20 MW electrolyser. Can we still extract additional value from it?



- A 69 MW onshore wind farm has offered a pay-as-produced PPA for 60 EUR/MWh.
- With 50 kWh/kgH<sub>2</sub> consumption, hydrogen production costs 3 EUR/kgH<sub>2</sub>.
- With the hydrogen price at 5 EUR/kgH<sub>2</sub>, the set up is profitable.
- But, can the hydrogen sales be maximized, while PPA purchases are minimized?
- What is the optimal volume to get from the wind farm? 10%, 15%, ...?

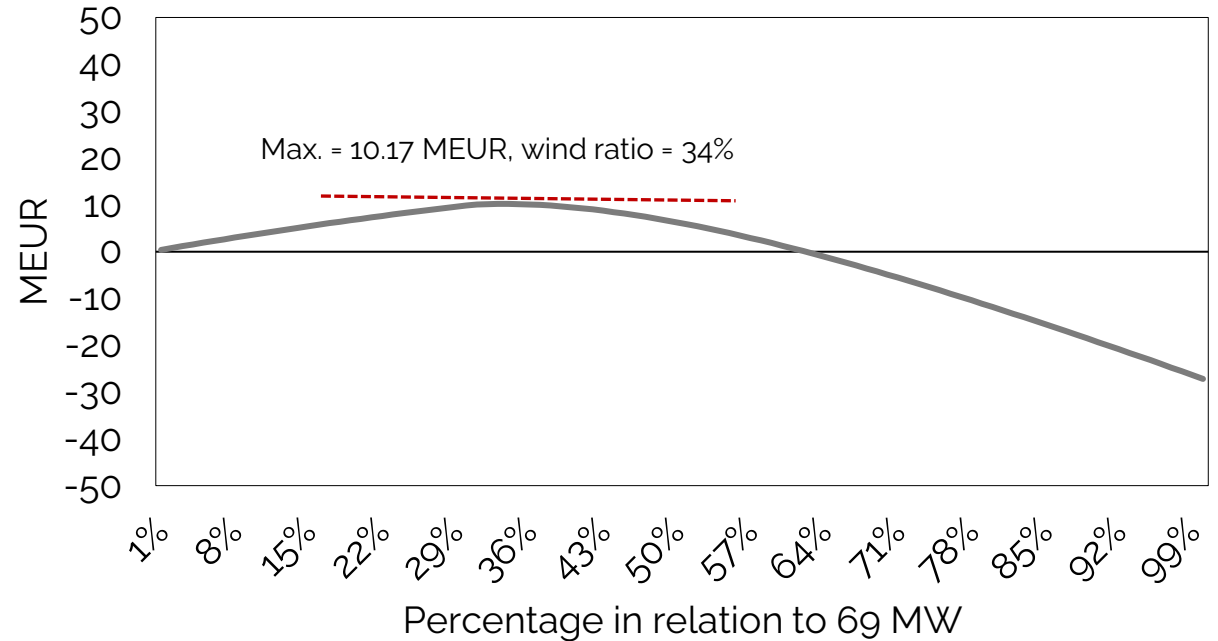


# Scenario 2a – Source extra green energy



- Small portions of volume underutilize the electrolyser.
- At the optimal, which happens at 34% (23.46 MW), the hydrogen sales reach their peak.
- Beyond this point, hydrogen sales no longer increase, and buying additional PPA power becomes unattractive.

Hydrogen sales minus PPA purchases (20 MW electrolyser @ 5 EUR/kgH<sub>2</sub>)



Buying 34% of the PPA volume increases the NPV to 12.6 MEUR. There are two additional sources of cashflows for the PV owner:

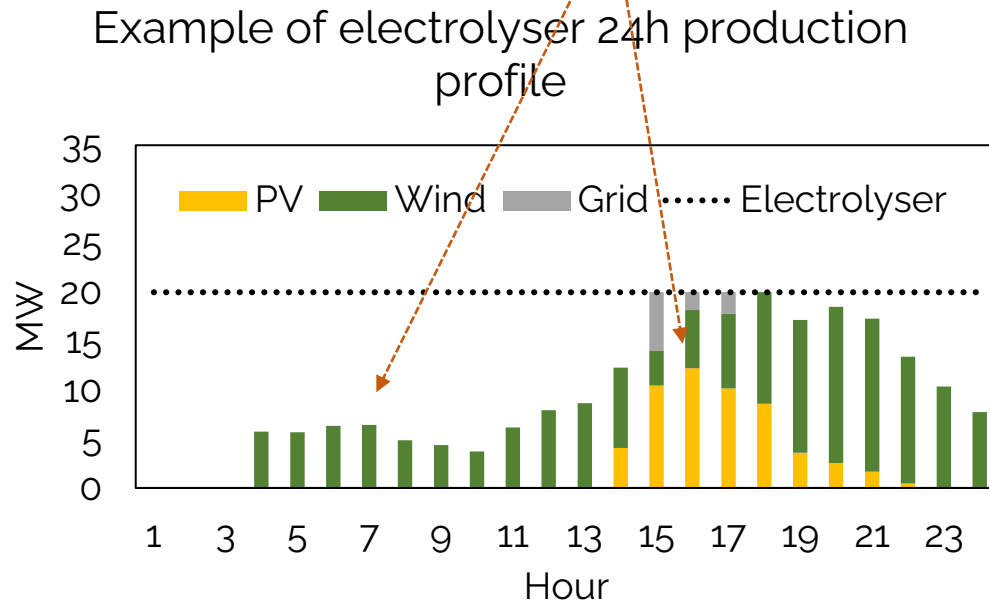
- Increased hydrogen sales (cost = 3 EUR/kgH<sub>2</sub>, revenue = 5 EUR/kgH<sub>2</sub>).
- Resale of unused PPA volume in the spot market.



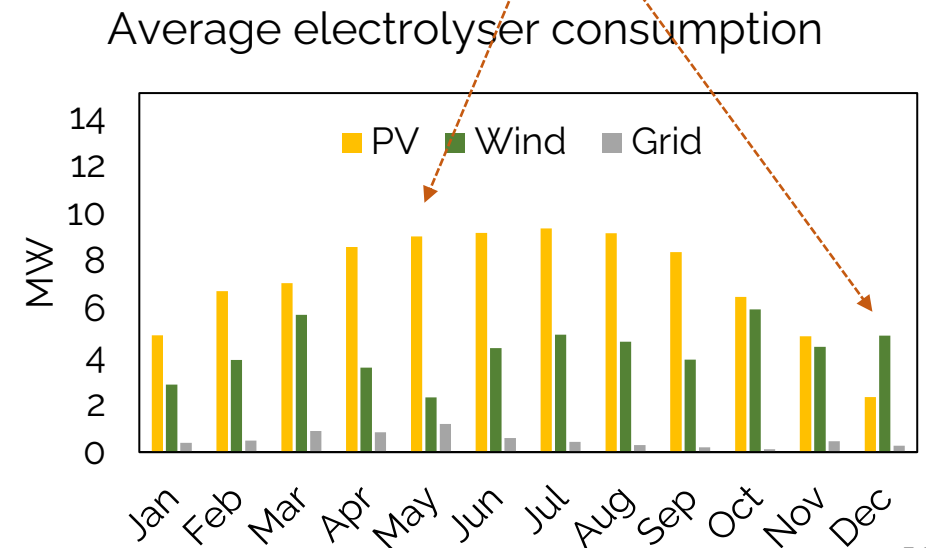
# Scenario 2 – Hybridization, additional gain

- An additional gain is the 'hybrid' (solar + wind) profile obtained. Hybrid plants are good candidates to supply electrolyzers with e.g. baseload demand.
- Hybridization is much easier in Portugal and Western Spain. See Spain's first hybrid wind-solar plant by Iberdrola in Burgos!

Profiles complement each other per day



Profiles complement each other per season



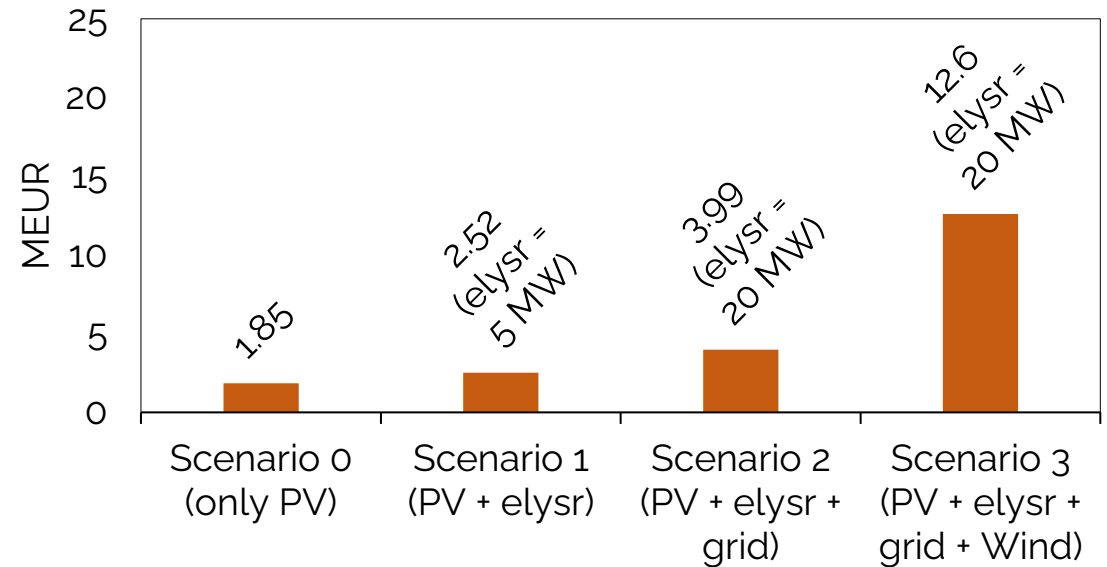
# Conclusions (1)

- Low hydrogen prices (anything less than 5 EUR/kgH<sub>2</sub>) do not justify the construction of (even) small electrolyzers.

Based on a 74 MW solar farm and a hydrogen price of 5 EUR/kgH<sub>2</sub>:

- Small electrolyzers (5 MW) are optimal, if they are to be supplied solely by the PV farm.
- Additional income can be made by buying green hydrogen from the grid and producing hydrogen with it. Medium size electrolyzers (20 MW) are better suited to reach the maximum value.

NPV across scenarios @ 5 EUR/kgH<sub>2</sub>



- Even more additional value can be unlocked by sourcing 34% of a 69 MW wind farm.
- Solar + wind = hybridization benefit.

# Conclusions (2)

- A green hydrogen market is taking shape and it will be large.
- In the meantime, it is important to obtain experience and assess business cases.
- Given certain conditions, optimization is key to achieve the highest returns on a project.
- Realistic price and renewable volume simulations provide key insights, **also for risks!**

**KYOS. Our analytics, your advantage.**



# Questions and Answers



Q&A!

# Contact Details



We look forward to supporting you with the right tools and advice in the rapidly changing energy sector!



[info@kyos.com](mailto:info@kyos.com)

<https://www.kyos.com/contact/>

KYOS  
Nieuwe Gracht 49  
2011 ND Haarlem  
The Netherlands

