Proposition de modèle économique pour l'approvisionnement d'un territoire en hydrogène décarboné

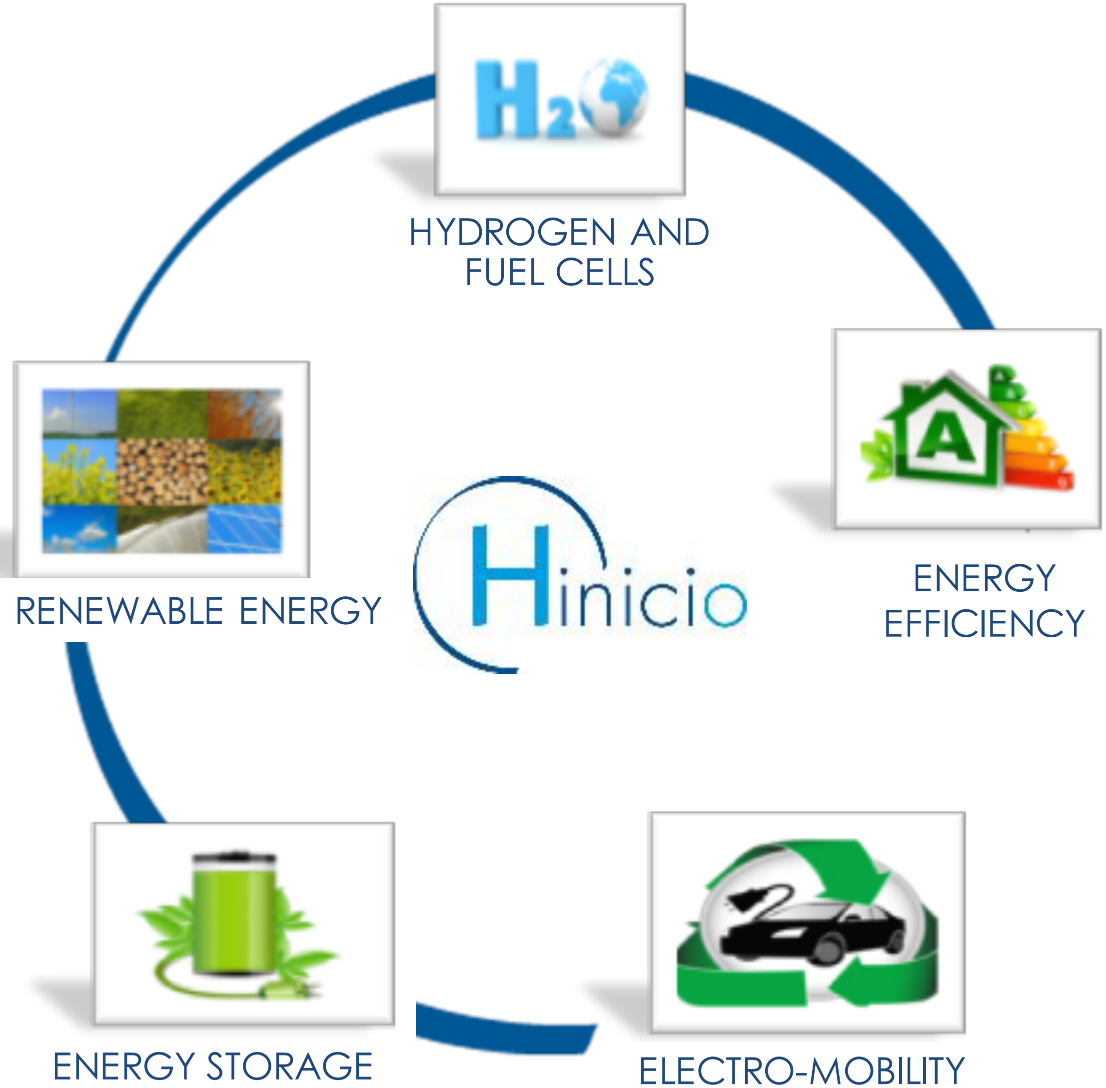
Journée organisée par l'AIM "stockage de l'électricité : réel bouleversement?

Liège, 5th Octobre 2016

Agenda

- Company presentation
- Introduction to Hydrogen
- A business case for Power to Hydrogen storage at regional (DSO connected) level to decarbonize transport
- Q&A

HINICIO in a nutshell



STRATEGY CONSULTANTS IN SUSTAINABLE ENERGY AND TRANSPORT

- Multidisciplinary approach and team:
  - Technology
  - Market/economics
  - Policy and regulation
- 3 offices:
  - Brussels (HQ)
  - Paris
  - Bogota
- Clients in more than 15 countries in Europe, Latin America and Asia

They trust us: Clients

PRIVATE SECTOR

- International companies
- Startups
- Investors
- Industrial associations

PUBLIC SECTOR

- International organisations
- European institutions
- Governments
- Public bodies

A short overview of references

Coordination for the elaboration of the French hydrogen and fuel cells roadmap

Definition of a strategic plan for the development the hydrogen and fuel cell sector for the Region of Rhône-Alpes

Definition of a regional roadmap for the development of hydrogen as an energy carrier with potential to address climate change.

Definition of a hydrogen roadmap in the Midi-Pyrénées Region and strategic support in view of the structuring of a dedicated technology platform

Hydrogen mobilty pilot project in the region of La Manche

A short overview of references

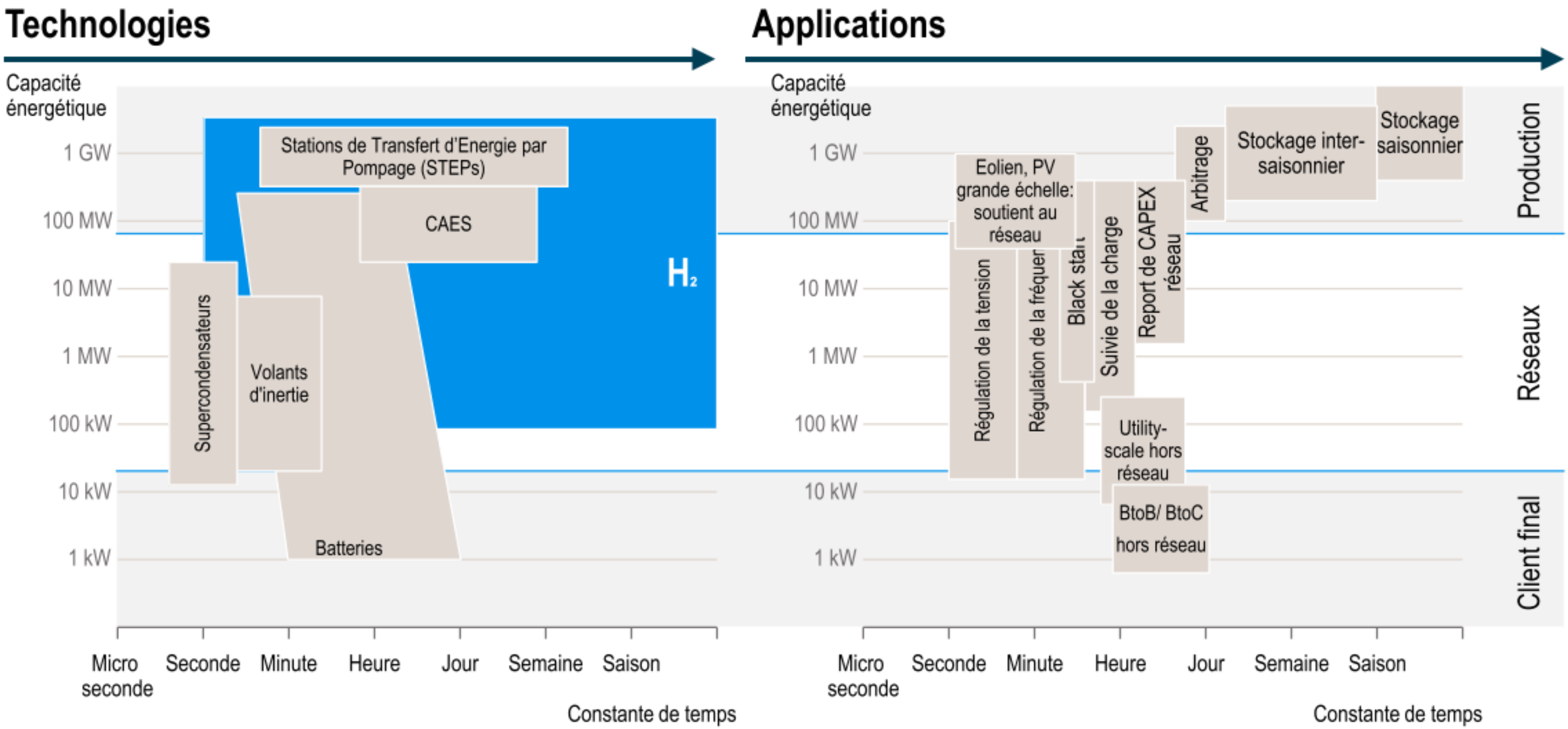
Grid impact analysis and assessment for increased penetration of renewable energy into the Jamaican Electricity Grid.

Developing a European wide Guarantee of Origin scheme for green hydrogen

Techno-economic and business case analysis for the use of hydrogen as a medium of storage for the distribution grid

Early business cases for H2 in Energy Storage and more broadly Power to H2 applications

H2 pops up as an energy carrier for storing renewables

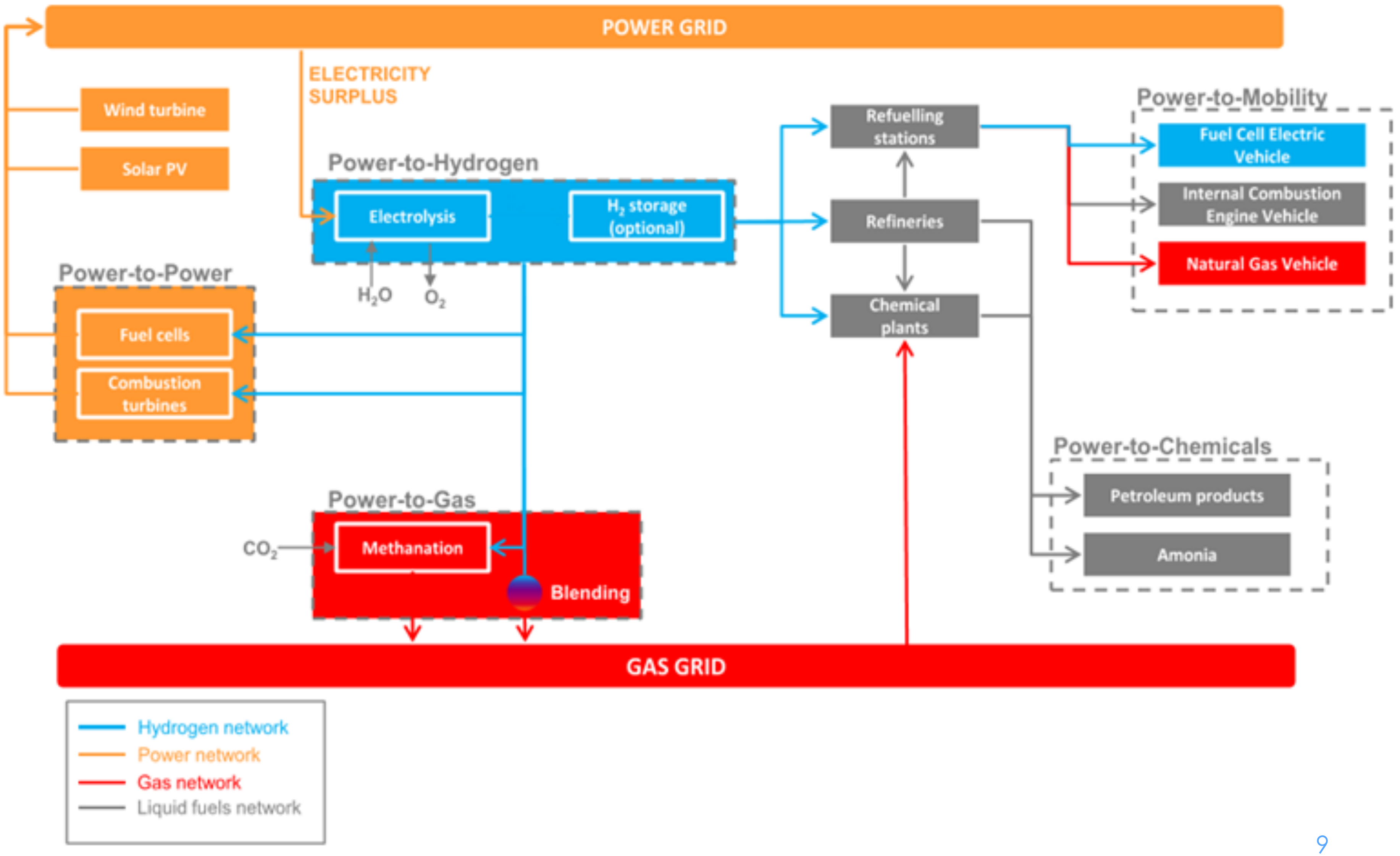


![Hinicio]

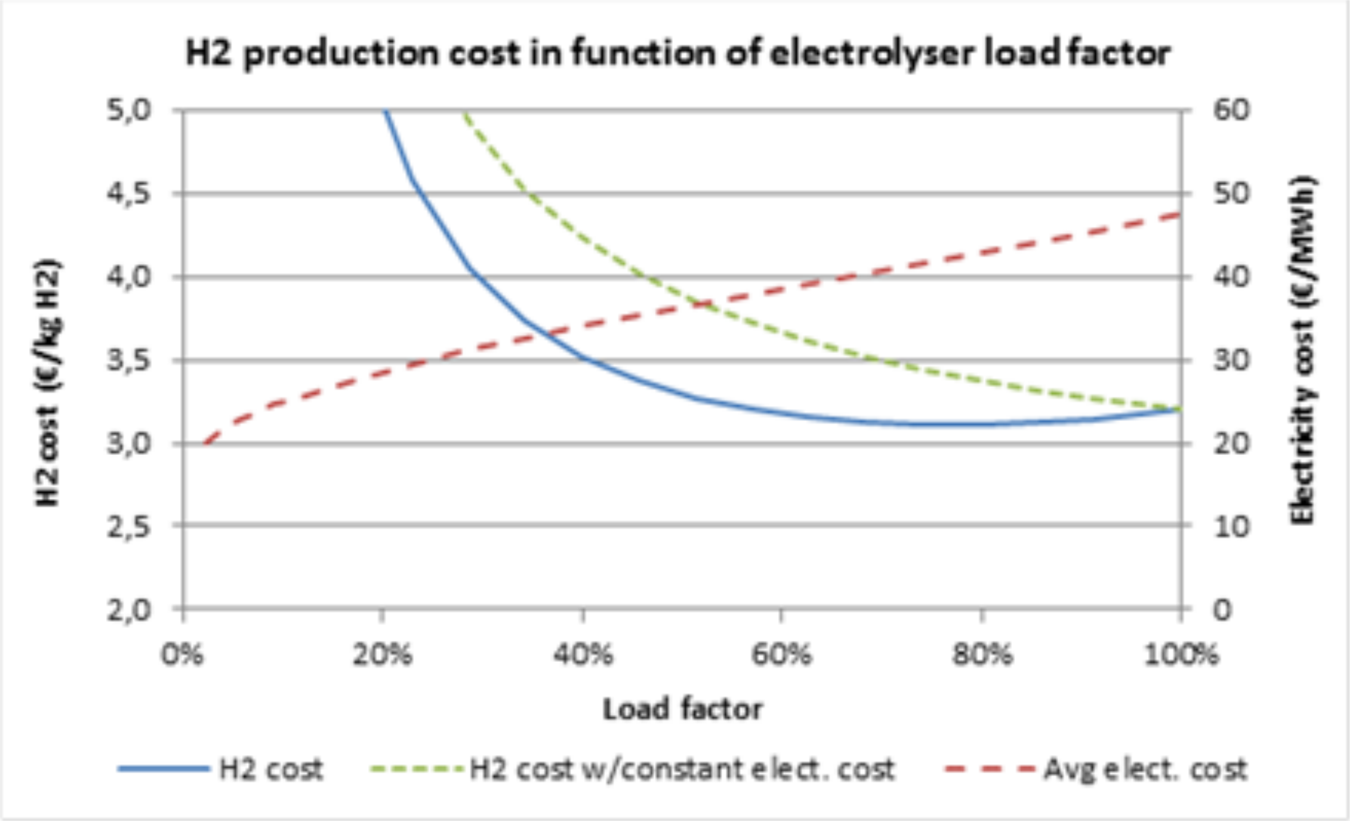
Worldwide H2 markets

INDUSTRY & MARKET SHARE	KEY APPLICATIONS	SUPPLY SYSTEM	H2 DEMAND per YEAR
 General Industry 1%	• Semiconductor • Propellant Fuel • Glass Production • Hydrogenation of Fats • Cooling of electrical Generators	• Small on-site • Tube trailers • Cylinders • Liquid H2	LOW >0.4 Mtons
 Metal Working 6%	• Iron Reduction • Blanketing gas • Forming gas	• Cylinders • Tube trailers	MEDIUM 2 Mtons
 Refining 30%	• Hydrocracking • Hydrotreating	• Pipeline • Large On-site	14 Mtons
 Chemical 63%	• Ammonia • Methanol • Polymers • Resins	• Pipeline • Large On-site	HIGH 29 Mtons

Definition of Power to Gas

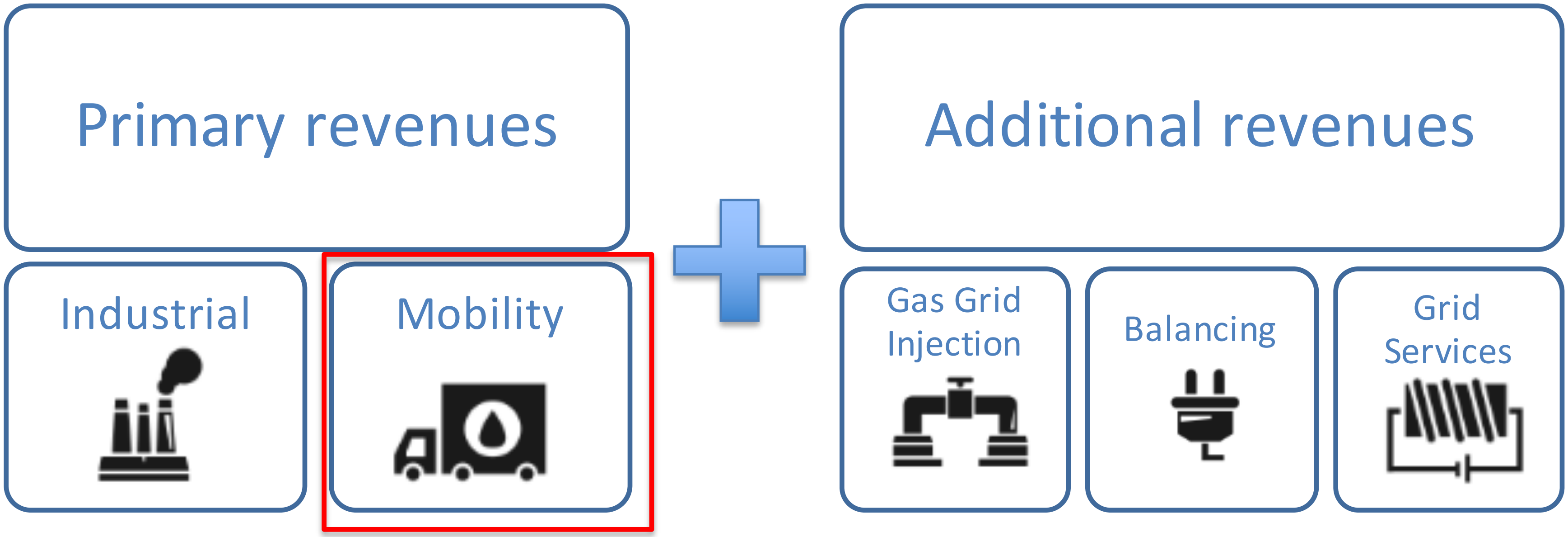


PEM electrolysis has interesting features for asset management

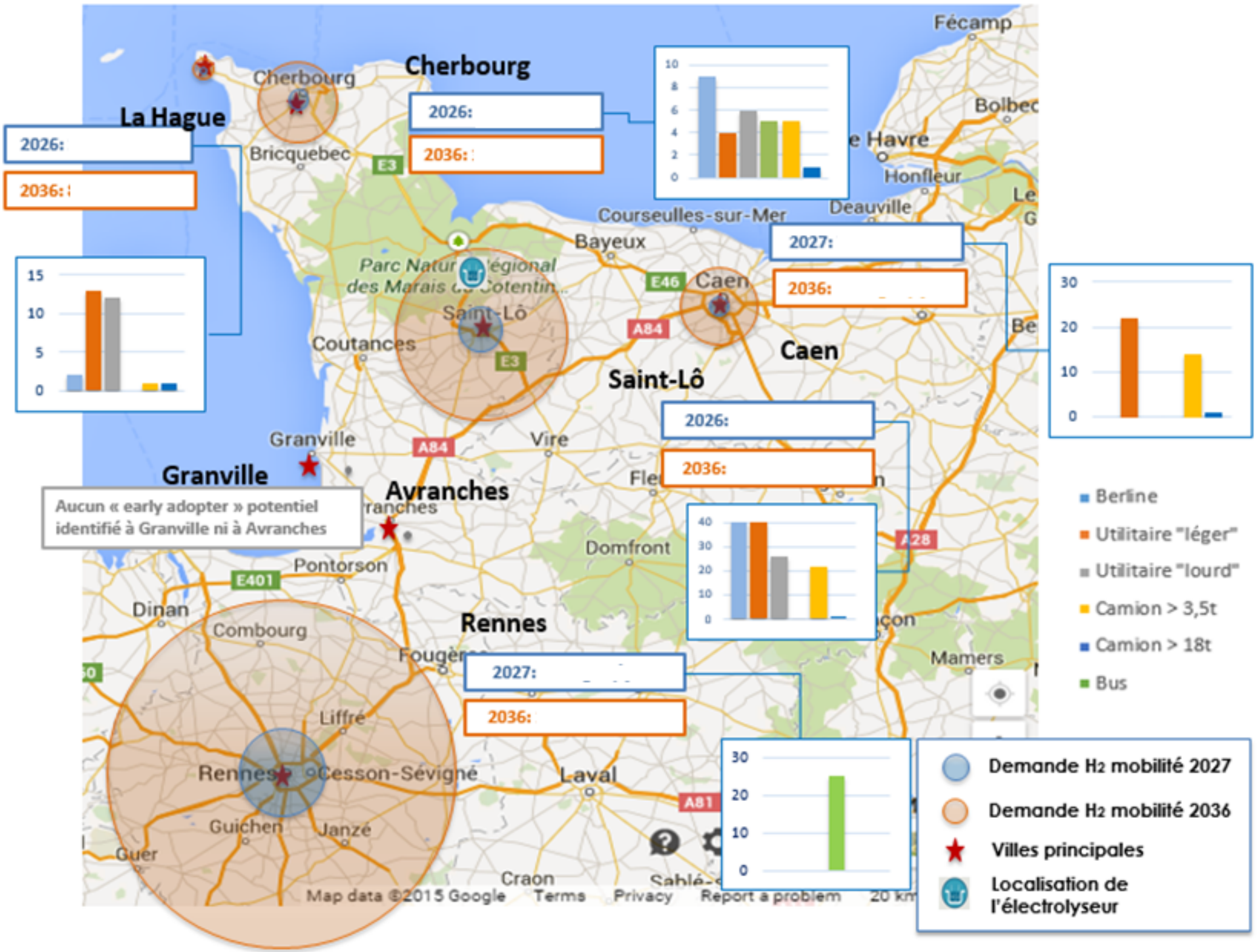


Total cost of hydrogen produced by a power-to-hydrogen system (source: Hinicio)

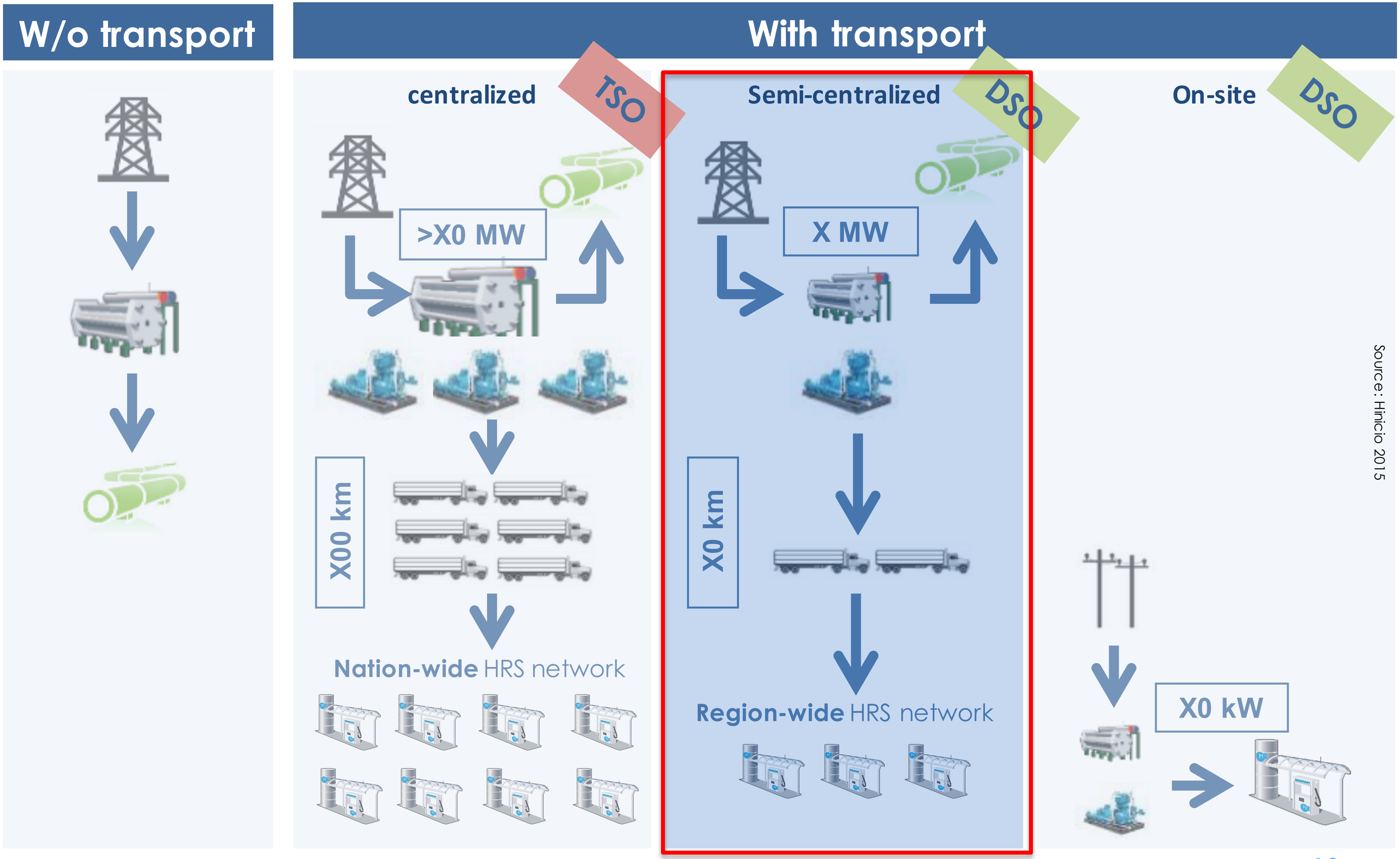
Revenue Streams within Power to Gas Projects



Mobility Demand on a regional level

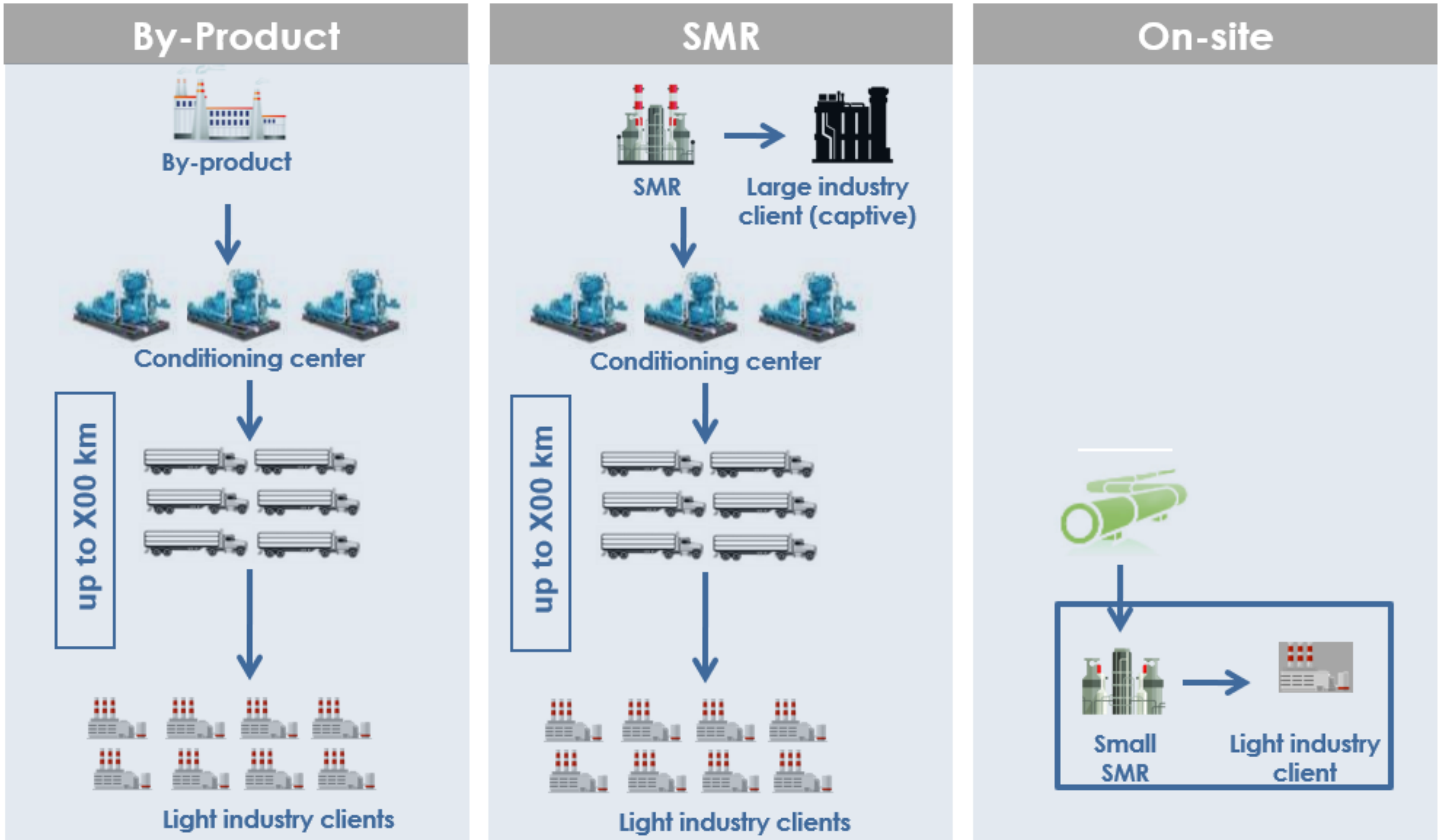


Novel techno-economic modelling of a semi-centralised hydrogen system



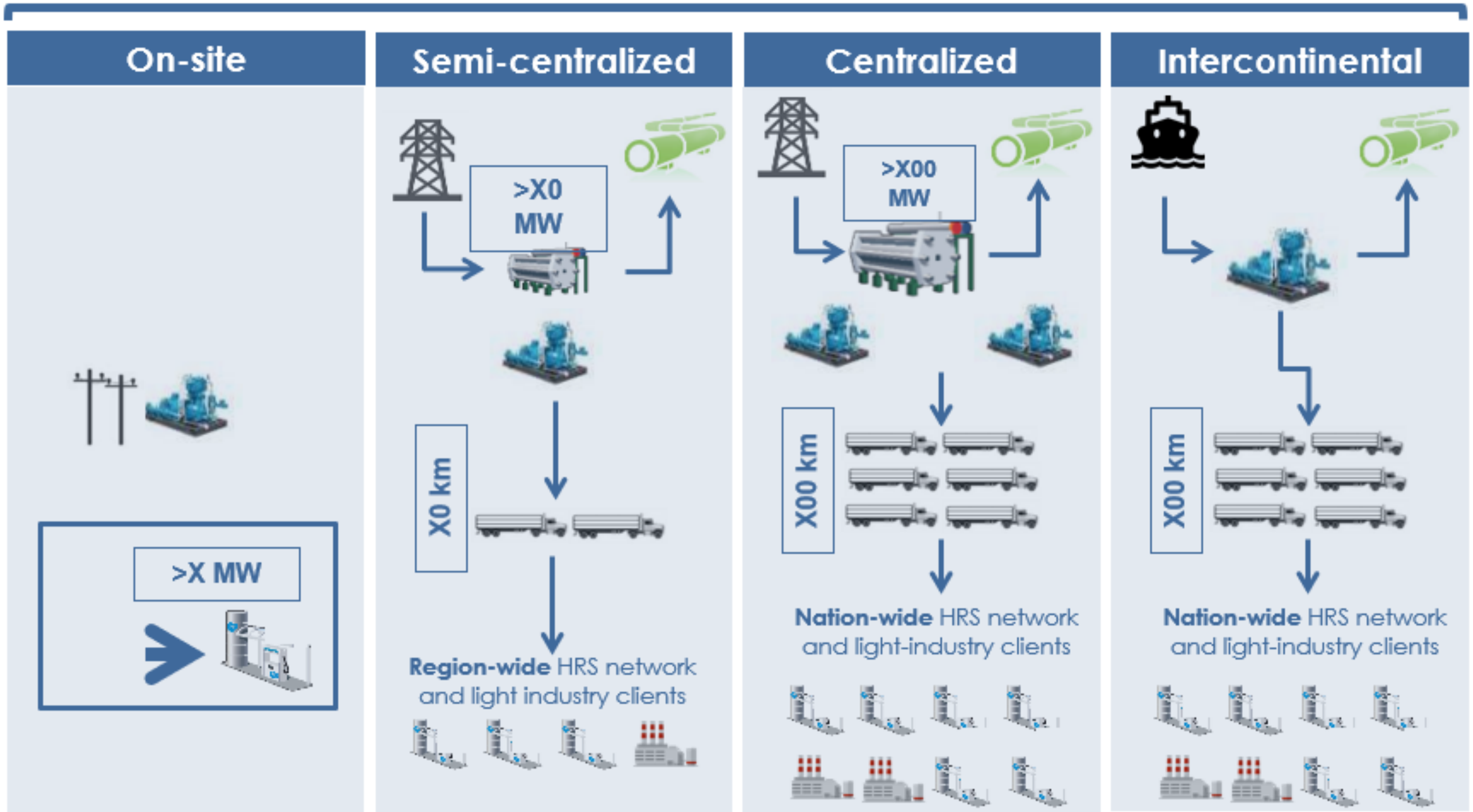
Source: Hinicio

Historic evolution of the hydrogen supply chain



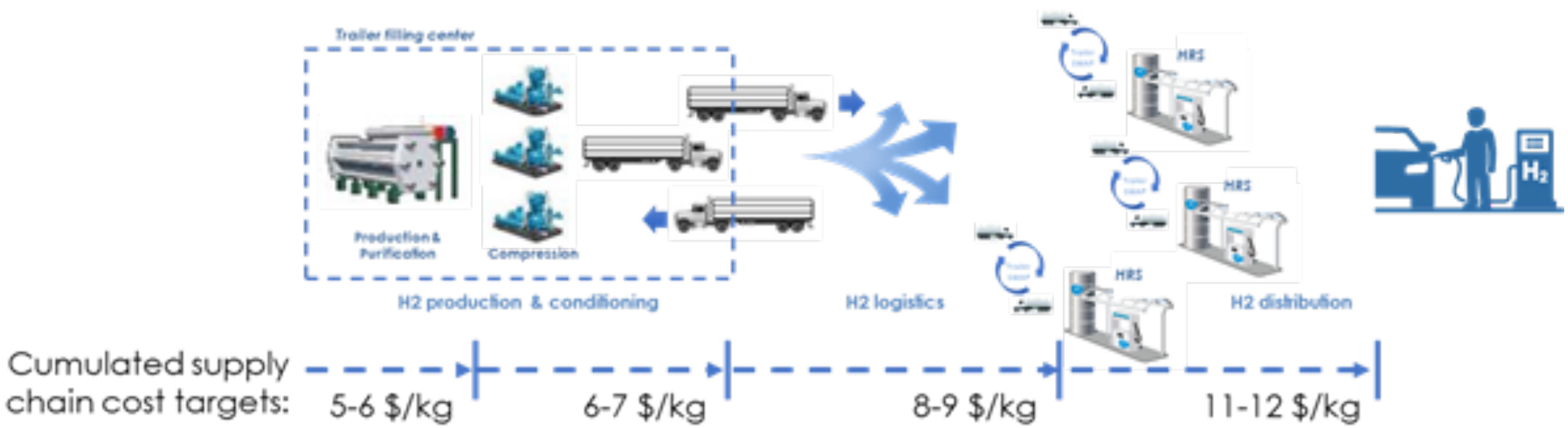
Source: Hinicio

Potential future ramp up pattern of the hydrogen supply chain.



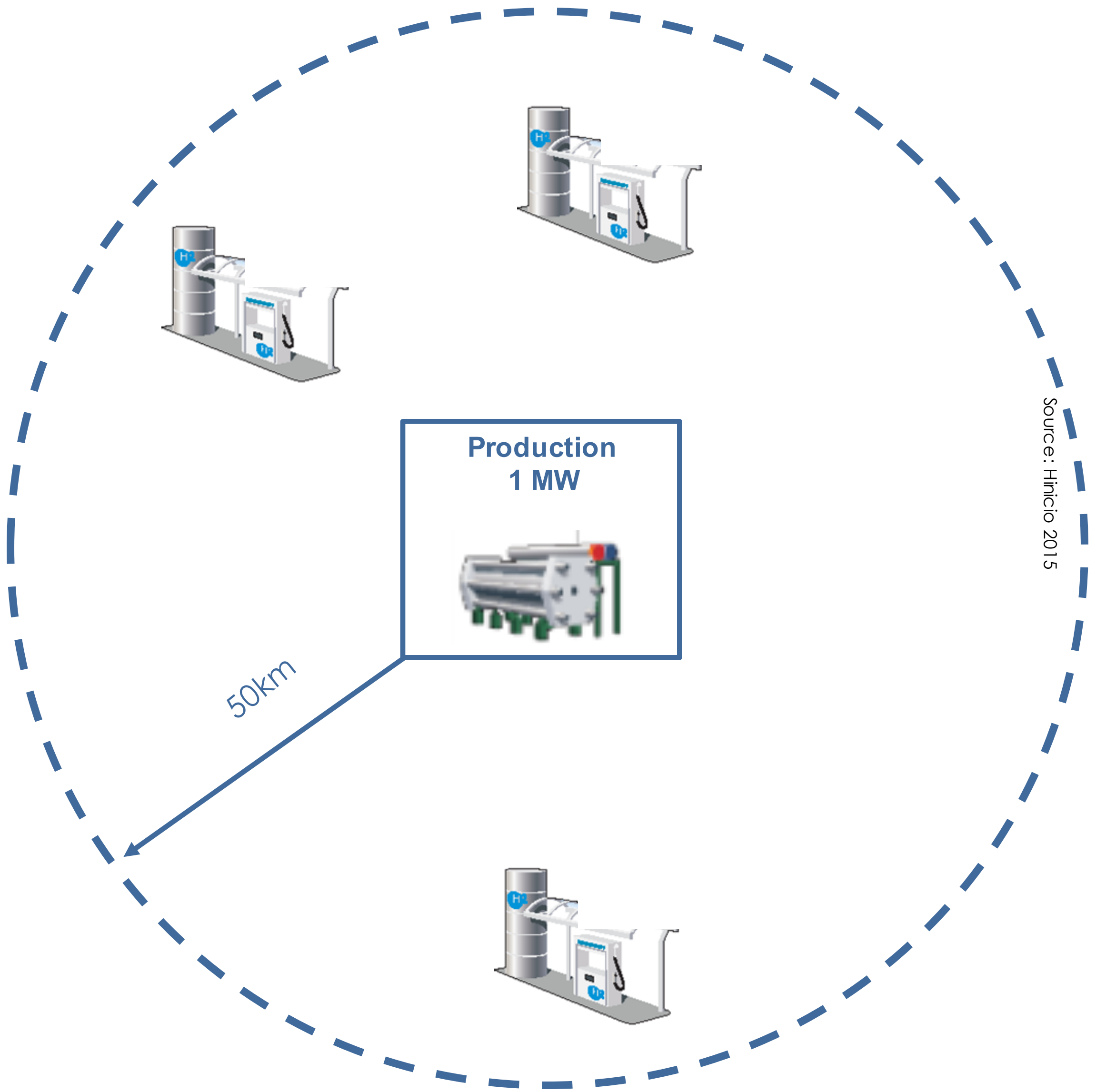
Source: Hinicio

Cummulated supply chain cost



Source: Hinicio

System dimensioning: starting from the demand



Main components of a semi-centralised Power-to-Gas system

kgH2 →

← €/kgH2

H2 production & conditioning

Production 1 MW

Conditioning

Storage and transport

Distribution

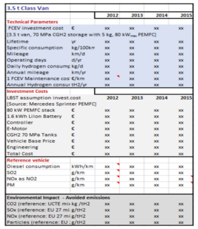
	H2 production & conditioning (Production 1 MW; Conditioning)	Storage and transport	Distribution	Consolidated Business Case
CAPEX	M€	M€	X	M€
OPEX	k€/yr	k€/yr	X	k€/yr
H2 cost €/kg	€/kg$_{H2}$	€/kg$_{H2}$	X	€/kg$_{H2}$
Revenues	-	-	X	k€/yr

Image: Hinicio

H2BCase by HINICIO: Dimensioning, optimizing and simulating your hydrogen supply chain

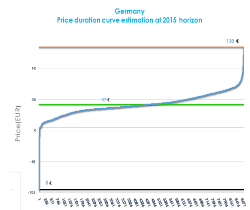
Techno-economic database of hydrogen technologies

- Production
- Conditioning
- Storage
- Logistics
- HRS
- Vehicles



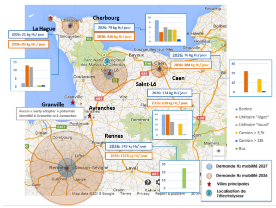
Energy markets

- Electricity spot price
- Balancing market
- Capacity market
- Natural gas market
- Carbon tax



Local data

- H2 Demand
- Gas grid
- Electricity grid
- Road access
- Distances



H2BCase

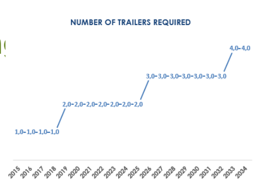
by Hinicio

All configurations

- centralised
- Semi-centralised
- On-site

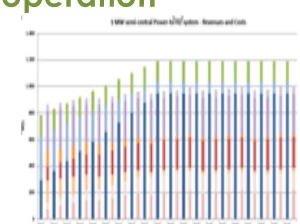
System sizing optimum

- Production
- Conditioning
- Storage
- Logistics
- HRS



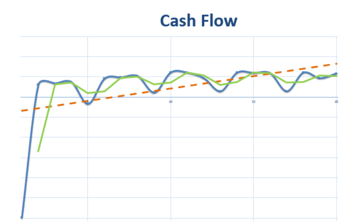
System operation

- Production
- Conditioning
- Storage
- Logistics
- HRS



Economics and finance

- CAPEX
- OPEX
- Revenues
- Cash flow
- IRR, NPV
- P&L



Images: Hinicio H2BCase model

14 scenarios assessed: France Vs Germany, 2015 Vs 2030

Scenario Nbr	1 (Ref)	2	3	4	5	6	7	8	9	10	11	12	13	14
Country	France		Germany											
Year of electrolyser commissioning	2015			2020	2030						2030		2030	
Initial/Final H2 Mobility demand (kg/d)	100/325 (50+50 / 140+185)	100/163 (50+50/(70+93)					No H2 mobility sales		100/163				200/650	
Electricity price duration curve or cost	France 2014		Germ. 2014	Germ. 2020	Germ. 2030					26% of wind el. Cost France	100% of wind el. cost France	17% of wind el. Cost Germ.	100% of wind el. cost France	
Grid charge	France 2015		Germany 2015 rates											
CSPE (€/MWh)	Electr.-int. 0.5					19.5								
H2 injection (€/MWh)	90 (FIT)				55,8			No inject.	No inject		55,8		55,8	
Electrolyser capex (M €/ MW)	1,9				0,55						0,55		0,55	
Electrolyser efficiency/stack lifetime	66%/4y				75%/10y						75%/10y		75%/10y	
Public subsidy on investment costs														25%

Scenario 1 - Reference - Assumptions

Scenario Nbr	1 (Ref)
Country	France
Year of electrolyser commissioning	2015
Initial/Final H2 Mobility demand (kg/d)	100/325
Electricity price duration curve	France 2014
Grid charge	France 2015 rates
CSPE (€/MWh)	Electro-int. 0.5
H2 injection price (€/MWh)	90 (FIT)
Electrolyser capex (M €/ MW)	1,9
Electrolyser efficiency/stack lifetime	66%/4y

Table: Hinicio

- **H2Mobility market** consumes **1/3 of electrolyser capacity in year 1** (1MW electrolyser – 100 kg/day – **100 FCEV/REX or 4 busses**) and increases to full electrolyser capacity in year 10.
- Electrolyser plant considered to be benefiting from **"electro intensif" regime** (low grid / tax fees).
- Available capacity permitting, **H2 is produced for injection into the Gas Grid** when **marginal costs of H2 production are lower than Feed-In-Tariff (assuming €90/ MWh)** to achieve increase revenue streams during market take-off phase of FCEV.
- No charges applied to the electricity consumed for producing the hydrogen injected into the gas grid

Representation of results per Scenario (1)

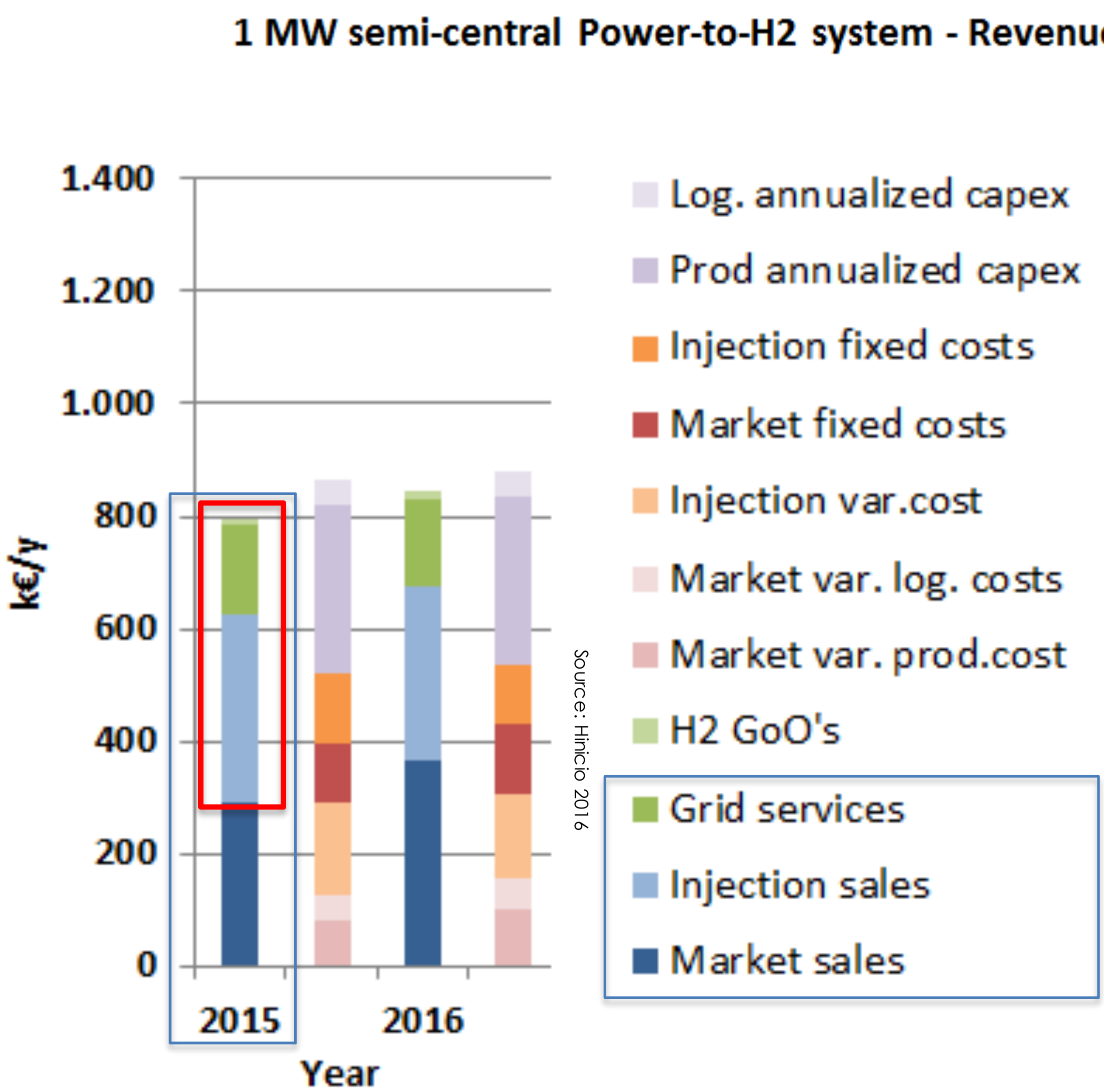


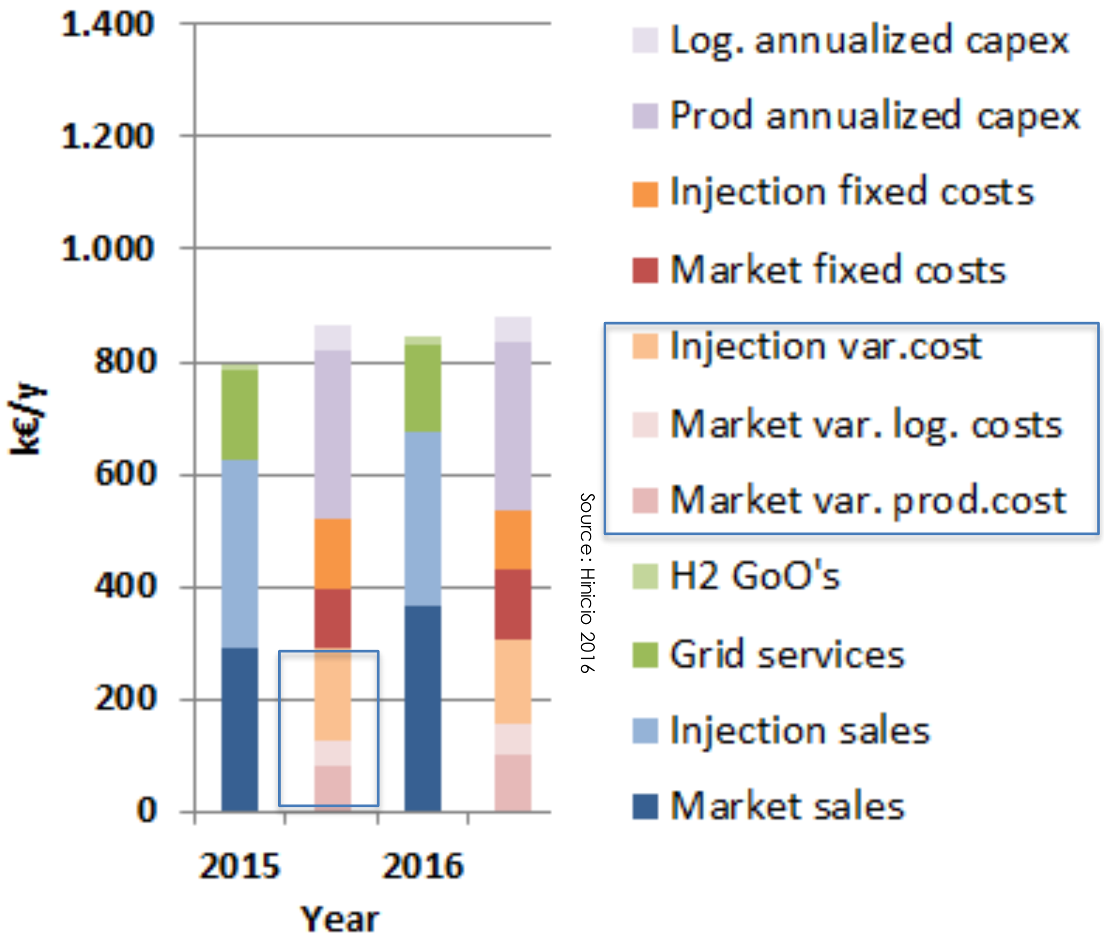
Figure: Hinicio, H2BCase Model

<u>Revenues:</u>

1. H2Mobility: €8 / kg @ 200 bar @ HRS
2. H2 injected @FIT: €90/MWh
3. Primary reserve: €18/MW/h

Representation of Results per Scenario (2)

1 MW semi-central Power-to-H2 system - Revenues and Costs (CAPEX depreciated)



Variable Costs:

1. H2Mobility: variable Electricity costs & water costs
2. H2Mobility: variable cost of trailer transport (€1/km and €45/hr)
3. Injection: variable electricity costs & water costs

Figure: Hinicio, H2BCase Model

Representation of results per Scenario (3)

1 MW semi-central Power-to-H2 system - Revenues and Costs (CAPEX depreciated)

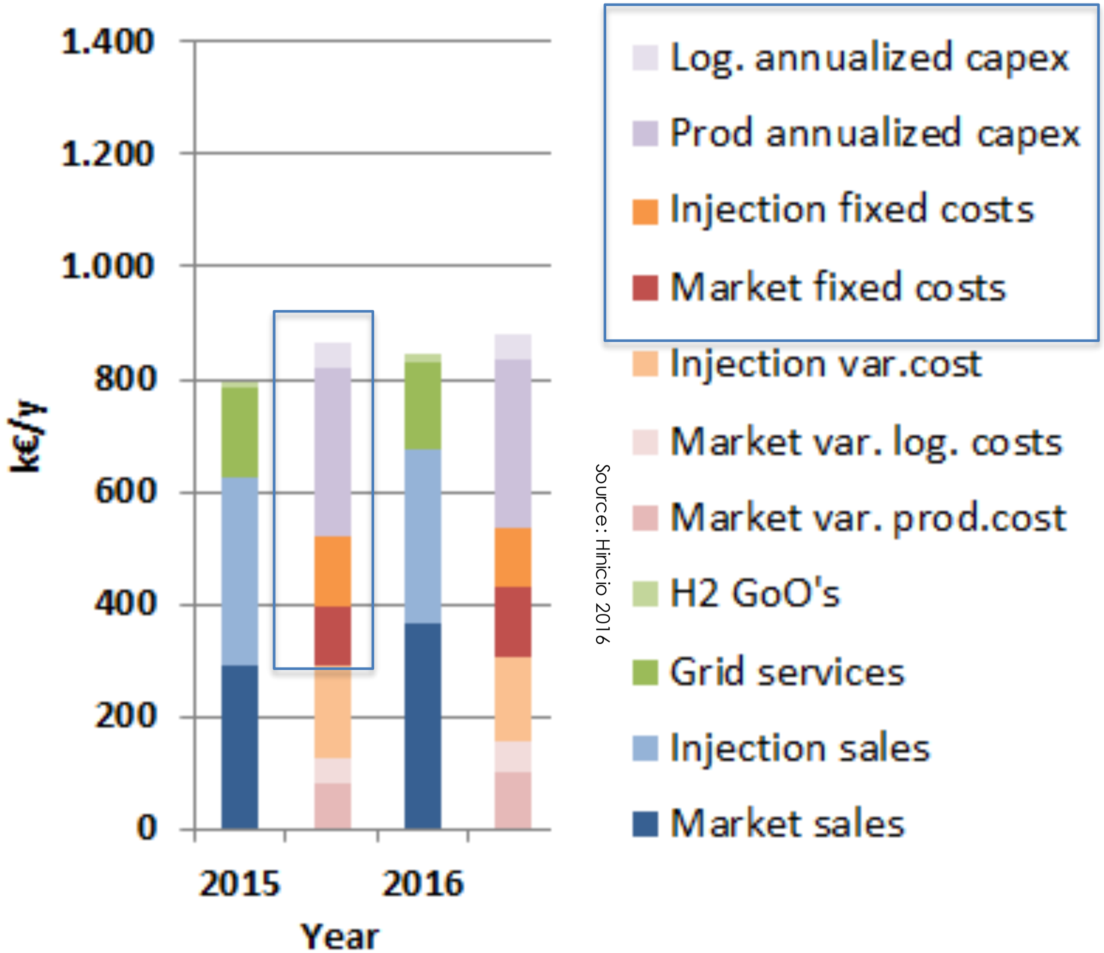
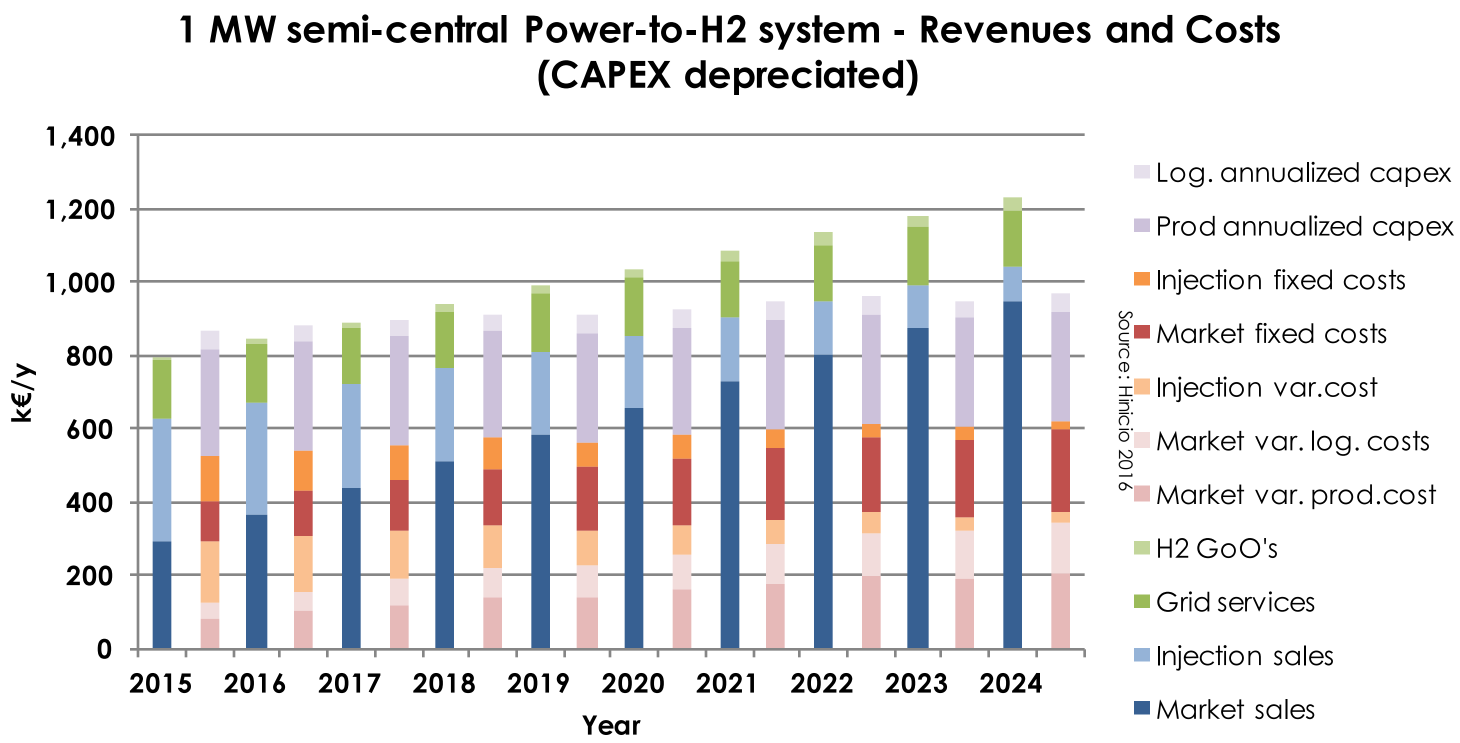


Figure: Hinicio, H2BCase Model

<u>Fixed Costs:</u>

1. H2 Mobility: electrolyser O&M (3% +3% of CAPEX) & Fixed part of Grid fee & Trailer & Storage @ HRS O&M
2. Injection: Electrolyser O&M (3% +3% of CAPEX) & Fixed part of Grid fee
3. Depreciation of Electrolyser + Stack Replacement + Compressor & Injection Skid
4. Depreciations of Trailer & Storage @ HRS

Scenario 1 - Reference - Results



IRR = 0% (10y)

Payback = 10 years

➔ **Injection into the Gas Grid and System Services complements revenue streams** during "valley of death" of FCEV market.

➔ **Its contribution to margin decreases** as hydrogen mobility market takes off.

Figure: Hinicio, H2BCase Model

France 2015 – Higher H2 Mobility demand from year 1

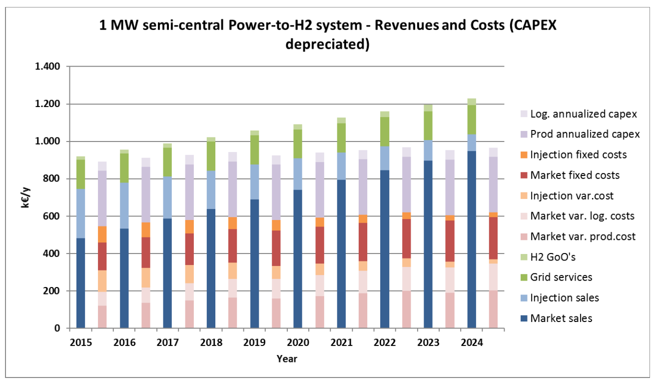
Parameter	1 - Ref
Country	France
Year of electrolyser commissioning	2015
Initial/Final H2 Mobility demand (kg/d)	100/325
Electricity price duration curve or cost	France 2014
Grid charge	France 2015
CSPE (€/MWh)	Electr.-int. 0.5
H2 injection price (€/MWh)	90 (FIT)
Electrolyser capex (M €/ MW)	1,9
Electrolyser efficiency/stack lifetime	66%/4y

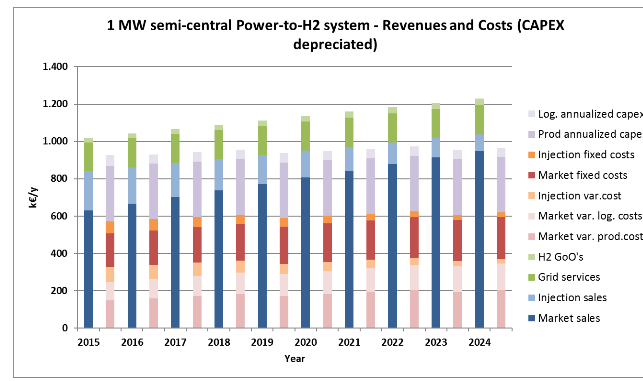
Table: Hinicio

- **H2Mobility market consumes 1/2 and 2/3** (instead of 1/3 base scenario) **of electrolyser capacity in year 1** (1MW electrolyser – 165 and 216 kg/day – **165/216 FCEV/REX or 6/8 busses**) and increases to full electrolyser capacity in year 10.

Demand year 1: 165 kg/d

Demand year 1: 216 kg/d





IRR = 3%

Payback = 9 years

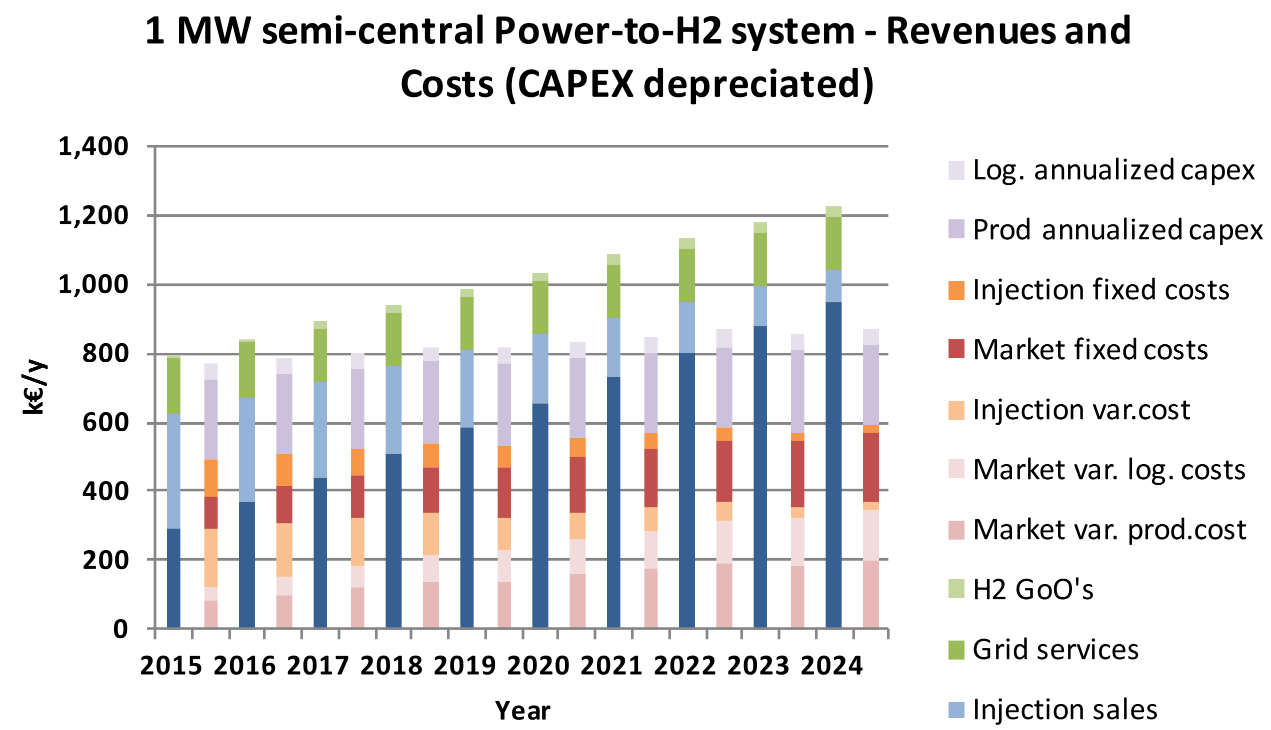
IRR = 6%

Payback = 8 years

France 2015 - With public subsidies (14)

Parameter	1 - Ref
Country	France
Year of electrolyser commissioning	2015
Initial/Final H2 Mobility demand (kg/d)	100/325
Electricity price duration curve or cost	France 2014
Grid charge	France 2015
CSPE (€/MWh)	Electr.-int. 0.5
H2 injection price (€/MWh)	90 (FIT)
Electrolyser capex (M €/ MW)	1,9
Electrolyser efficiency/stack lifetime	66%/4y

Table: Hinicio



IRR = 7%

Payback = 7 years

+ Public subsidy of 26% of CAPEX

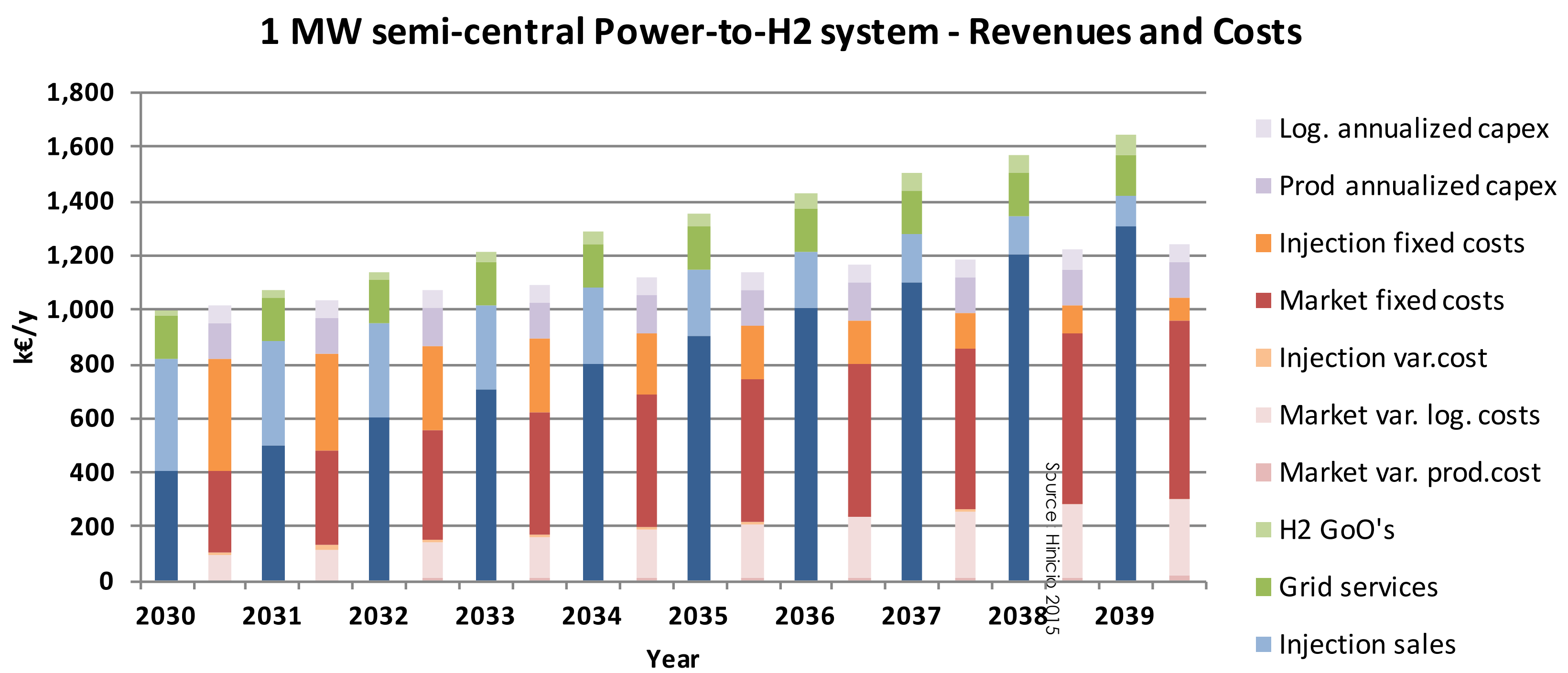
France 2030 - Assumptions

Parameter	1 - Ref	13
Country	France	
Year of electrolyser commissioning	2015	2030
Initial/Final H2 Mobility demand (kg/d)	100/325	200/325
Electricity price duration curve or cost	France 2014	wind el. cost France
Grid charge	France 2015	
CSPE (€/MWh)	Electr.-int. 0.5	
H2 injection price (€/MWh)	90 (FIT)	55.8
Electrolyser capex (M €/ MW)	1,9	0.55
Electrolyser efficiency/stack lifetime	66%/4y	75%/ 10y

- Electrolyser technology costs of 2030
- Securing 2/3 of maximum electrolyser capacity from the start
- Upfront purchase of the production of renewable generation capacity at projected full cost (Eur 60 / MWh, cfr ADEME projections)
- Caloric Value of H2 ~ Natural Gas (37.8 €/MWh cfr: IEA, nouveau mix 2030) + Carbon tax of 90€/t CO2

Table: Hinicio

Scenario 13 – France 2030 - Results



IRR = 7% (10y)

Payback = 7 years

Figure: Hinicio, H2BCase Model

Conclusion: **There is a potential business case for Power-to-Gas**

- From a technical standpoint, **Power-to-Gas is one promising option in our portfolio towards the energy transition** in order to simultaneously integrate more intermittent renewables and decarbonize road transport **thanks to responsiveness of the PEM electrolysis technology**

- From an economic standpoint, **Power-to-Gas appears as a credible option in the mid-to-long term** for the supply of low carbon hydrogen at the local level in low electricity marginal cost environments. **The business case could potentially fly with no public support if** an adequate (and long expected…) carbon pricing environment is put in place and regulatory barriers are dealt with **to allow injection into the gas grid and participate in system services and balancing.**

Key challenges and enabling measures for Power-to-Hydrogen.

	Electricity system	Green H_2 production	Conditioning and logistics	Distribution	End use
Key Challenges	Electricity prices				Transport - Initial high costs and low volumes - Investment and technology risk perception
	Difficulty to monetize electrolyser flexibility				Industry - High green hydrogen price vs. fossil-based hydrogen
		Technology scale-up			Injection into natural gas grid - Hydrogen cost vs. natural gas - Blending limits (technical)
Enabling measures	Facilitate access to low-cost renewable electricity	Promote market uptake de-risking/insurance instruments ("take or pay")			Transport -Market pull regulations (zero-emission zones, emissions standards, etc.) -Market push instruments (CAPEX subsidy, tax rebates…)
	Partial exemptions from regular grid fees for electrolysers*				Industry -Carbon pricing -Sectorial mandates (emissions, RE content, etc.)
	Partial exemptions of grid charges, taxes and levies for electrolysers*				Injection into natural gas grid - Feed-in tariff - Carbon pricing - Harmonized blending limits
	Create a level playing field for flexibility services to unlock access for electrolysers				

*Provided that they run in system-beneficial mode

Source: Hinicio

Conclusion: **There is a potential business case for Power-to-Gas**

- From a technical standpoint, **Power-to-Gas is one promising option in our portfolio towards the energy transition** in order to simultaneously integrate more intermittent renewables and decarbonize road transport.

- From an economic standpoint, **Power-to-Gas appears as a credible option in the mid-to-long term** for the supply of low carbon hydrogen at the local level in low electricity marginal cost environments. **The business case could potentially fly with no public support** if an adequate (and long expected…) carbon pricing environment is put in place.

- **In the short-term, industry-compatible profitability levels could be achieved** with a reasonable amount of public money.

- **Power-to-Gas is a demand-driven business model.** It will only fly if the sales of a big bulk of production can be contractually secured from day one with local customers.

- **Innovative financing mechanisms** (insurance, guarantees…) are required to mitigate the risk of demand projections not materializing. **"Take-or-pay" is the name of the game**: we need **public banks** to take on that risk (BPI, CDC…).

- **France is a good place to start** : electricity is cheap and the tax regime is rather favorable. A number of regulatory barriers remain to be addressed though: FIT for hydrogen injection, access to ancillary services markets, grid charges and tax fees, etc.

Acknowledgment

This presentation builds on the results of the study *"Short term and long term opportunities to leverage synergies between the electricity and transport sectors through power-to-hydrogen"*

HINICIO and LBST would like to thank ***Fondation Tuck*** for supporting this study under its ***The Future of Energy*** programme

Q & A

Your knowledge partner on sustainable energy and transport

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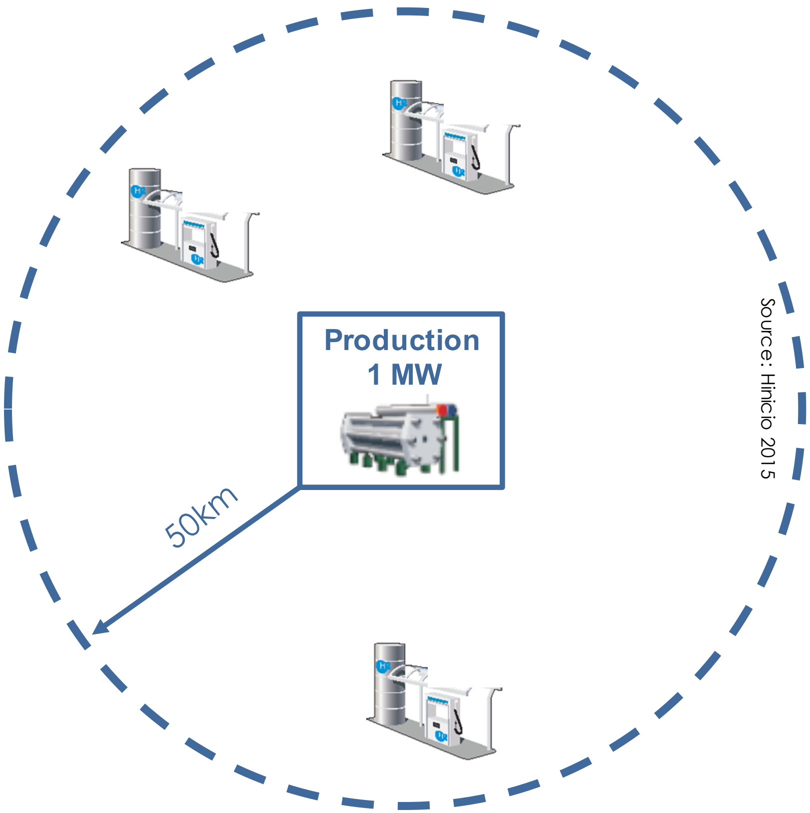
Comparing electrolyser technologies

	Alkaline	PEM
Development stage	**Industrial since 1920s**	**Early stage commercialization**
Maximum capacity	**Unit : 3.8 MW/67,7 kg/h** **Plant : 100 MW/1900 kg/h** (Zimbabwe)	**6 MW/ 120 kg/h** (3 x 2 MW pilot unit)
Current density	**Up to 0.4 A/cm^2**	**Up to 2 A/cm^2** (R&D: 3.2 A cm^{-2} at 1.8 V at 90°C)
Dynamic response	**Less than one minute**	**Within seconds**
Peak load	**100%**	**200% (30 min)**
Turn down	**20 – 40 %**	**<10 %**
Operating pressure (typical)	**A few bars**	**Tens of bars**
Investment costs	**1.1 M€/MW***	**1.9 M€/MW***
Operating cost	**5 - 7 %**	**4 %**

*Includes installation and balance of plant costs

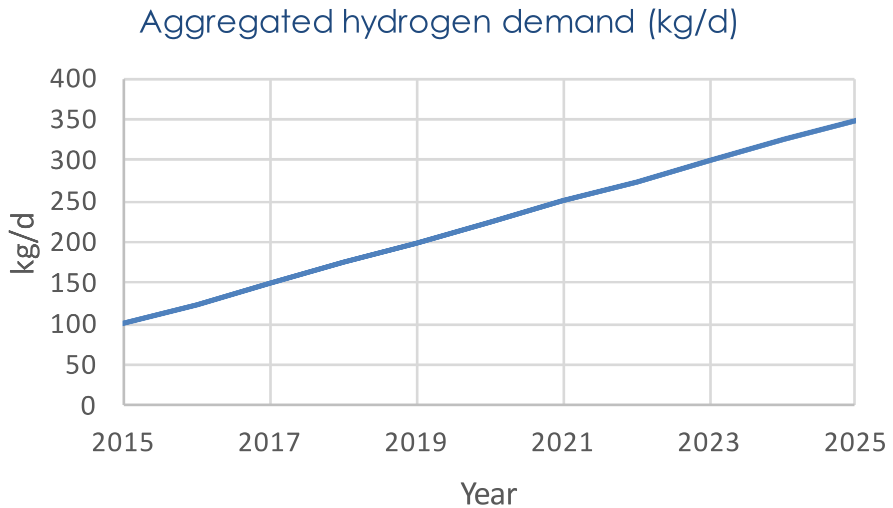
System dimensioning: starting from the demand



Electrolyser dimensioning and location

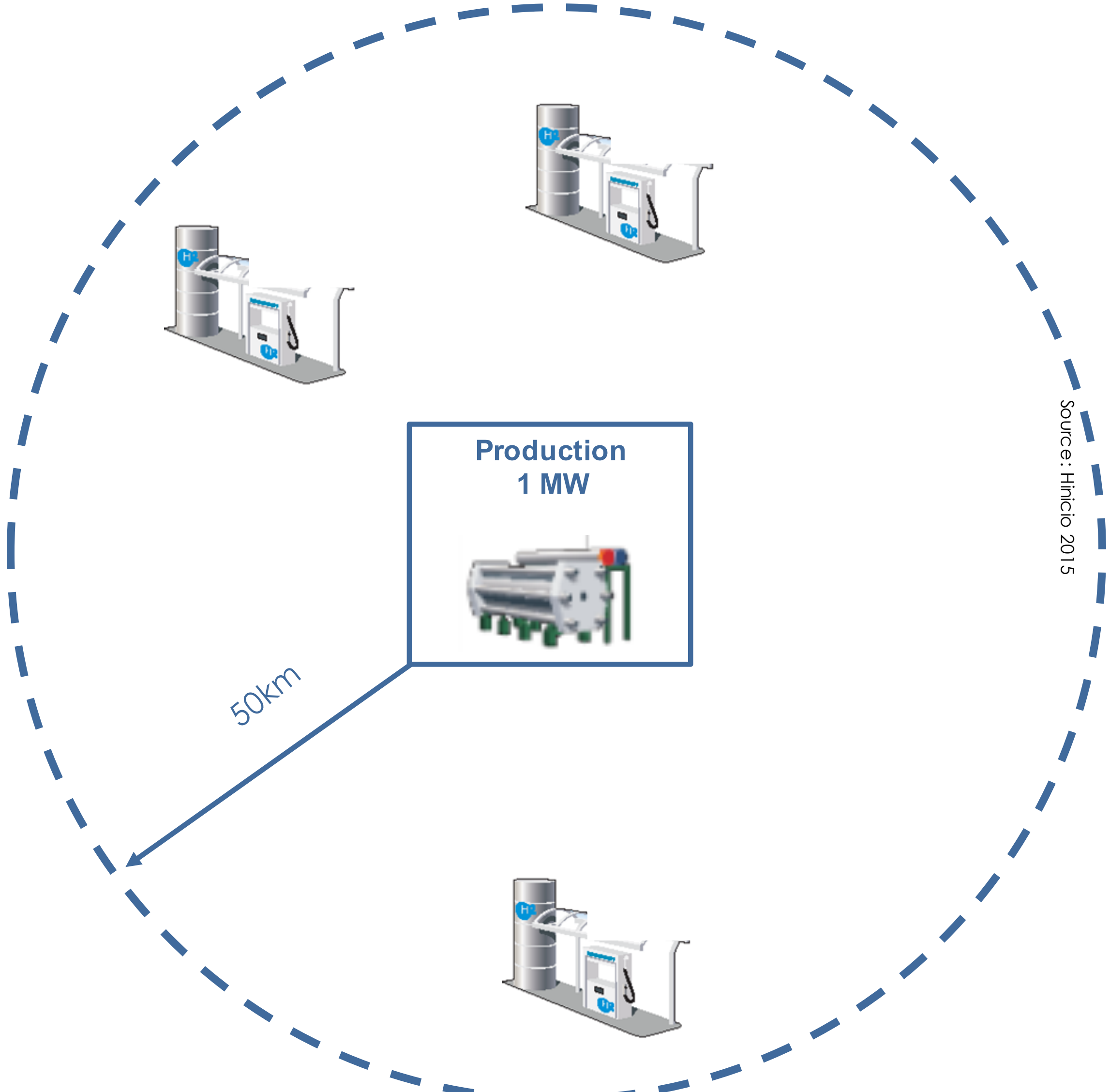
- Dimensioning:
Hypothetical demand of **325 kg/day** requiring a **1 MW** of electrolysers capacity

- Location:
The electrolyser is located where its makes most sense with regards to **interfacing with the power and natural gas grid, operations and logistics.**



Image& figures: Hinicio

System dimensioning: starting from the demand



System dimensioning: costs and revenues of the electolyser and conditioning center

CAPEX

1 MW electrolyser including conditioning and trailer filling center and grid injection skid:

- 2015: 2.5 M€
- 2030: 1.2 M€

OPEX

- Electricity costs
  - Spot market price/Energy purchase price
  - Grid charges and other fees
  - Grid charge exemption for electricity used for injection of H2
- O&M : 6% CAPEX/year

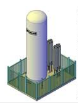
REVENUES

- H2 injection: 90 €/MWh
- Primary/ secondary reserve payments: 18 €/MW/h

Image: Hinicio, H2BCase model

System dimensioning: Hydrogen storage and distribution system

How to dimension hydrogen logistics and storage?

- Size of storage @ HRS 
- Size of trailers 
- Number of trailers

3-step dimensioning method

1 The HRS storage is sized according to the specific cost of delivery vs. the specific cost storage capacity (€/kg): **delivery every 3 to 4 days at full capacity.**

2 The trailer capacity is chosen in order to have a **filling time of less than one day** from the electrolyser.

3 The number of trailers needed in the supply chain is determined based on **time to refill vs total hydrogen consumption.**

One 200 kg trailer is sufficient for initial volumes, 3 trailers when full electrolyser capacity is reached.

System dimensioning: costs of logistics and storage

Storage and transport

CAPEX

- CAPEX trailer * N_trailers
- N_supply-chain fleet = Rotation time * Demand / Trailer cap.
- **CAPEX 200 kg trailer: 125k€**

OPEX

N_delivery X Cost of delivery

- Delivery cost:
  - 45 €/h
  - 1.0 €/km
- N_delivery = Consumption / Effective capacity

REVENUES

- H2 sales: **8€/kgH2** (delivered from the electrolyser to the hydrogen refueling stations at 200 bar)

Image: Hinicio, H2BCase model

PtG can build on a more favorable electricity tax regime in France

	FRANCE	GERMANY
GRID ACCESS	€ 18 / MWh	€ 0 / MWh (electro-intensive)
RENEWABLE ENERGY CHARGE	€ 0.5 / MWh (electro-intensive)	€ 70* / MWh
TOTAL	✔ € 19.5 / MWh	✘ € 70 / MWh

* Agglomerated average cost including the concession fees and appropriations

Table: Hinicio & LBST