Les défis technologiques de la filière hydrogène

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IMPLICATIONS PROJETS HYDROGÈNE

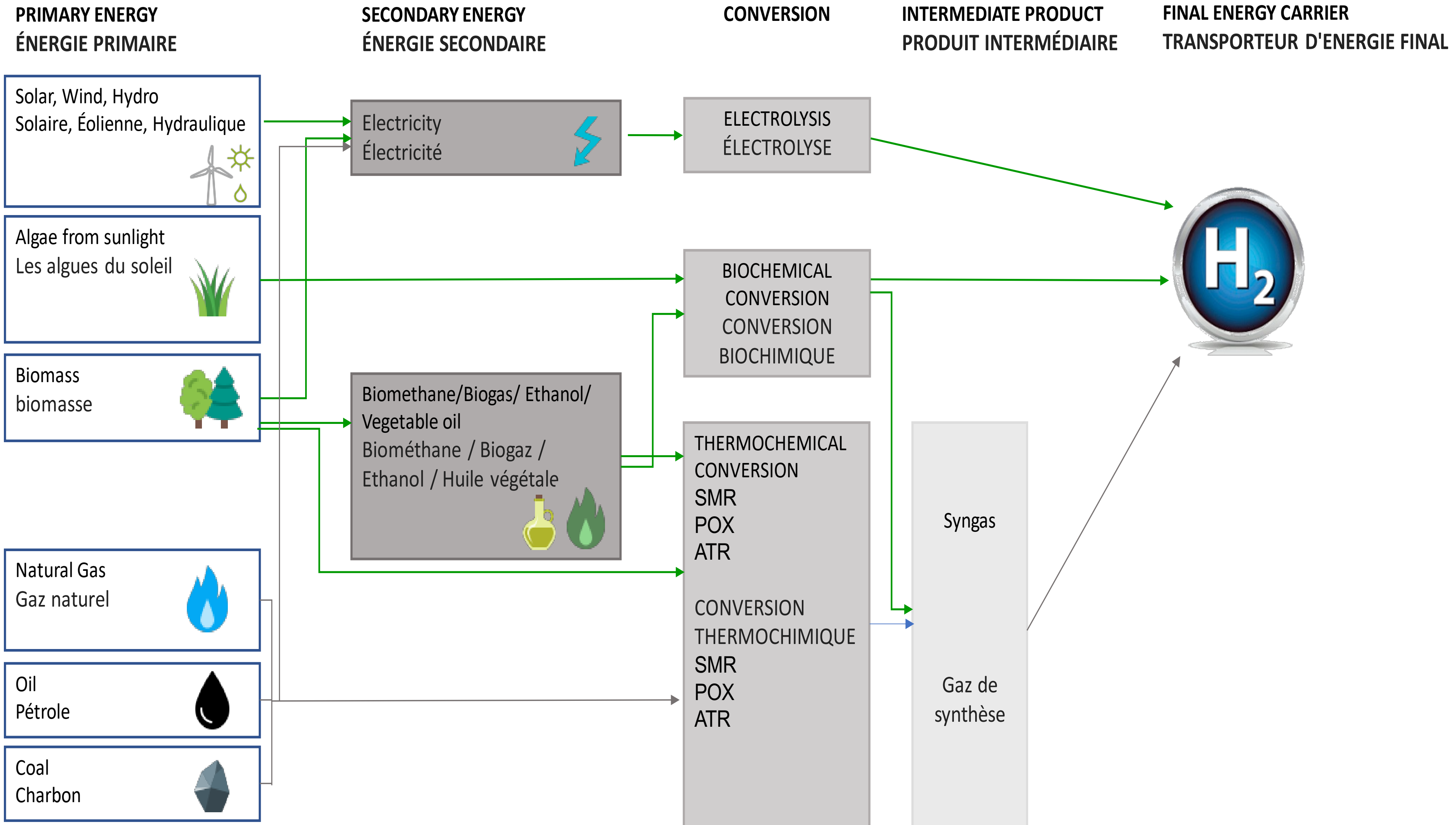
- Route Map du Québec;
- Production d'hydrogène à partir de la biomasse, déchets et gaz naturel (gazéification, pyrolyse…);
- Stockage d'hydrogène sous forme de liquide chimique (Ammoniac, MCH-Toluène);
- Réactions chimiques avec l'hydrogène:
  - Production ammoniac (Micro-ondes, Chemical Looping);
  - Avec CO2 pour Méthanol (avec la compagnie Total);
  - Différentes hydrogénations dans des réacteurs multiphasiques.
- CCS-CCU

LES DÉFIS TECHNOLOGIQUES DE LA FILIÈRE HYDROGÈNE

- Différentes méthodes de production: Gris-Bleu-Vert
- Les coûts de production
- Différentes méthodes de transport;
- Les coûts de transport
- Différentes utilisations
- Chimie verte: d'où provient le "C"
- CCS/CCU: quelques vérités

H_2: il faut le produire (1), le stocker et le transporter (2) et faire quelque chose avec(3)!

1. PROCESSES FOR PRODUCING HYDROGEN AND HYDROGEN BASED PRODUCTS



1. COST AND PERFORMANCE CHARACTERISTICS OF VARIOUS H2 PRODUCTION PATHWAYS AS OF 2019

Process	Status of Technology	Efficiency [%]	Costs Relative to SMR	GHG emission
Steam methane reforming (SMR)	Mature	70-80	1	High due to use of natural gas as feedstock
Water electrolysis	Mature	60-80	2.4-3.4	Zero emission using hydroelectricity or other renewable source
Biomass gasification	R&D	30-40	1.2-4	Neutral CO_2
Biomass pyrolysis	Mature	35-50	1.24-3	Neutral CO_2
Biogas conventional reforming	Mature		--	Neutral CO_2
Biogas catalytic membrane reactor	Early R&D	45%	--	Neutral CO_2
Biochemical conversion of biomass to hydrogen	R&D	Photobiological: 10-11 Dark fermentation: 60-80 Photo Fermentation: 0.1	2.9-3.1	Neutral/negative CO_2

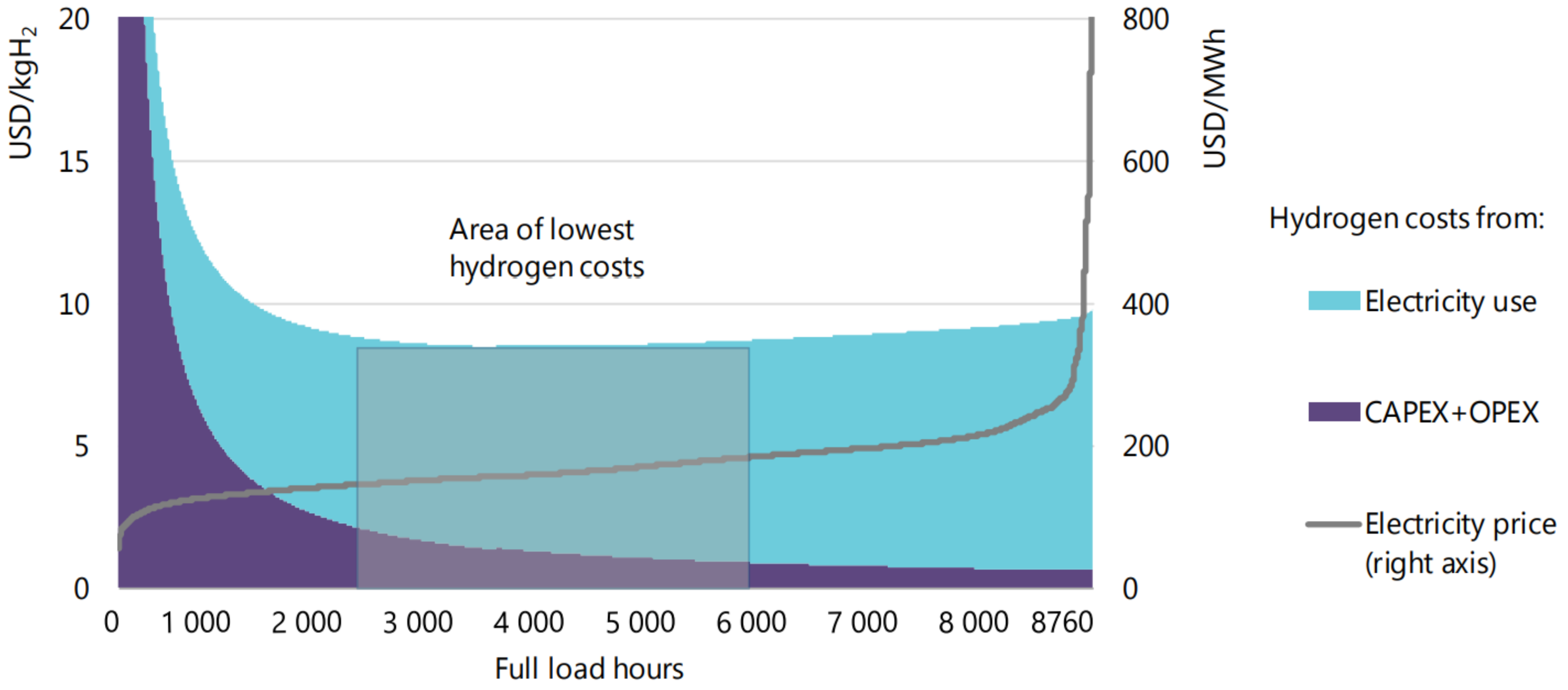
Cout de production: Electrolyse = 3*SMR

1. HYDROGEN PRODUCTION

Currently, hydrogen consumption worldwide is about 65 million tones per year which are mainly produced from fossil fuels, natural gas and coal.

- As a result, hydrogen production emits globally about 830Mt CO_2/year (IEA, 2019). (SMR: 1t H_2=8.5t CO_2)

1. HYDROGEN COSTS FROM ELECTROLYSIS USING GRID ELECTRICITY



ELECTROLYSER KEY FEATURES

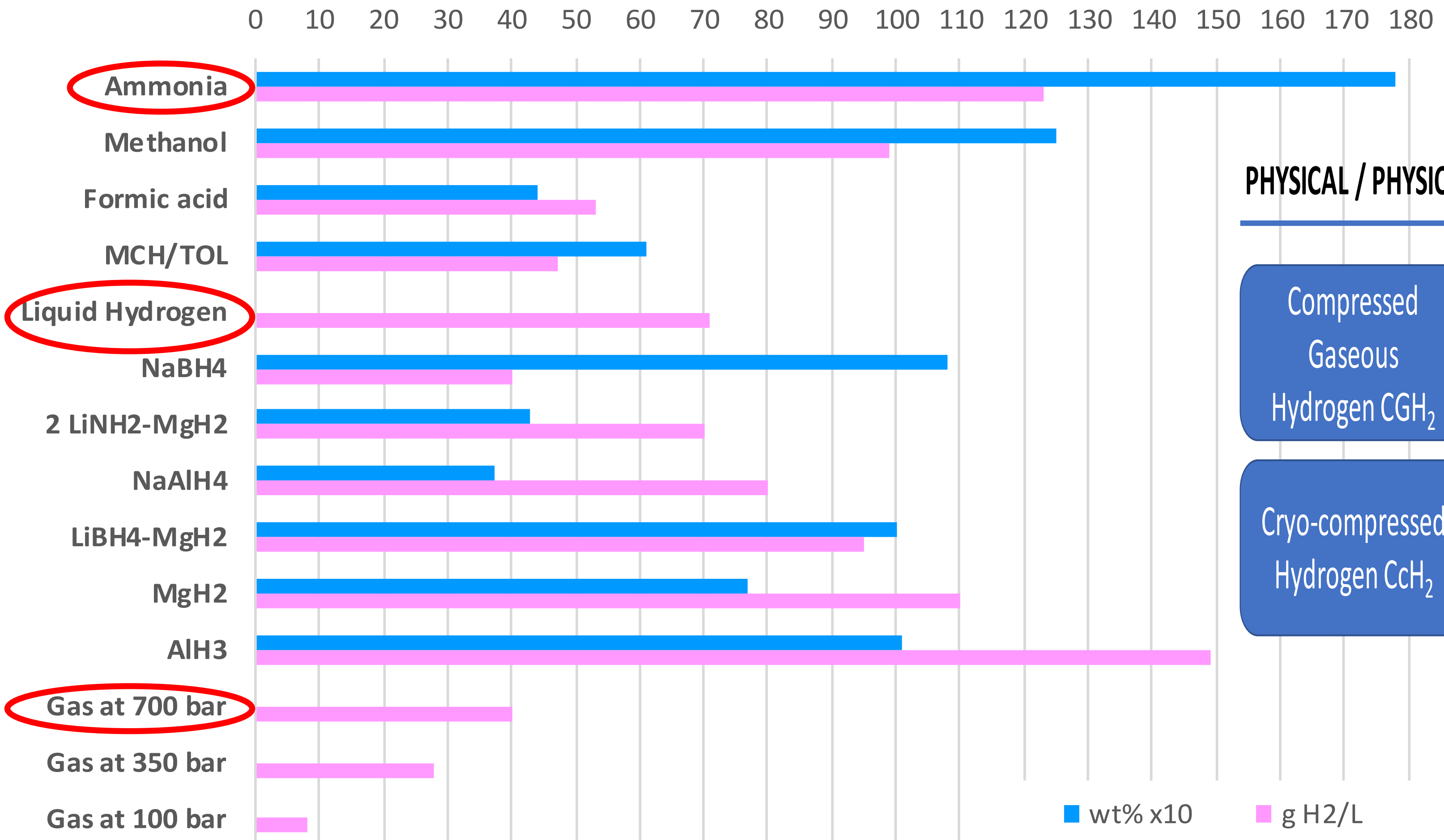
	Alkaline electrolysis cells (AEC)	Proton exchange membrane cell (PEMC)	Solid oxide electrolysis cells (SOEC)
Electrolyte	KOH/NaOH (liquid)	Polymer (solid)	Ceramic (solid)
Operating Pressure (bar)	2-10	15-30	<30
Operating Temperature (°C)	60-90 (up to 200)	50-90	500-1000
Stack Lifetime (h)	<90,000	<40,000	<40,000
System Lifetime (year)	20-30	10-20	-
Efficiency (HHV)	62-82%	67-84%	~90%
Cold Startup (min)	>15	<10	>60
Annual Degradation (%)	2-4	2-4	17
Cost at 2019 (US$/kW)	700–1400	1400–2400	> 2300
Target Cost by 2050 ($/kW)	~574	~700	~200
Maturity	Commercial	Commercial	R&D
Largest capacity as of 2019 (MW)	10 [2]	20 [3]	

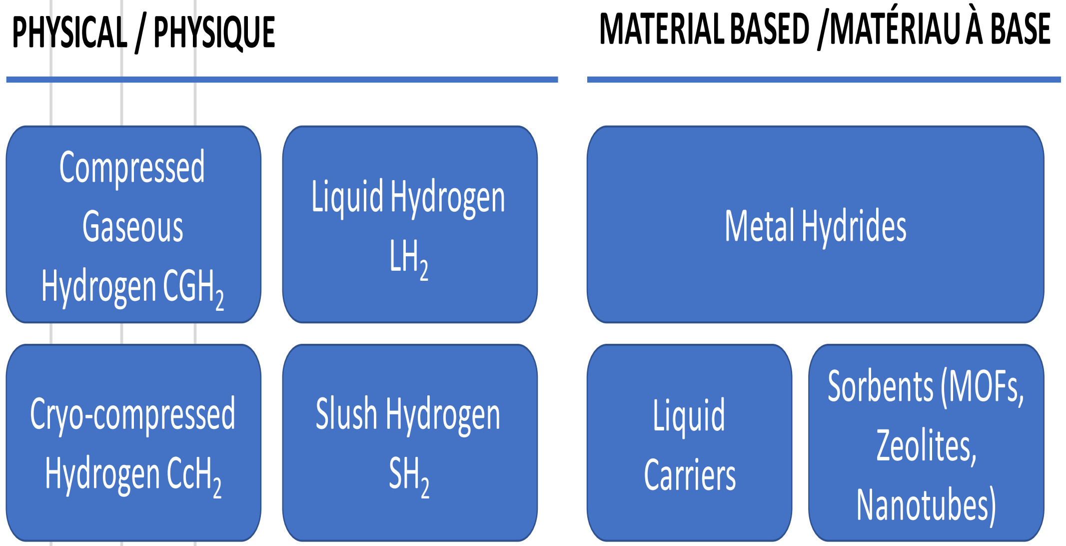
COST BREAKDOWN FOR H_2 PRODUCTION PEM AND AEC ELECTROLYSIS BASELINE CASES

	AEC		PEMC	
Component	Current forecast	Future forecast	Current forecast	Future forecast
Production cost (2019 $/kg)	$3.60	$2.74	$5.15	$2.98
Capital-Related Costs	$1.29	$0.72	$2.27	$0.86
Decommissioning Costs	$0.19	$0.10	$0.36	$0.13
Fixed O&M	$0.46	$0.26	$0.86	$0.33
Feedstock Costs	$1.43	$1.43	$1.44	$1.44
Other Raw Material Costs	$0.01	$0.01	--	--
Other Variable Costs (including utilities)	$0.22	$0.22	$0.22	$0.22

Note: Capital cost of 574 US$/kW and 700 US$/kW were used for the future forecasts for AEC and PEMC in 2030.

2. VOLUMETRIC (G/L) AND GRAVIMETRIC (WT% MULTIPLIED BY TEN) HYDROGEN STORAGE DENSITIES OF CONSIDERED TECHNOLOGIES





SOYONS RÉALISTES!

- OCP (Nigeria seulement): 750,000 t ammoniac /an, 1 Mt d'engrais/an
- Electrolyseur PEM: 1 GW et 85 TWh
- Production H_2 = 140,000 t/an
- Consommation d'eau = 2,3 Mm^3/an (eq. à 100,000 habitants)
- Capex (PEM) = 1.5-2 G$US
- Électricité (rendement 70%) = 1.5 GW

Comment?

- Noor (3,000 ha)
- 4 centrales solaires = 580 MW (ele?)
- Il faut plus que le double de Noor!

2. COUT DU TRANSPORT

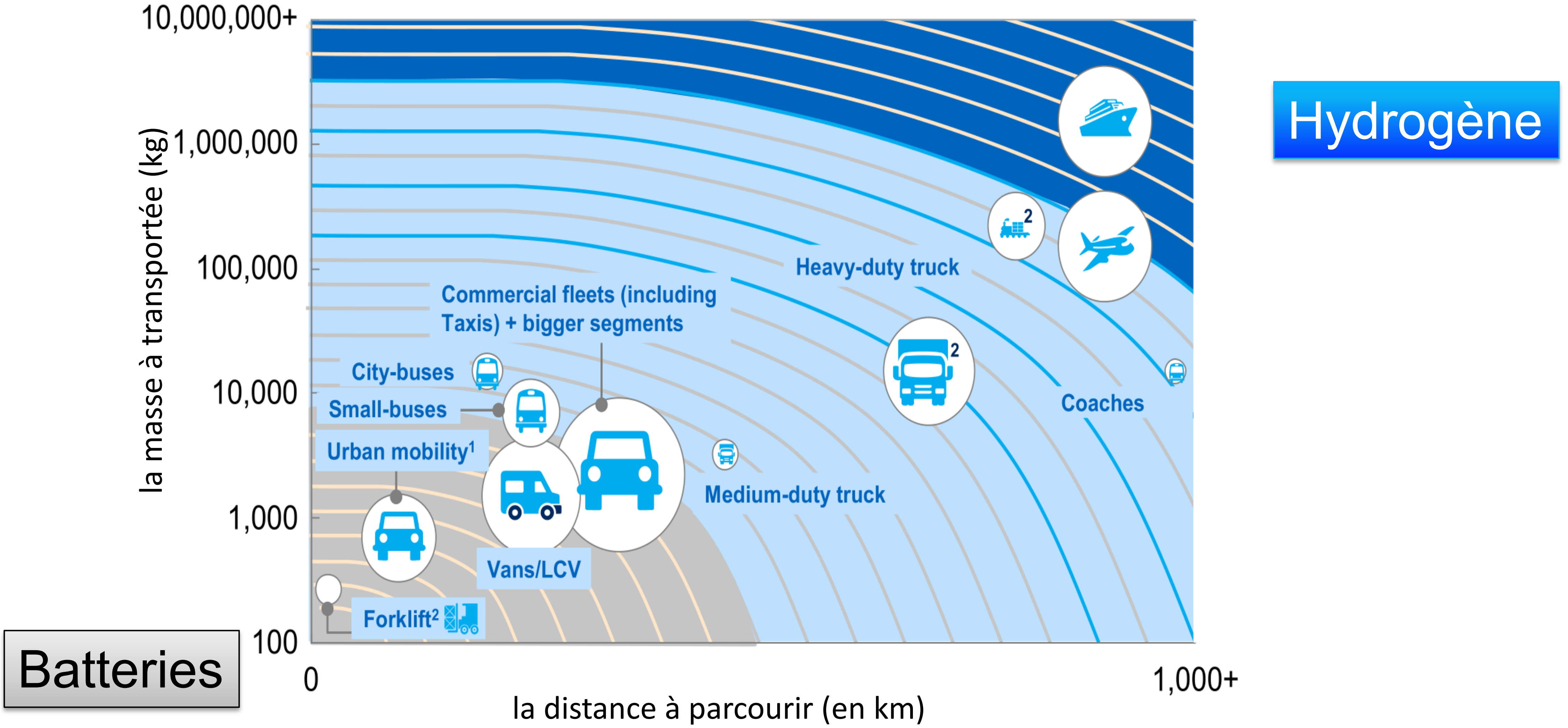
CAPEX:

- Comparing the different technologies, the hydrogen liquefaction process requires the lowest capital investment compared to other options.
- The highest capital cost is for ammonia production due to the high-pressure process.

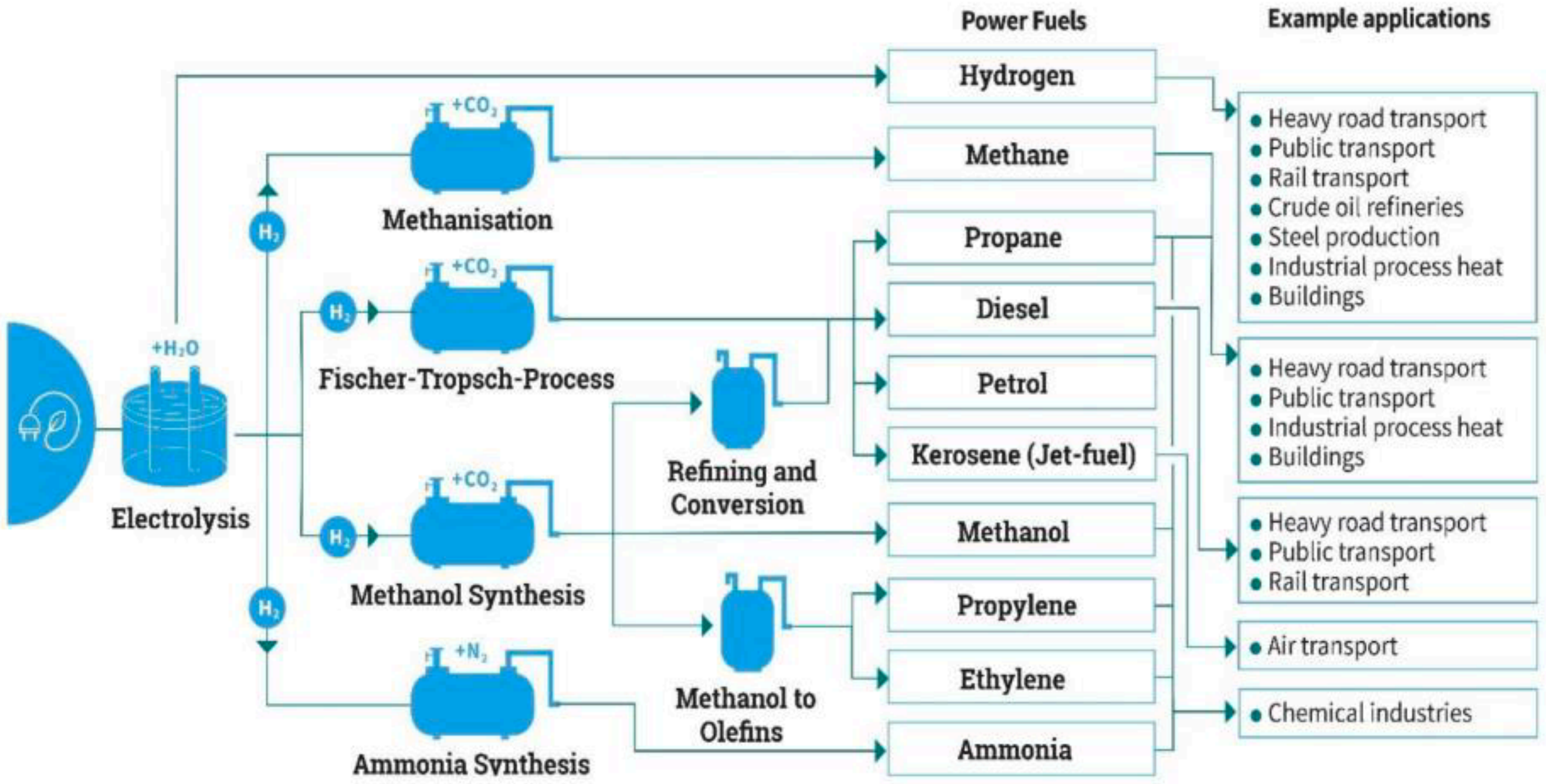
OPEX:

- Comparing operation costs of different carrier production also puts liquefaction of hydrogen and ammonia at the best place.
  - It has the lowest OPEX compared to all other options.
- Based on the costing model results (500,000kg/y) the LH_2 cost is at US$ 3-5/kg H_2, MCH at US$ 7.55/kg and ammonia at US$ 4/kg H_2.
  - The cost includes the production and dehydrogenation of carrier and transmission.
  - However, these costs are expected to decrease significantly with the developments on more efficient process from liquefaction and novel ammonia production processes at lower temperatures.

3. H2 POUR TRANSPORT



3. CHIMIE VERTE: BESOIN DE C (AUTRE QUE AMMONIAC)



3. CCS---POST-COMBUSTION CO2 CAPTURE DISADVANTAGES – AN OVERVIEW

- CO2 capture is significantly **energy intensive** process.
- Plot space requirements are significant.
  - The back-end at existing plants is often already crowded by other emission control equipment.
- Most sorbents **need very pure flue gas** to minimize sorbent degradation and contamination.
  - Typically < 10 ppmv or as low as 1 ppmv of SO_2 plus NO_2 is required depending on the particular sorbent
- Solvent stability is a major issue which causes **increase of OPEX for solvent replacement**.
- Solvent reclamation to remove **degradation products** enforces additional cost and challenges for waste management.
- Solvent emission can cause **negative environmental impact** which potentially can prevent a permit to operate.
- **Loss of solvent** due to emission also will increase OPEX.
- **Water consumption is significantly high**.
- **Waste water treatment** is complicated and expensive.
- **Corrosive nature of the solvent** enforces using corrosive-resistance MoC which results in higher CAPEX.

CONCLUSION: LES DÉFIS TECHNOLOGIQUES DE LA FILIÈRE HYDROGÈNE

1. Les coûts de production de H_2 vert : 3x SMR (CH_4): à diminuer
2. Transport d'H_2 par ammoniac: améliorer le procédé Haber-Bosch
3. Différentes utilisations:
   - transport (Grosses masses et longues distances)
   - Chimie verte: d'où provient le "C" attention aux technologies CCS/CCU: tout reste possible

INSTAURATION D'UNE FEUILLE DE ROUTE (1/2)

Actions techniques:

- Un volet production (objectifs chiffrés de volume et de coûts, quantité de CO_2 évitée) par technologie (électrolyse, gazéifieur, SMR décarboné);
- Un volet consommation chiffrée par application (mobilité, chimie verte, sidérurgie) incluant les émissions évitées grâce à l'utilisation de l'hydrogène;
- L'identification des partenaires possibles et des propositions de mécanismes de support.

INSTAURATION D’UNE FEUILLE DE ROUTE (2/2)

Actions politiques:

- L’instauration d’un cadre politique, légal et réglementaire cohérent et incitatif pour aider à dé-risquer les investissements privés ;
- La mise en place d’incitatifs financiers (subventions, réduction de taxes, réglementation, facilitation de projets de démonstration) pour favoriser les investissements ;
- La sensibilisation du public sur l’intérêt de l’hydrogène dans le cadre de la transition énergétique et la mise en place de mesures pour encourager son adoption ;
- Le développement des compétences (formations universitaires, programmes de recherche, plateformes d’innovation) dans les secteurs d’application les plus porteurs.

PRODUCTION DE CARBURANTS OU DE VECTEURS ÉNERGÉTIQUES VERTS.