Multistage stochastic optimization of a hydrogen supply chain

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Why hydrogen ?

- Hydrogen displays promising features for decarbonization industry, transportation and building sectors
- Transition towards a hydrogen economy requires hydrogen costs to come down, through optimal choices of infrastructure design and operation
- The optimal choices of design and operation rely on multistage stochastic optimization

Problem statement for the management of a hydrogen supply chain

Solving the problem by decomposition method

Numerical results

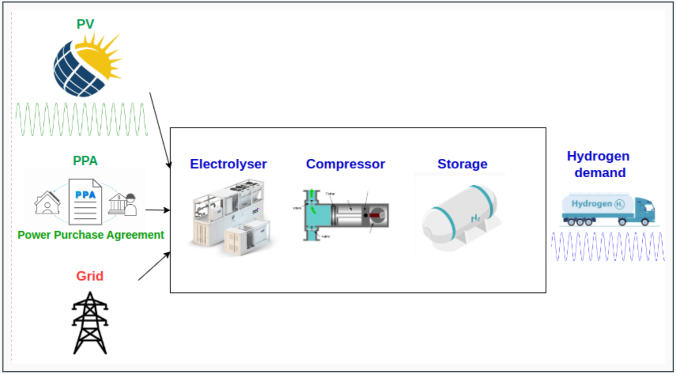
Optimizing the stock capacity

Future works and extensions

Problem statement for the management of a hydrogen supply chain

Problem statement

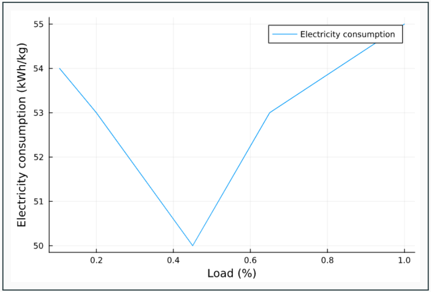
- Schiever company: diesel trucks → hydrogen trucks



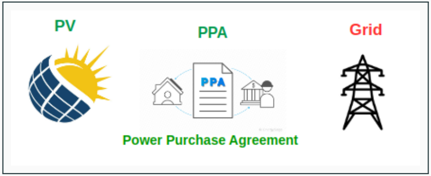
The objective is to minimize the operation cost of this supply chain by making decisions every hour during one week

Special characteristics of the problem

- A nonlinear electricity consumption for the electrolyser



- An energy mix to power the supply chain



Decisions and uncertainties

Decision	Description
$\mathbf{E}_h^{\mathrm{PPA}}$	Electricity from PPA contract (kWh)
$\mathbf{E}_{h+1}^{\mathrm{G}}$	Electricity from the grid (kWh)
$\mathbf{l}_h^{\mathrm{E}}$	Load at which the electrolyser is functioning (%)
$\mathbf{M}_h^{\mathrm{E}\curvearrowleft}$	Turn the electrolyser to cold, idle or start mode
$\mathbf{H}_h^{\rightarrow\mathrm{D}}$	Quantity of hydrogen extracted from the storage (kg) to satisfy demand

Uncertainty	Description
$\mathbf{E}_{h+1}^{\mathrm{PV}}$	Renewable (PV) electricity (kWh) during $[h, h+1[$
$\mathbf{D}_{h+1}$	Demand of hydrogen (kg) during $[h, h+1[$

Optimization problem formulation

$$\min_{(\mathbf{E}^{\mathrm{PPA}}_h, \mathbf{E}^{\mathrm{G}}_{h+1}, \mathbf{M}^{\mathrm{E}\curvearrowleft}_h, \mathbf{I}^{\mathrm{E}}_h, \mathbf{H}^{\to\mathrm{D}}_h)_{h\in\mathbb{H}}} \mathbb{E}_{(\mathbf{D}_{h+1}, \mathbf{E}^{\mathrm{PV}}_{h+1})_{h\in\mathbb{H}}} \Big[\sum_{h\in\mathbb{H}} \underbrace{c^{ppa}\mathbf{E}^{\mathrm{PPA}}_h + c^g_h \mathbf{E}^{\mathrm{G}}_{h+1}}_{\text{Electricity cost}} + \underbrace{c^d(\mathbf{D}_{h+1} - \mathbf{H}^{\to\mathrm{D}}_h)_+}_{\text{Demand dissatisfaction cost}} + K\Big(\big(\mathbf{E}^{\mathrm{PPA}}_h, \mathbf{E}^{\mathrm{G}}_{h+1}, \mathbf{E}^{\mathrm{PV}}_{h+1}\big)_{h\in\mathbb{H}}\Big)\Big]$$

subject to

- nonanticipativity constraints
- operational constraints
- renewable energy constraints
- a coupling constraint between the energy mix and the hydrogen equipments

$$\underbrace{\mathbf{E}^{\mathrm{PPA}}_h + \mathbf{E}^{\mathrm{G}}_{h+1} + \mathbf{E}^{\mathrm{PV}}_{h+1}}_{\text{electricity supply}} = \underbrace{g(\mathbf{M}^{\mathrm{E}\curvearrowleft}_h, \mathbf{M}^{\mathrm{E}}_h, \mathbf{I}^{\mathrm{E}}_h)}_{\text{electricity consumption}}$$

Optimization problem formulation

$$\min_{(\mathbf{E}_h^{\mathrm{PPA}}, \mathbf{E}_{h+1}^{\mathrm{G}}, \mathbf{M}_h^{\mathrm{E}\curvearrowleft}, \mathbf{I}_h^{\mathrm{E}}, \mathbf{H}_h^{\to\mathrm{D}})_{h\in\mathbb{H}}} \mathbb{E}_{(\mathbf{D}_{h+1}, \mathbf{E}_{h+1}^{\mathrm{PV}})_{h\in\mathbb{H}}} \Bigg[\sum_{h\in\mathbb{H}} \underbrace{c^{ppa}\mathbf{E}_h^{\mathrm{PPA}} + c_h^g \mathbf{E}_{h+1}^{\mathrm{G}}}_{\text{Electricity cost}} + \underbrace{c^d \left(\mathbf{D}_{h+1} - \mathbf{H}_h^{\to\mathrm{D}}\right)_+}_{\text{Demand dissatisfaction cost}} + K\Big(\big(\mathbf{E}_h^{\mathrm{PPA}}, \mathbf{E}_{h+1}^{\mathrm{G}}, \mathbf{E}_{h+1}^{\mathrm{PV}}\big)_{h\in\mathbb{H}}\Big)\Bigg]$$

subject to

- nonanticipativity constraints
- operational constraints
- **renewable energy constraints**
- a coupling constraint between the energy mix and the hydrogen equipments

$$\underbrace{\mathbf{E}_h^{\mathrm{PPA}} + \mathbf{E}_{h+1}^{\mathrm{G}} + \mathbf{E}_{h+1}^{\mathrm{PV}}}_{\text{electricity supply}} = \underbrace{g\left(\mathbf{M}_h^{\mathrm{E}\curvearrowleft}, \mathbf{M}_h^{\mathrm{E}}, \mathbf{I}_h^{\mathrm{E}}\right)}_{\text{electricity consumption}}$$

Renewable energy constraints of the problem

- Constraint on energy from the grid

$$\overbrace{\frac{\sum_{h\in\mathbb{H}} \mathbf{E}^{\mathrm{G}}_{h+1}}{\sum_{h\in\mathbb{H}} \mathbf{E}^{\mathrm{PPA}}_{h} + \mathbf{E}^{\mathrm{G}}_{h+1} + \mathbf{E}^{\mathrm{PV}}_{h+1}} \leq p}^{\text{Electricity from the grid is less than p percent of the total electricity}}$$
$$\iff \sum_{h\in\mathbb{H}} \Big((1-p)\mathbf{E}^{\mathrm{G}}_{h+1} - p(\mathbf{E}^{\mathrm{PPA}}_{h} + \mathbf{E}^{\mathrm{PV}}_{h+1})\Big) \leq 0$$

reformulated as a cost function

$$K\Big((\mathbf{E}^{\mathrm{PPA}}_{h}, \mathbf{E}^{\mathrm{G}}_{h+1}, \mathbf{E}^{\mathrm{PV}}_{h+1})_{h\in\mathbb{H}}\Big) = \alpha \max\Big(0, \sum_{h\in\mathbb{H}} \Big((1-p)\mathbf{E}^{\mathrm{G}}_{h+1} - p(\mathbf{E}^{\mathrm{PPA}}_{h} + \mathbf{E}^{\mathrm{PV}}_{h+1})\Big)\Big)$$

- Constraint on PPA contract

$$\overbrace{\sum_{h\in\mathbb{H}} \mathbf{E}^{\mathrm{PPA}}_{h} \leq \overline{E^{\mathrm{PPA}}}}^{\text{Electricity from the PPA contract is bounded}}$$

State dynamics for the Schiever case

To solve the problem by dynamic programming,

we introduce the mode of electrolyser and three stock variables

State variable	Description
M_h^{E}	mode of the electrolyser ($\{start, idle, cold\}$)
S_h	quantity of hydrogen in the storage (kg)
Q_h	"cumul of electricity"
P_h	remaining stock of available PPA (kWh)

State dynamics for the Schieve case

Letting $X_h = (M_h^{\mathrm{E}}, S_h, P_h, Q_h)$ be the four dimensional state, we have a state dynamics $\mathbf{X}_{h+1} = f(\mathbf{X}_h, \mathbf{I}_h^{\mathrm{E}}, \mathbf{M}_h^{\mathrm{E}\curvearrowleft}, \mathbf{H}_h^{\to\mathrm{D}}, \mathbf{E}_h^{\mathrm{PPA}}, \mathbf{E}_{h+1}^{\mathrm{G}}, \mathbf{E}_{h+1}^{\mathrm{PV}}, \mathbf{D}_{h+1})$ with

$$\mathbf{M}_{h+1}^{\mathrm{E}} = \mathbf{M}_h^{\mathrm{E}\curvearrowleft} \qquad \text{(Mode of the electrolyser)}$$

$$\mathbf{S}_{h+1} = \mathbf{S}_h + \underbrace{\mathbf{I}_h^{\mathrm{E}} \mu(\mathbf{M}_h^{\mathrm{E}}, \mathbf{M}_h^{\mathrm{E}\curvearrowleft}) \overline{m^{\mathrm{E}}}}_{\mathrm{H}_2 \text{ produced}} - \underbrace{\mathbf{H}_h^{\to\mathrm{D}}}_{\mathrm{H}_2 \text{ extracted}} \qquad \text{(Stock of hydrogen)}$$

$$\mathbf{P}_{h+1} = \mathbf{P}_h - \mathbf{E}_h^{\mathrm{PPA}} \qquad \text{(Stock of PPA)}$$

$$\mathbf{Q}_{h+1} = \mathbf{Q}_h + p\mathbf{E}_{h+1}^{\mathrm{G}} - (1-p)(\mathbf{E}_h^{\mathrm{PPA}} + \mathbf{E}_{h+1}^{\mathrm{PV}}) \qquad \text{(Cumul of electricity)}$$

Thanks to the state Q_h, the cost $K\big((\mathbf{E}_h^{\mathrm{PPA}}, \mathbf{E}_{h+1}^{\mathrm{G}}, \mathbf{E}_{h+1}^{\mathrm{PV}})_{h\in\mathbb{H}}\big)$ can be written as $J(\mathbf{Q}_T) = \alpha \max(0, \mathbf{Q}_T)$

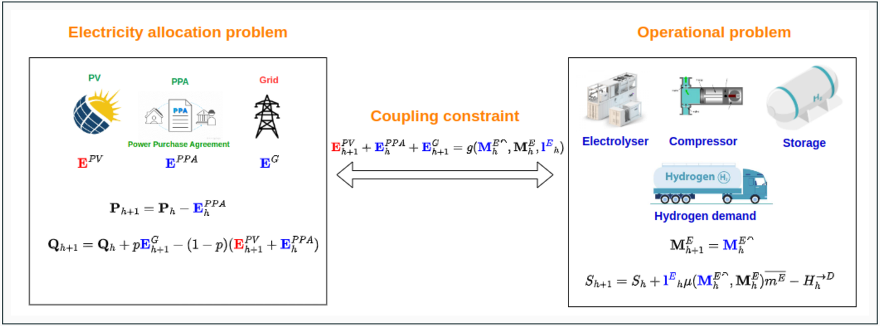
Numerical considerations

A difficult numerical problem:

- one week horizon with hourly decisions (168 time steps)
- four dimensional state
  - using Stochastic Dynamic Programming,
    we discretize the states
  - the stock of PPA (P) and of the "cumul of electricity" (Q)
    take large values and require a fine discretization
    which is numerically demanding
- two random variables
- five decisions at each hour

Solving the problem by decomposition method

A decomposition approach



A decomposition approach

$$\mathrm{val}(\mathcal{P}) = \min_{(\mathbf{E}^{\mathrm{PPA}}_h, \mathbf{E}^{\mathrm{G}}_{h+1}, \mathbf{M}^{\mathrm{E}\curvearrowleft}_h, \mathbf{I}^{\mathrm{E}}_h, \mathbf{H}^{\to\mathrm{D}}_h)_{h\in\mathbb{H}}} \mathbb{E}_{(\mathbf{D}_{h+1}, \mathbf{E}^{\mathrm{PV}}_{h+1})_{h\in\mathbb{H}}} \Big[\underbrace{\sum_{h\in\mathbb{H}} c^{ppa}\mathbf{E}^{\mathrm{PPA}}_h + c^g_h \mathbf{E}^{\mathrm{G}}_{h+1} + K\Big((\mathbf{E}^{\mathrm{PPA}}_h, \mathbf{E}^{\mathrm{G}}_{h+1}, \mathbf{E}^{\mathrm{PV}}_{h+1})_{h\in\mathbb{H}}\Big)}_{\text{electricity cost}} + \underbrace{\sum_{h\in\mathbb{H}} c^d (\mathbf{D}_{h+1} - \mathbf{H}^{\to\mathrm{D}}_h)_+}_{\text{demand dissatisfaction cost}} \Big]$$

subject to nonanticipativity constraints, operational constraints, electricity constraints and the following coupling constraint

$$\underbrace{\mathbf{E}^{\mathrm{PPA}}_h + \mathbf{E}^{\mathrm{G}}_{h+1} + \mathbf{E}^{\mathrm{PV}}_{h+1}}_{\text{electricity supply}} = \underbrace{g(\mathbf{M}^{\mathrm{E}\curvearrowleft}_h, \mathbf{M}^{\mathrm{E}}_h, \mathbf{I}^{\mathrm{E}}_h)}_{\text{electricity consumption}}$$

Decoupling the operational and electricity problems

Dualize the coupling constraints with Lagrange multipliers: $\lambda = \{\lambda_h\}_{h\in\mathbb{H}}$

- electrolyser/compressor/storage operational (O) problem

$$\phi^O(\lambda) = \min_{(\mathbf{M}_h^{\mathrm{E}\curvearrowleft},\mathbf{I}_h^{\mathrm{E}},\mathbf{H}_h^{\to\mathrm{D}})_{h\in\mathbb{H}}} \mathbb{E}_{(\mathbf{D}_{h+1})_{h\in\mathbb{H}}}\Big[\sum_{h\in\mathbb{H}} c^d(\mathbf{D}_{h+1} - \mathbf{H}_h^{\to\mathrm{D}})_+ - \sum_{h\in\mathbb{H}} \lambda_h\big(g(\mathbf{M}_h^{\mathrm{E}\curvearrowleft},\mathbf{M}_h^{\mathrm{E}},\mathbf{I}_h^{\mathrm{E}})\big)\Big]$$

s.t. (undetailed) operational constraints

- electricity (E) allocation problem

$$\phi^E(\lambda) = \min_{(\mathbf{E}_h^{\mathrm{PPA}},\mathbf{E}_{h+1}^{\mathrm{G}})_{h\in\mathbb{H}}} \mathbb{E}_{(\mathbf{E}_{h+1}^{\mathrm{PV}})_{h\in\mathbb{H}}}\Big[\sum_{h\in\mathbb{H}} c^{ppa}\mathbf{E}_h^{\mathrm{PPA}} + c_h^g\mathbf{E}_{h+1}^{\mathrm{G}} + K\Big((\mathbf{E}_h^{\mathrm{PPA}},\mathbf{E}_{h+1}^{\mathrm{G}},\mathbf{E}_{h+1}^{\mathrm{PV}})_{h\in\mathbb{H}}\Big) + \sum_{h\in\mathbb{H}} \lambda_h\big(\mathbf{E}_h^{\mathrm{PPA}} + \mathbf{E}_{h+1}^{\mathrm{G}} + \mathbf{E}_{h+1}^{\mathrm{PV}}\big)\Big]$$

s.t. electricity constraints

Decoupling the operational and electricity allocation problems

- For a fixed deterministic multiplier $\lambda = \{\lambda_h\}_{h\in\mathbb{H}}$, independently:
  - compute $\phi^O(\lambda)$ (operational problem) by Stochastic Dynamic Programming (SDP)
    $\phi^O(\lambda) = V_0^{O,\lambda}(S_0, M_0^{\mathrm{E}})$
    given by induction $V_h^{O,\lambda} = \mathrm{B}^{O,\lambda}(V_{h+1}^{O,\lambda})$
  - compute $\phi^E(\lambda)$ (electricity allocation problem) by Stochastic Dual Dynamic Programming (SDDP)
    $\phi^E(\lambda) = V_0^{E,\lambda}(P_0, Q_0)$
    given by induction $V_h^{E,\lambda} = \mathrm{B}^{E,\lambda}(V_{h+1}^{E,\lambda})$
- Update the multiplier λ by a gradient based optimization algorithm to maximize the dual function $\phi^O(\lambda) + \phi^E(\lambda)$

$$\phi^O(\lambda) + \phi^E(\lambda) \le \underbrace{\max_{\lambda'} \phi^O(\lambda') + \phi^E(\lambda')}_{\text{dual problem}} \le \underbrace{\mathrm{val}(\mathcal{P})}_{\text{primal problem}}$$

Policy design

For a fixed multiplier $\lambda = \{\lambda_h\}_{h \in \mathbb{H}}$

- we obtain a feasible policy $\pi^\lambda = \{\pi_h^\lambda\}_{h \in \mathbb{H}}$ for the problem $(\mathcal{P})$ by

$$\overbrace{\pi_h^\lambda}^{\text{policy}}(S_h, M_h^{\mathrm{E}}, P_h, Q_h) = \underset{(\mathbf{E}_h^{\mathrm{PPA}}, \mathbf{M}_h^{\mathrm{E}\curvearrowleft}, \mathbf{I}_h^{\mathrm{E}}, \mathbf{H}_h^{\to\mathrm{D}})}{\arg\min} \; \mathbb{E}_{(\mathbf{D}_{h+1}, \mathbf{E}_{h+1}^{\mathrm{PV}})}\Big[\min_{\mathbf{E}_{h+1}^{\mathrm{G}}} L_h\Big(\mathbf{E}_h^{\mathrm{PPA}}, \mathbf{E}_{h+1}^{\mathrm{G}}, \mathbf{E}_{h+1}^{\mathrm{PV}}, \mathbf{H}_h^{\to\mathrm{D}}\Big) + \underbrace{V_{h+1}^{O,\lambda}(\mathbf{S}_{h+1}, \mathbf{M}_{h+1}^{\mathrm{E}}) + V_{h+1}^{E,\lambda}(\mathbf{P}_{h+1}, \mathbf{Q}_{h+1})}_{\text{surrogate additive value function}} \Big]$$

  under nonanticipativity constraints, operational constraints, renewable energy constraints and the coupling constraint
- we have $\mathrm{val}(\mathcal{P}) \leq \mathrm{val}(\mathcal{P}_{\pi^\lambda})$,
  where $\mathrm{val}(\mathcal{P}_{\pi^\lambda})$ denotes the cost when applying the policy π^λ

PV and demand data

The independent random variables $(\mathbf{D}_{h+1}, \mathbf{E}^{\mathrm{PV}}_{h+1})_{h\in\mathbb{H}}$ are given by

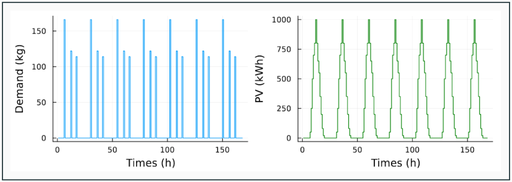
Table 1: Probability distribution of $\mathbf{D}_{h+1}$

Outcome	$0.8\mu^{d}_{h+1}$	$0.9\mu^{d}_{h+1}$	μ^{d}_{h+1}	$1.1\mu^{d}_{h+1}$	$1.2\mu^{d}_{h+1}$
Probability	$\frac{1}{5}$	$\frac{1}{5}$	$\frac{1}{5}$	$\frac{1}{5}$	$\frac{1}{5}$

Table 2: Probability distribution of $\mathbf{E}^{\mathrm{PV}}_{h+1}$

Outcome	$0.8\mu^{pv}_{h+1}$	$0.9\mu^{pv}_{h+1}$	μ^{pv}_{h+1}	$1.1\mu^{pv}_{h+1}$	$1.2\mu^{pv}_{h+1}$
Probability	$\frac{1}{5}$	$\frac{1}{5}$	$\frac{1}{5}$	$\frac{1}{5}$	$\frac{1}{5}$

where $(\mu^{d}_{h+1}, \mu^{e^{\mathrm{PV}}}_{h+1})_{h\in\mathbb{H}}$ are deterministic and given in the following figure



Monte-Carlo evaluation of a policy

- Let $(d, e^{\mathrm{PV}}) = (d_{h+1}, e^{\mathrm{PV}}_{h+1})_{h \in \mathbb{H}}$ be a sample of hydrogen demand and PV production

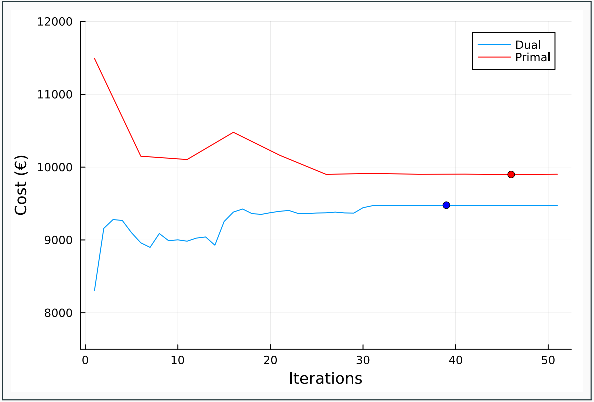
  We simulate a policy as follows:
  $x_0 \rightsquigarrow \pi_0^\lambda(x_0) \rightsquigarrow (d_1, e_1^{\mathrm{PV}}) \rightsquigarrow x_1 = f(x_0, \pi_0^\lambda(x_0), (d_1, e_1^{\mathrm{PV}})) \rightsquigarrow \pi_1^\lambda(x_1) \rightsquigarrow (d_2, e_2^{\mathrm{PV}}) \rightsquigarrow x_2 = f(x_1, \pi_1^\lambda(x_1), (d_2, e_2^{\mathrm{PV}})) \ldots \rightsquigarrow (d_{h+1}, e_{h+1}^{\mathrm{PV}}) \rightsquigarrow x_h = f(x_{h-1}, \pi_h^\lambda(x_{h-1}), (d_{h+1}, e_{h+1}^{\mathrm{PV}}))$
- Let $\{(d, e^{\mathrm{PV}})_i\}_{i \in [\![1,N]\!]}$ be a set of noise trajectories, we use the approximation

$$\mathrm{val}(\mathcal{P}_{\pi^\lambda}) \approx \frac{1}{N}\sum_{i=1}^{N} \mathrm{val}(\mathcal{P}^i_{\pi^\lambda})$$

  where $\mathrm{val}(\mathcal{P}^i_{\pi^\lambda})$ is the cost of the simulation for the noise trajectory $(d, e^{\mathrm{PV}})_i$

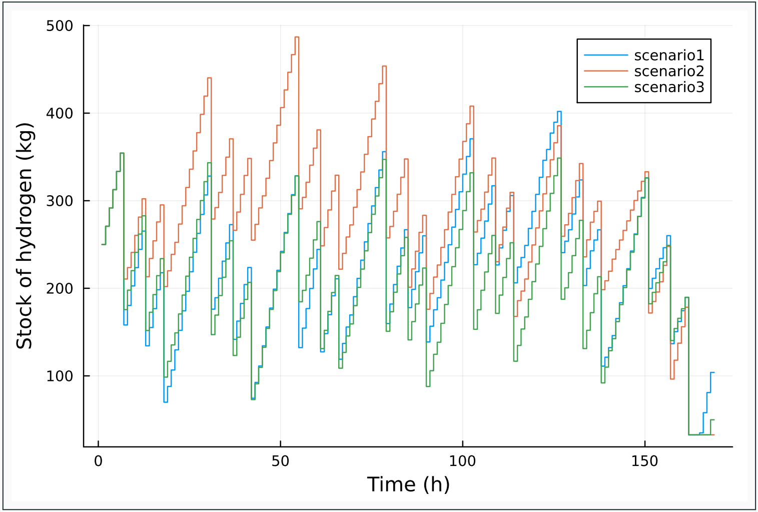
Numerical results

Maximizing the dual function



maximization of the dual function with decomposition algorithm

Evolution of the hydrogen stock over time



Electricity consumption over time

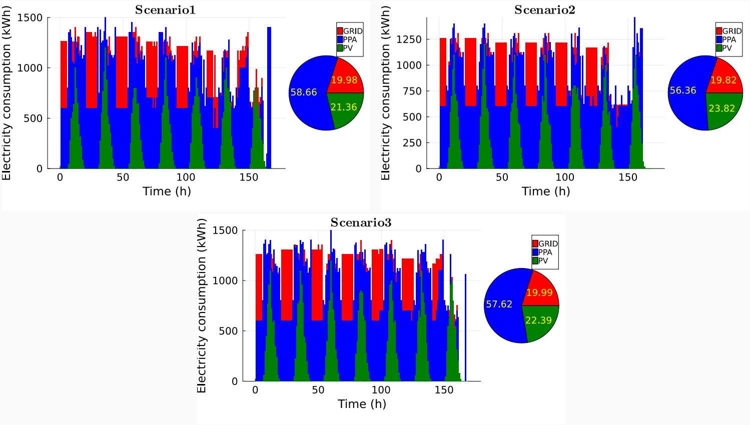


Figure 1: Time evolution of the electricity consumption for the three different scenarios

Optimizing the stock capacity

The design optimization problem

The stock design problem can be written as

$$\min_{i \in \mathbb{I}} \min_{(\mathbf{U}_h)_{h\in\mathbb{H}} \in Y_i} \mathbb{E}_{(\mathbf{D}_{h+1}, \mathbf{E}^{\mathrm{PV}}_{h+1})_{h\in\mathbb{H}}} \Big[\sum_{h\in\mathbb{H}} L_h\Big(\mathbf{E}^{\mathrm{PPA}}_h, \mathbf{E}^{\mathrm{G}}_{h+1}, \mathbf{E}^{\mathrm{PV}}_{h+1}, \mathbf{H}^{\rightarrow \mathrm{D}}_h\Big) + K\Big((\mathbf{E}^{\mathrm{PPA}}_h, \mathbf{E}^{\mathrm{G}}_{h+1}, \mathbf{E}^{\mathrm{PV}}_{h+1})_{h\in\mathbb{H}}\Big)\Big] + c_i \ ,$$

where $\mathbb{I}$ is the set of designs, $\mathbf{U}_h = (\mathbf{E}^{\mathrm{PPA}}_h, \mathbf{E}^{\mathrm{G}}_{h+1}, \mathbf{M}^{\mathrm{E}\curvearrowleft}_h, \mathbf{I}^{\mathrm{E}}_h, \mathbf{H}^{\rightarrow \mathrm{D}}_h)$, Y_i is the set of nonanticipativity constraints, operational constraints (that depends on i), renewable energy constraints and the coupling constraints between the energy mix and the hydrogen equipments and c_i is the cost of the design i.

An alternative design optimization problem

We consider the following optimization problem

$$\min_{i \in \mathbb{I}} \max_{\lambda \in \mathbb{R}^T} \phi^E(\lambda) + \phi_i^O(\lambda) + c_i \ ,$$

where

- $\phi^E(\lambda)$ is the electricity allocation problem
  that does not dependant on i
- $\phi_i^O(\lambda)$ is the operational problem that depends on i

The computation of $\phi_i^O(\lambda)$ is faster than the computation of $\phi^E(\lambda)$, which is the key ingredient used in the following algorithm to solve the minmax optimization problem

Solving the minmax problem

1. set $\mathbb{J} \leftarrow \mathbb{I}$, choose an initial design $i \in \mathbb{J}$, set $\mathbb{J} \leftarrow \mathbb{J} \backslash \{i\}$, choose an initial multiplier $\lambda^0 \in \mathbb{R}^T$
2. maximize the dual function $\phi^E + \phi_i^O + c_i$ associated to the design problem i. The multiplier obtained at the end of the optimization is denoted by λ^*
3. store the oriented pair $(i, \phi^E(\lambda^*) + \phi_i^O(\lambda^*) + c_i)$ in the list $\mathbb{O}$
4. for all $i' \in \mathbb{J}$, if $\phi_i^O(\lambda^*) + c_i < \phi_{i'}^O(\lambda^*) + c_{i'}$, it follows that $\max\limits_{\lambda \in \mathbb{R}^T} \phi^E(\lambda) + \phi_i^O(\lambda) + c_i < \max\limits_{\lambda \in \mathbb{R}^T} \phi^E(\lambda) + \phi_{i'}^O(\lambda) + c_{i'}$ and therefore that the design i' is not optimal, set $\mathbb{J} \leftarrow \mathbb{J} \backslash \{i'\}$
5. if $\mathbb{J} \neq \{\varnothing\}$, choose $i \in \mathbb{J}$, set $\mathbb{J} \leftarrow \mathbb{J} \backslash \{i\}$, set $\lambda^0 \leftarrow \lambda^*$ and goto2
6. if $\mathbb{J} = \{\varnothing\}$, search for the best design in the list $\mathbb{O}$

In one numerical experiment with six different stock capacity, this algorithm entered step 2 only once, the other five designs were removed at step 4, which gives promising perspectives

Future works and extensions

Future works and extensions

- We modeled a hydrogen supply chain with three sources of energy
- We solved the optimal management of the Schiever supply chain with decomposition method involving two subproblems:
  - an operational problem solved by SDP
  - an electricity allocation problem solved by SDDP
- We proposed a simple algorithm to optimize the capacity of the hydrogen storage
- The next step will be to consider the design of the hydrogen equipments (storage and electrolyser) and the PPA contracts

Thanks for your attention

Any questions ?

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