The Role of Green Hydrogen in a Solar powered World : Case studies & business models

PVSEC-30

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Agenda

- Determining the role of hydrogen in renewable systems
- Use cases, from single systems to whole countries
- The economics of Swiss H_2 solar fuels
- Take-home messages

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Determining the role of hydrogen

The global optimality problem

- The energy system of tomorrow will be more complex than today
  - A greater number of involved technologies
  - A greater number of stakeholders

- But it still will have to be (at least) as performant as today
  - As reliable
  - As cost-effective

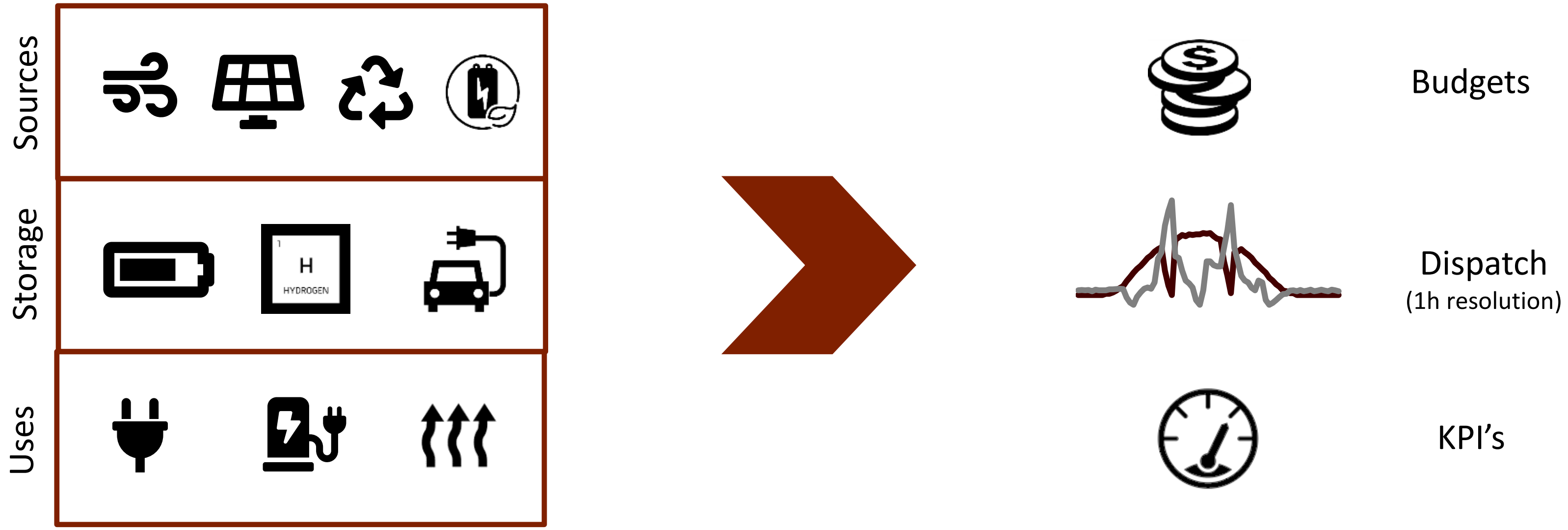
- How can such a system be properly designed?
  - When every single parameter influences all the others
  - Taking care of the details while always keeping the bigger picture in mind

- We have developed our own design method: the **Grid New Deal tool**

Determining the role of hydrogen

Our approach

- Economic **optimization** under technical constraints
  - Minimization of LCOE
  - Complying with the technological requirements of the considered new technologies



Sources

Storage

Uses

Budgets

Dispatch
(1h resolution)

KPI's

- Developing our own solution allows us to
  - Taylor our tool to our **customers' needs**
  - Ensure a complete **mastery** of the underlying hypothesis

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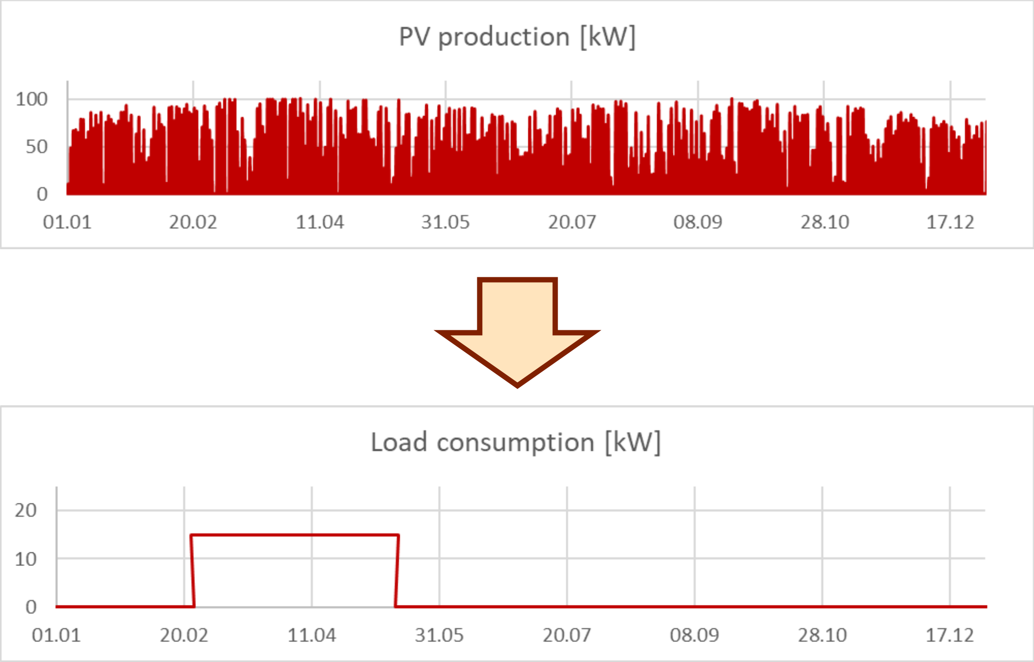
Use cases

Single system – a remote installation in the Swiss mountain

- Customer’s issues
  - Supplying a load with **high availability requirements** in a remote location
  - Building a MV-line is expensive and has a huge impact on the environment
  - **Consumption only during 3 months** per year (winter)

- Our proposition:
  - Transform a yearly PV production into a winter ribbon thanks to an **hybrid system**

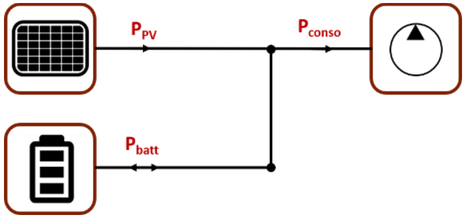


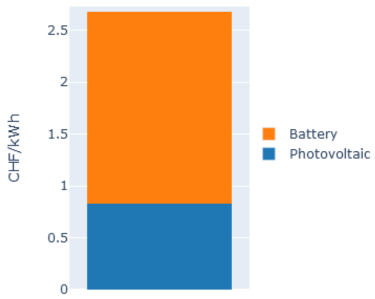
Use cases

Single system – a remote installation in the Swiss mountain

- Comparison of 3 different scenarios

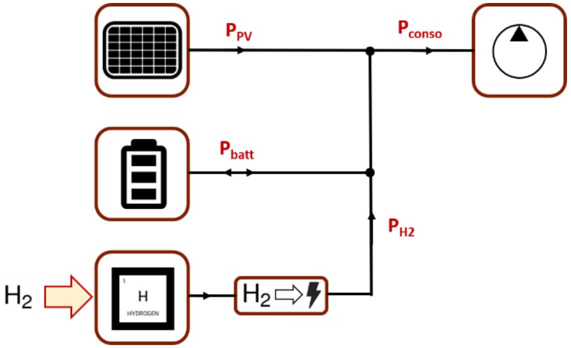
Scenario 1

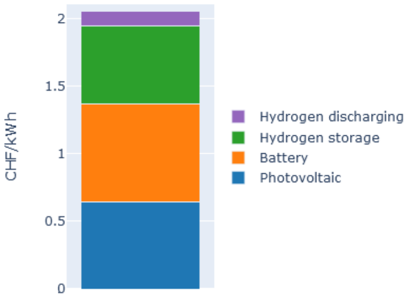




2.68 CHF/kWh

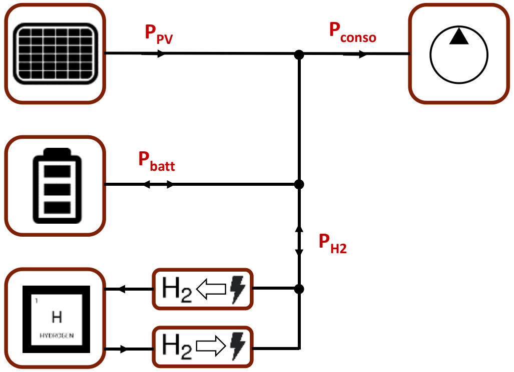
Scenario 2

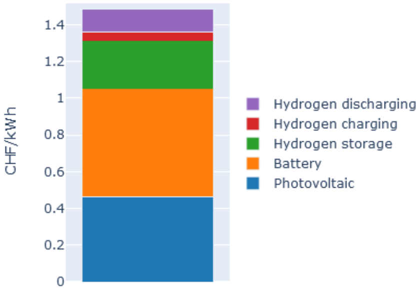




2.05 CHF/kWh

Scenario 3





1.48 CHF/kWh

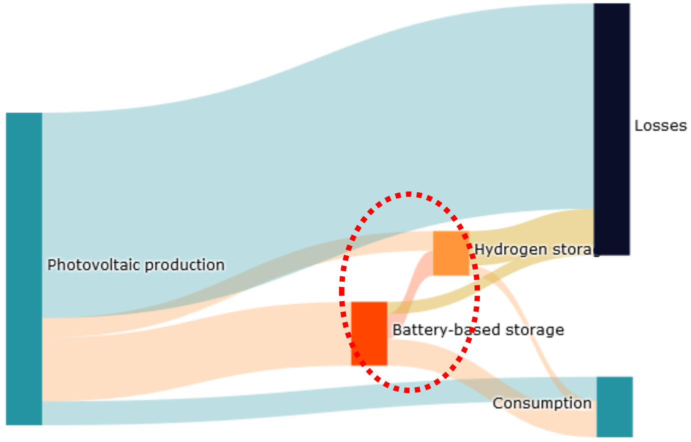
Cheaper than building a new line !

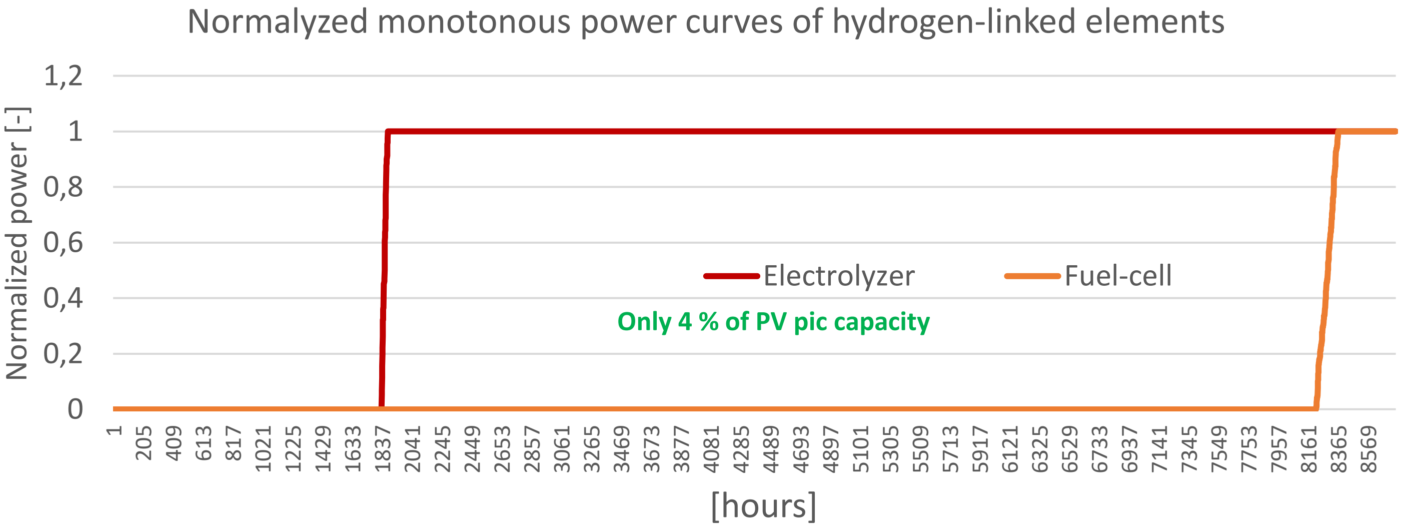
- **Hybridization** is the path to reducing energy costs

Use cases

Single system – a remote installation in the Swiss mountain

Scenarios → Modelling → Optimization → **Analyze**



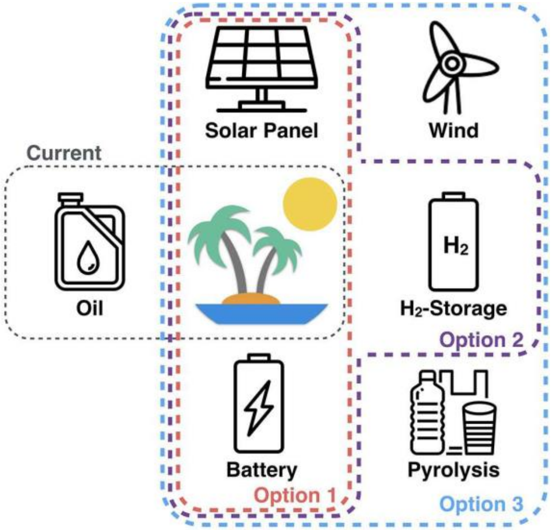


Only 4 % of PV pic capacity

Use cases

Reduced scale territory – the island of Rapa Nui

- How to optimally decarbonize the island electricity production?



- Study conducted alongside Swiss Federal Institute of Technologies (EPFL)

- Published in Frontiers Energy Research
    - "Benefits of a diversified energy mix for remote areas: the case of Easter Island"

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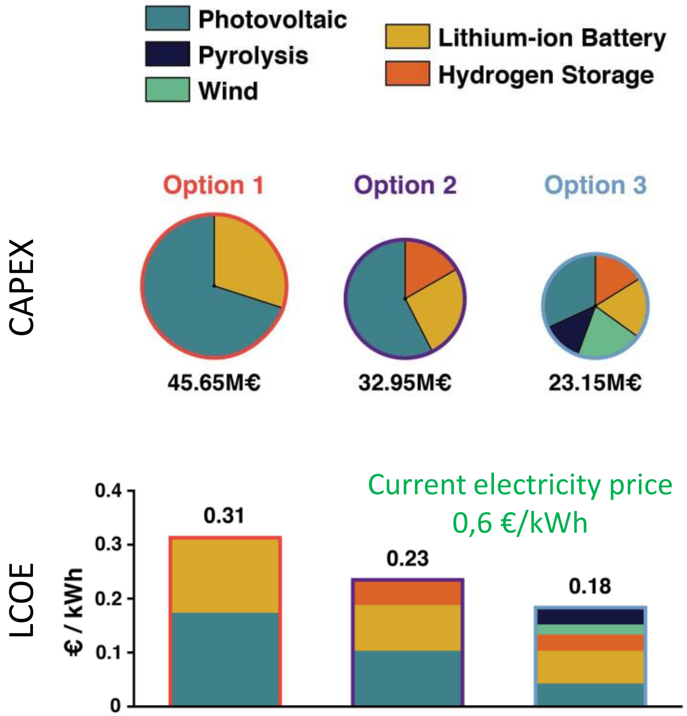
Use cases

Reduced scale territory – the island of Rapa Nui

- Here again, **hybridization with H_2 is the key** to:
    - Cost efficiency
        - CAPEX reduction of 50%
        - LCOE reduction of 42%
    - Energy efficiency
        - Losses divided by 5.5!



Current electricity price 0,6 €/kWh

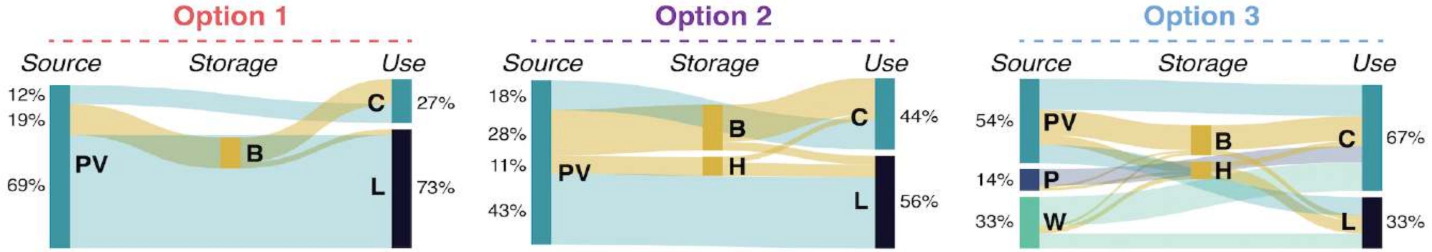


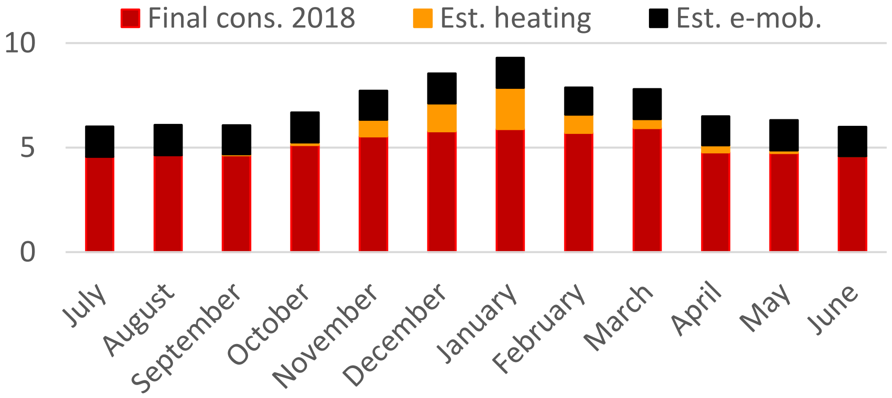
Figure 2. Summary of annual energy fluxes between energy sources, storage systems and uses. Energy sources include photovoltaic (**PV**), wind turbines (**W**) and Pyrolysis (**P**); storage systems include lithium-ion batteries (**B**) and hydrogen-based storage (**H**); and uses include consumption (**C**) and losses (**L**).

Use cases

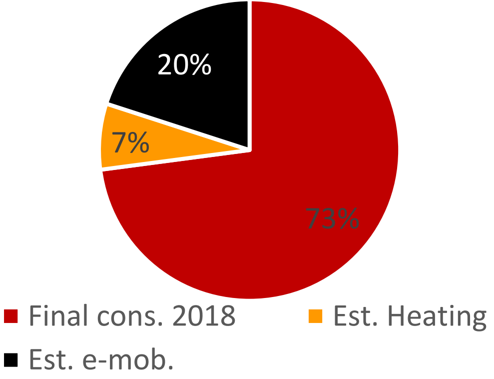
A whole country – Switzerland energy transition

- Switzerland problematic
  - Reduction of local production
    - Nuclear power plants are being phase out (35% in 2019)
  - Increase of local consumption
    - Electrification of mobility and building heating

Monthly distribution of the estimated final consumption [TWh]



Annual breakdown of estimated final consumption



- How to ensure security of supply without increase dependency to neighbouring countries?

Use cases

A whole country – Switzerland energy transition

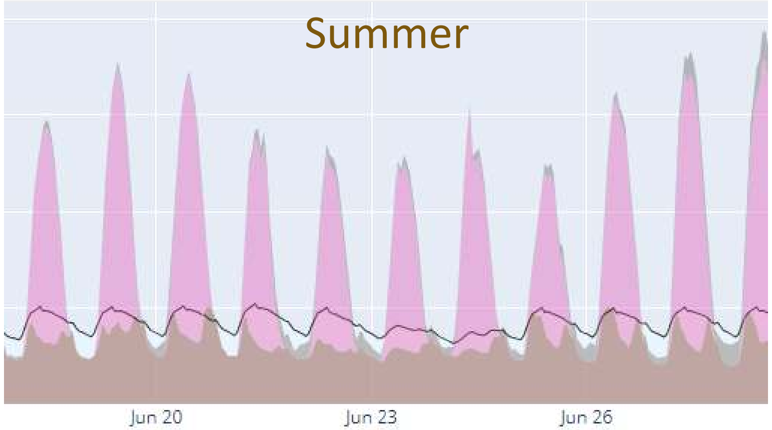
- Different scenarios depending on sun, wind and storage development
  A. Solar and battery
  B. Solar, battery and hydrogen storage to control imports
  C. Solar, battery, hydrogen storage and wind to control imports

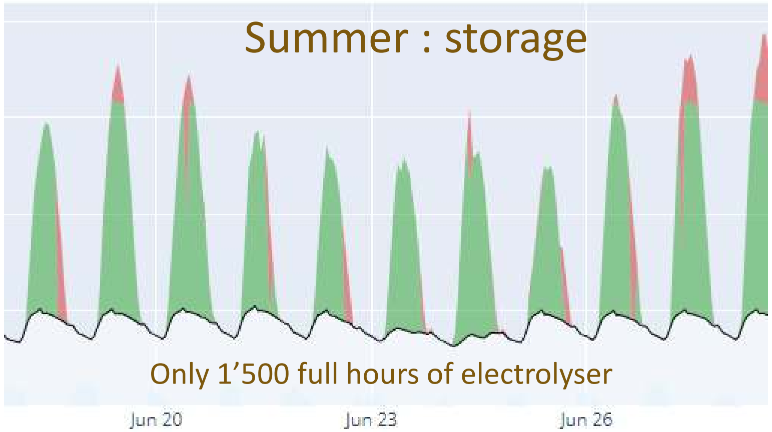
	Scenario A	Scenario B	Scenario C
Final consumption	84.7 TWh (61.9 TWh in 2018)		
Installed PV power	50 GWp	67 GWp	50 GWp
Installed Wind Power	0	0	5.3 GW
Daily storage capacity (battery)	100 GWh		
Electrolyser		38 GW	22 GW
Additionnal seasonal storage (H_2)	0	26 TWh	19.9 TWh
Fuel cell		8,8 GW	8,8
Raw Energy import (7 TWh in 2018)	**19.6 TWh**	**7 TWh**	**7 TWh**

Use cases

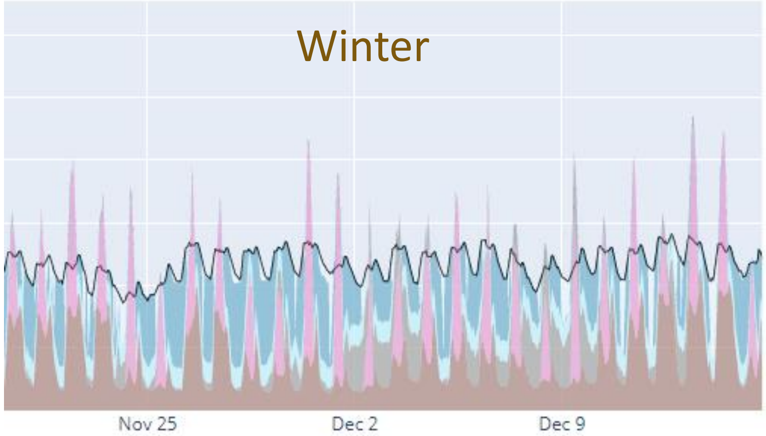
A whole country – Switzerland energy transition

- A **diverse renewable production** (sun and wind) and **seasonal storage** are the keys to achieve the transition without increasing dependency toward neighbouring countries


Summer


Summer : storage

Only 1'500 full hours of electrolyser

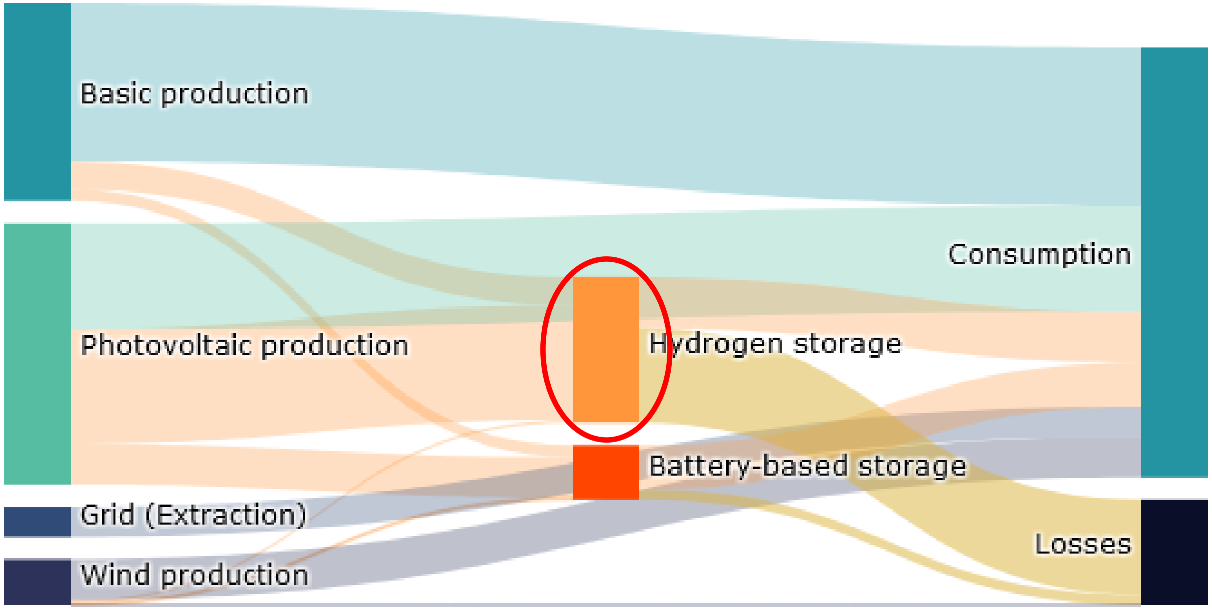

Winter

https://gridview.gridnewdeal.com/cockpit/demo/?case=3#results

Use cases

A whole country – Switzerland energy transition

- A **diverse renewable production** (sun and wind) and **seasonal storage** are the keys to achieve the transition without increasing dependency toward neighbouring countries



Scenario C

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Economics

The capital role of storage costs

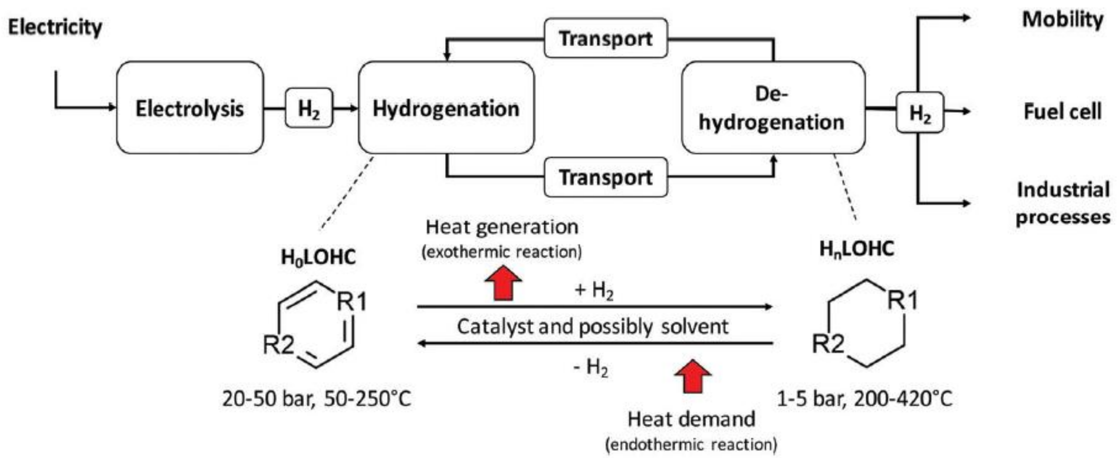
- We run of full CAPEX/OPEX evaluation based on each component price
- The costs of the of the seasonal storage is of the uttermost importance!

	Gazeous H_2	**Liquid carrier**
CAPEX	24 kCHF/MWh	2 kCHF/MWh
OPEX	0.2 kCHF/MWh/y	0.02 kCHF/MWh/y
Full system price (Capex)	**615-806 BCHF**	**97-128 BCHF**
National LCOE range (depending on scenarios)	**0.42 – 0.57 CHF/kWh**	**0.10 – 0.14 CHF/kWh**

- Only cheap hydrogen storage can lead to a cost competitive transition
  - Use Switzerland 14 million m^3 of oil storage for liquid hydrogen carrier

Choice of liquid carrier

Case Study: Liquid Organic Hydrogen Carriers



LOHC storage and transport concept (H_0LOHC: unloaded LOHC, H_nLOHC: loaded LOHC).

LOHC	Reason for consideration
N-Ethylcarbazole (NEC)	Well-studied nitrogenous LOHC
Dibenzyltoluene (DBT)	Already existing application as a LOHC; safe and convenient handling
1,2-Dihydro-1,2-azaborine (AB)	Unique characteristics through integration of boron and nitrogen
Formic acid (FA)	Safe and convenient handling
Methanol (MET)	Very high storage density
Naphthalene (NAP)	Well-studied cycloalkane; high storage density
Toluene (TOL)	Well-studied cycloalkane; planned application as a LOHC

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2019, 12, 290

- For our Case-Study: Dibenzyltoluene has been used in the calculation
  - Existing promising development in Germany
  - Easy to transport, lower toxicity, not flammable

Seasonal storage of solar fuel with H_2

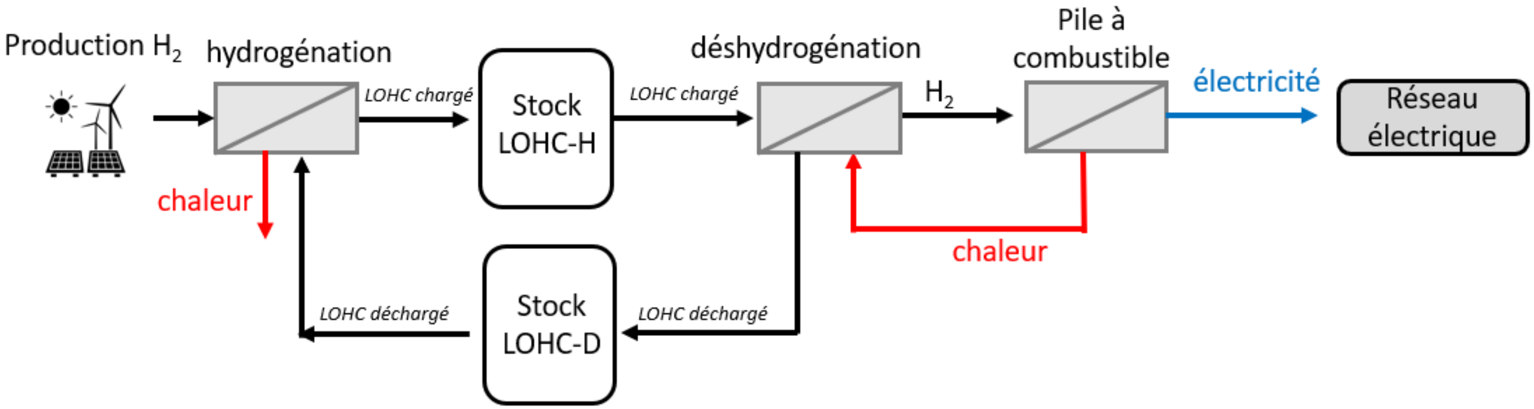
Case Study: Liquid Organic Hydrogen Carriers

- Concept
  - Use of the existing infrastructure (Pipeline and oil tank storage) of an decommissionned Raffinery
  - Storage of hydrogen with Liquid Organic Hydrogen Carriers (ca. 1 TWh potential H_2 storage with BDT & 2 TWh with Methanol)
  - Close to a waste incinerator (Avaibility of heat and potential CO_2 source)

Seasonal storage of solar fuel with H_2

Case Study: Liquid Organic Hydrogen Carriers

- Seasonal storage scenario



Production H_2

hydrogénation

LOHC chargé

Stock LOHC-H

LOHC chargé

déshydrogénation

H_2

Pile à combustible

électricité

Réseau électrique

chaleur

LOHC déchargé

Stock LOHC-D

LOHC déchargé

chaleur

- Open : Centralized H_2 production in the raffinery or decentralized H_2 production in industirs where heat can be used, for industrial processes)
- Storage in the existing oil tank (ca. 500’000 m^3)
- Electricity production with a high temperature fuel cell, creating high temperature losses using the breaking the liquid LOHC to H_2
- Potential cost of hydrogen stored in the raffinery with summer surplus of electricity : 3-4 CHF/kg H_2
- Cost of winter electricity (150 MW renewable flexible generation in Winter) : 30 cts/kWh (short term), 15 Rp/kWh (mid term) : it is possible !

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Take-home messages

- Diversifying production and storage technologies is the key for the transition toward a decarbonized energy system.
- Only a massive deployment of renewable energy production will make storage and green H_2 cost competitive.
- With a system view of seasonal H_2 storage, the full load hours of electrolyser is not the main issue, H_2 storage cost is by far more central
- Policies and market designs must be adapted to this new paradigm to provide to right signals to the investors and correctly remunerate the value of hybridization : **IEA PVPS Task 1 and 14 are addressing this need**.
- Only a global approach, involving in depth technical, economic and regulatory understandings is able to provide appropriate answers to these challenges.

More information?

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