

Le rôle de l'hydrogène dans la transition énergétique du Québec

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Émissions de CO₂ au Québec

8.5 MT

Résidentiel et commercial



Taux de population urbaine: 81%

31.1 MT

Agriculture



Transports



34 MT

6,45 millions de véhicules

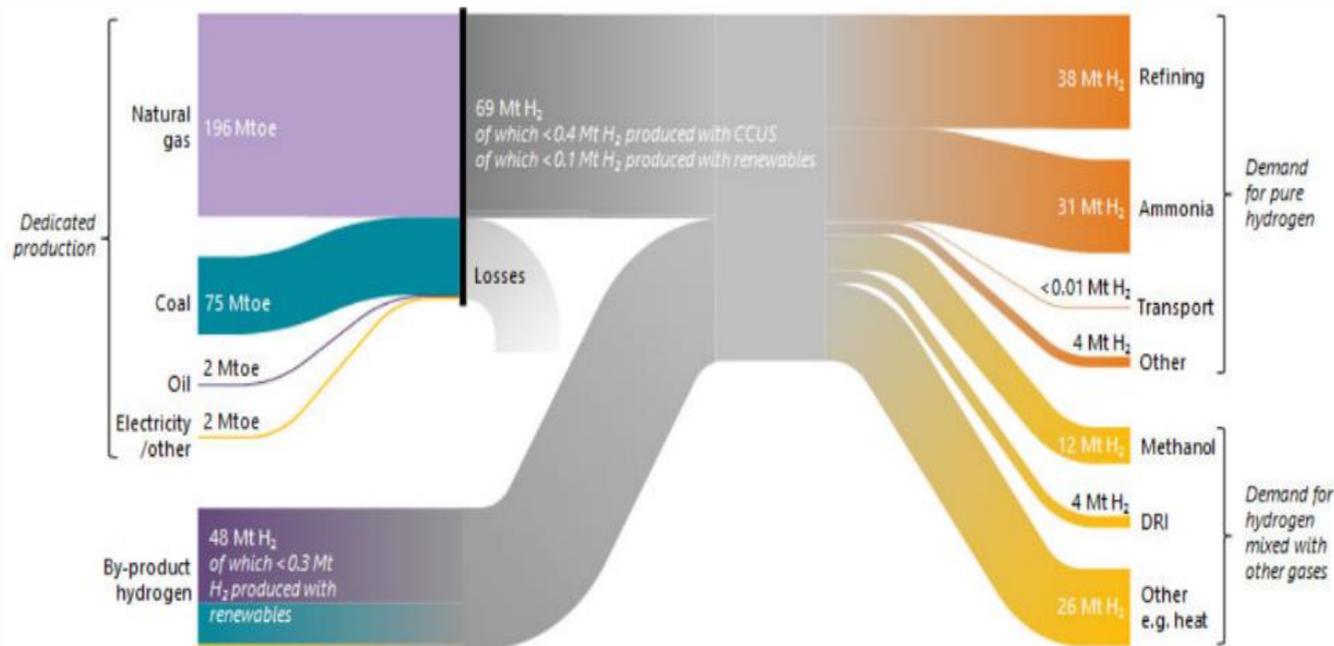
Industrie



8,4 millions de consommateurs

Chaînes de valeur de l'hydrogène

L'hydrogène est considéré par un nombre croissant de grandes puissances industrielles tant en Asie qu'en Europe comme un vecteur clé dans la transition énergétique vers une économie bas carbone.

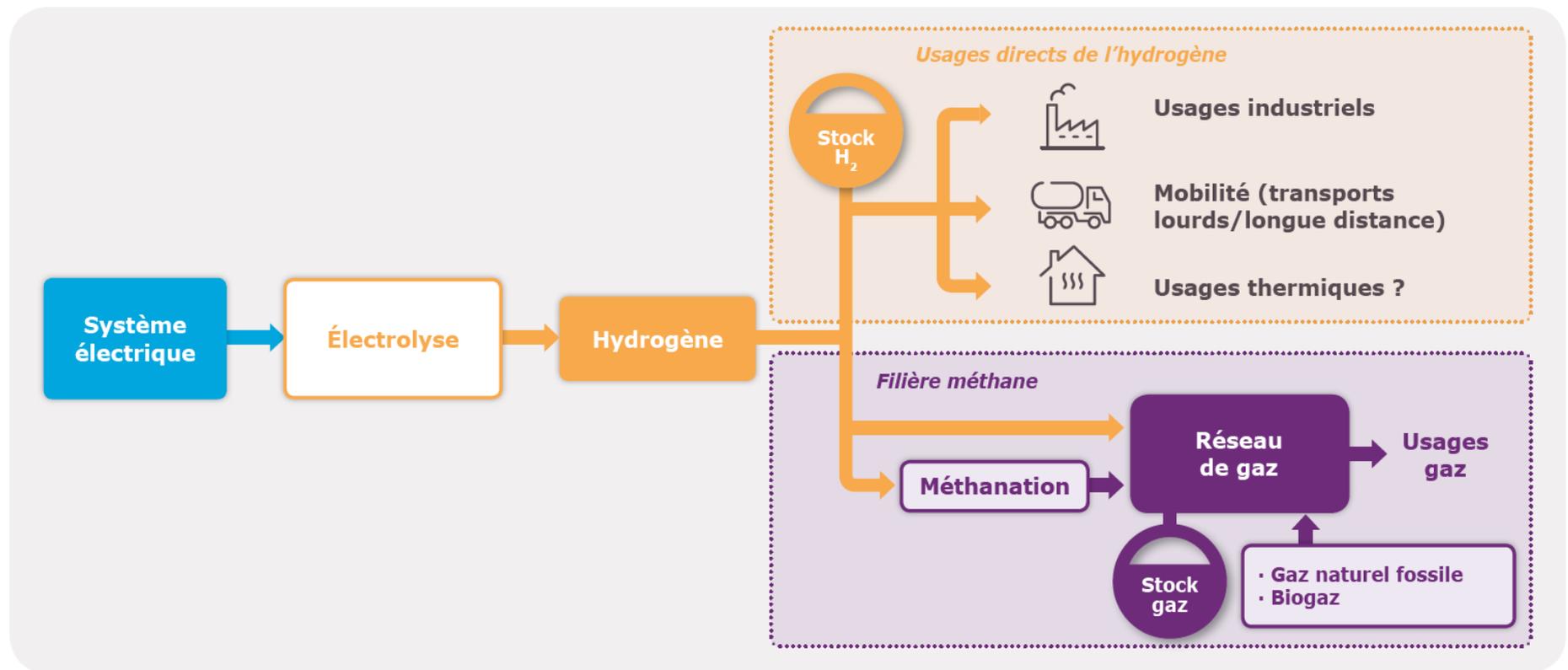


IEA 2019

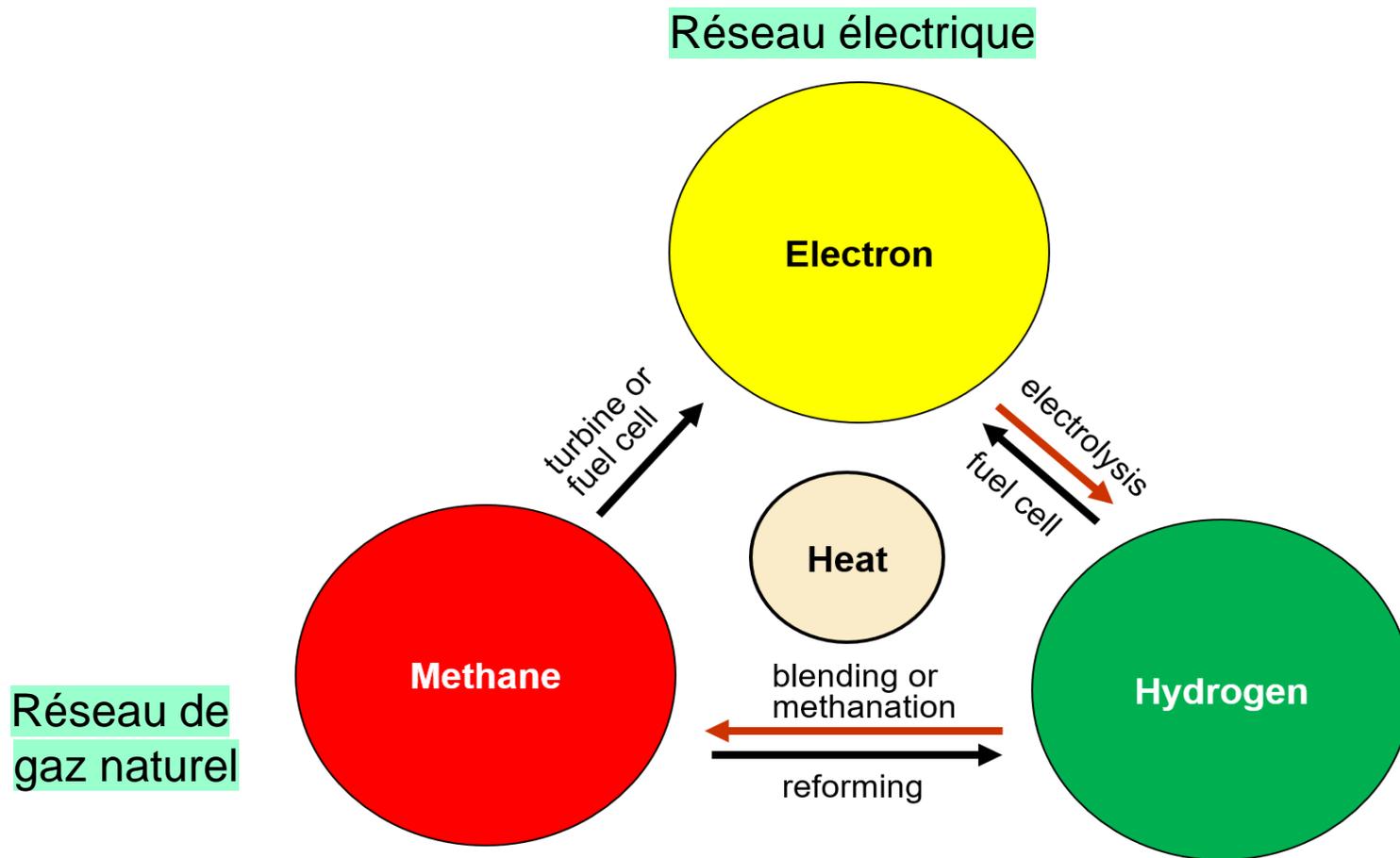
Québec: environ 100 kT/a (90 kT pour le raffinage)

L'hydrogène vert: un des piliers pour réussir la transition énergétique

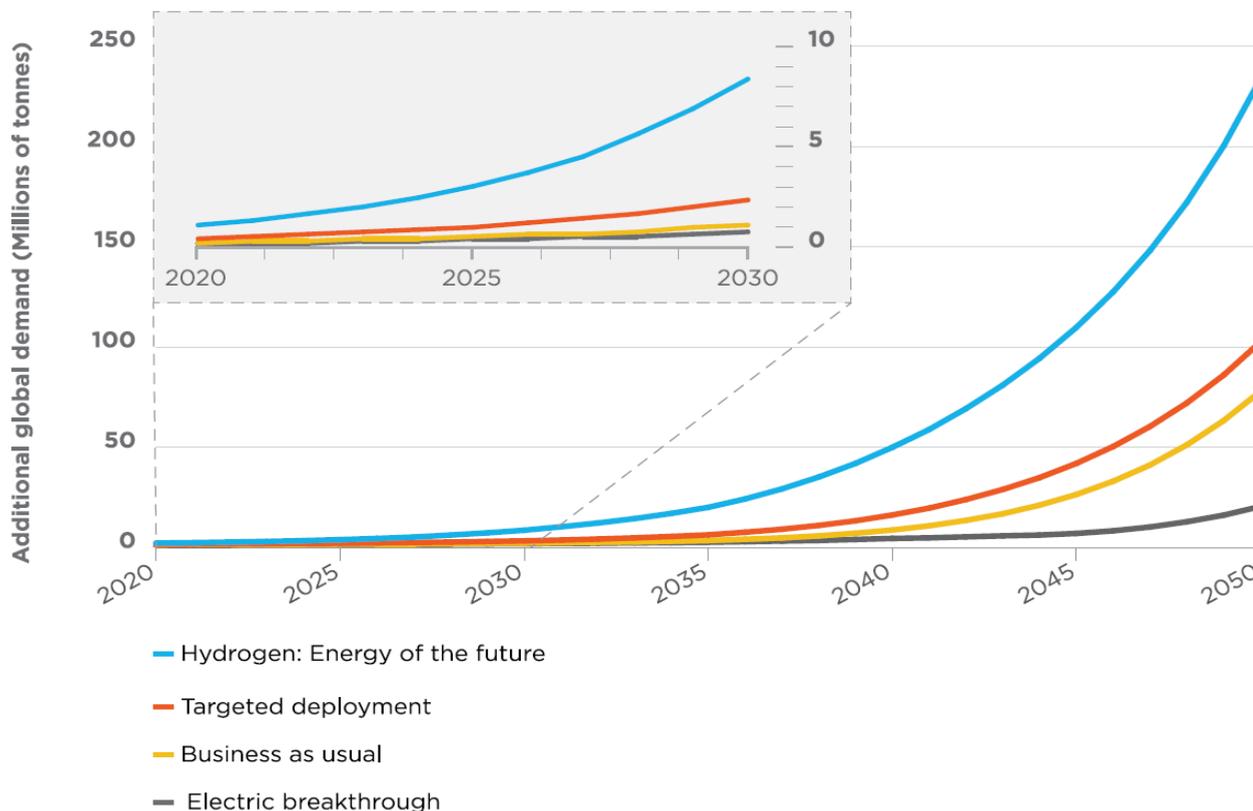
L'hydrogène vert produit à partir d'électricité renouvelable peut permettre de décarboner des usages (transport, industrie) et d'accroître la flexibilité du réseau électrique (passerelle).



Passerelles entre les réseaux



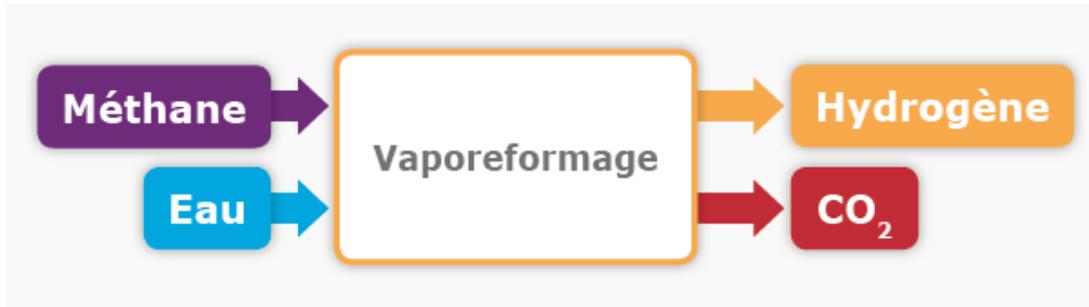
Évolution de la consommation d'hydrogène



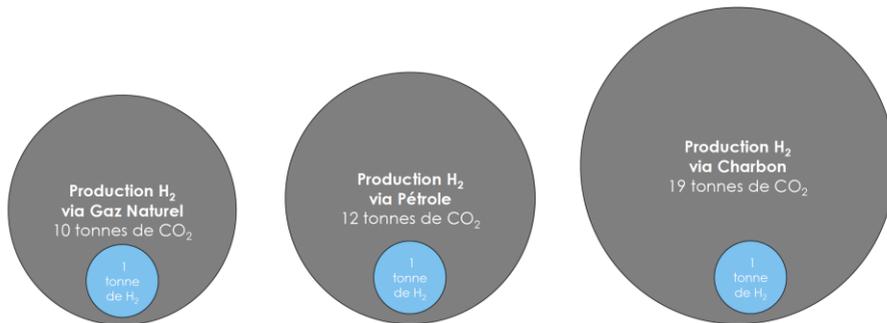
SIA Partners 2019

Le scénario optimiste de l'*Hydrogen Council* (2017) prévoit en 2050 une demande supplémentaire de 500 MT/an

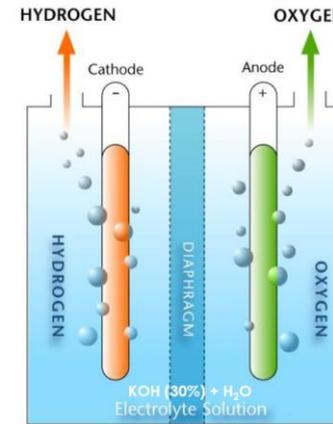
Technologies de production



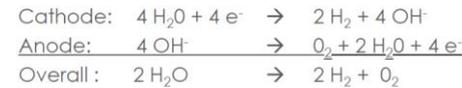
Réformage: 95% de la production mondiale



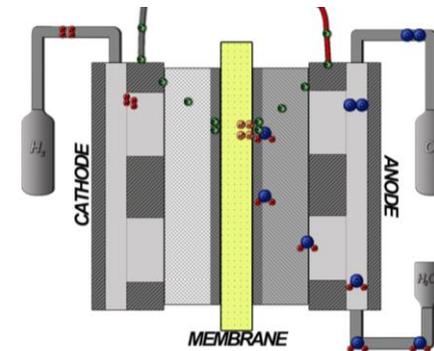
Plus de 1 GT de GES émis chaque année



Ael (mature)



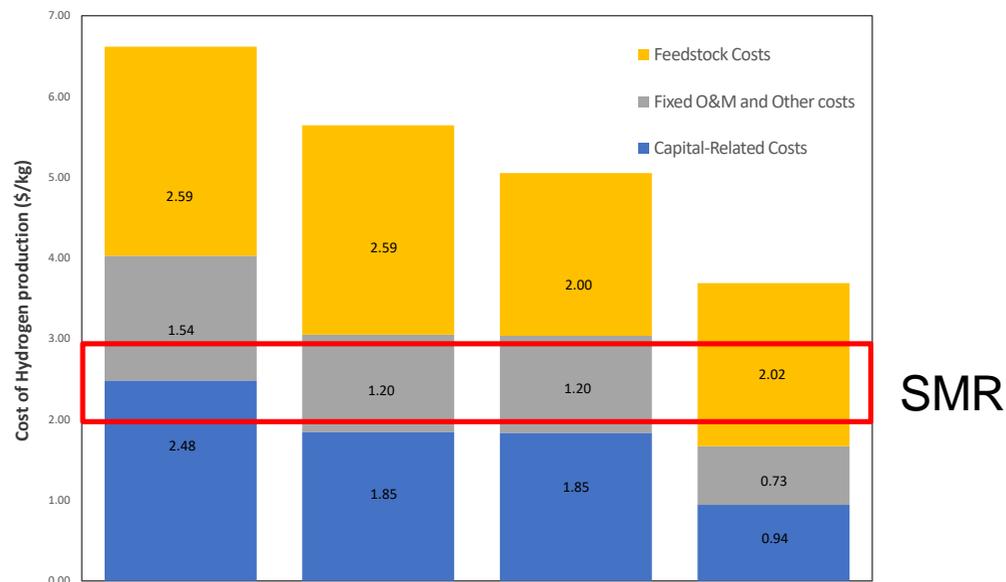
Électrolyse – sans GES
(si électricité verte)



PEM (en déploiement)



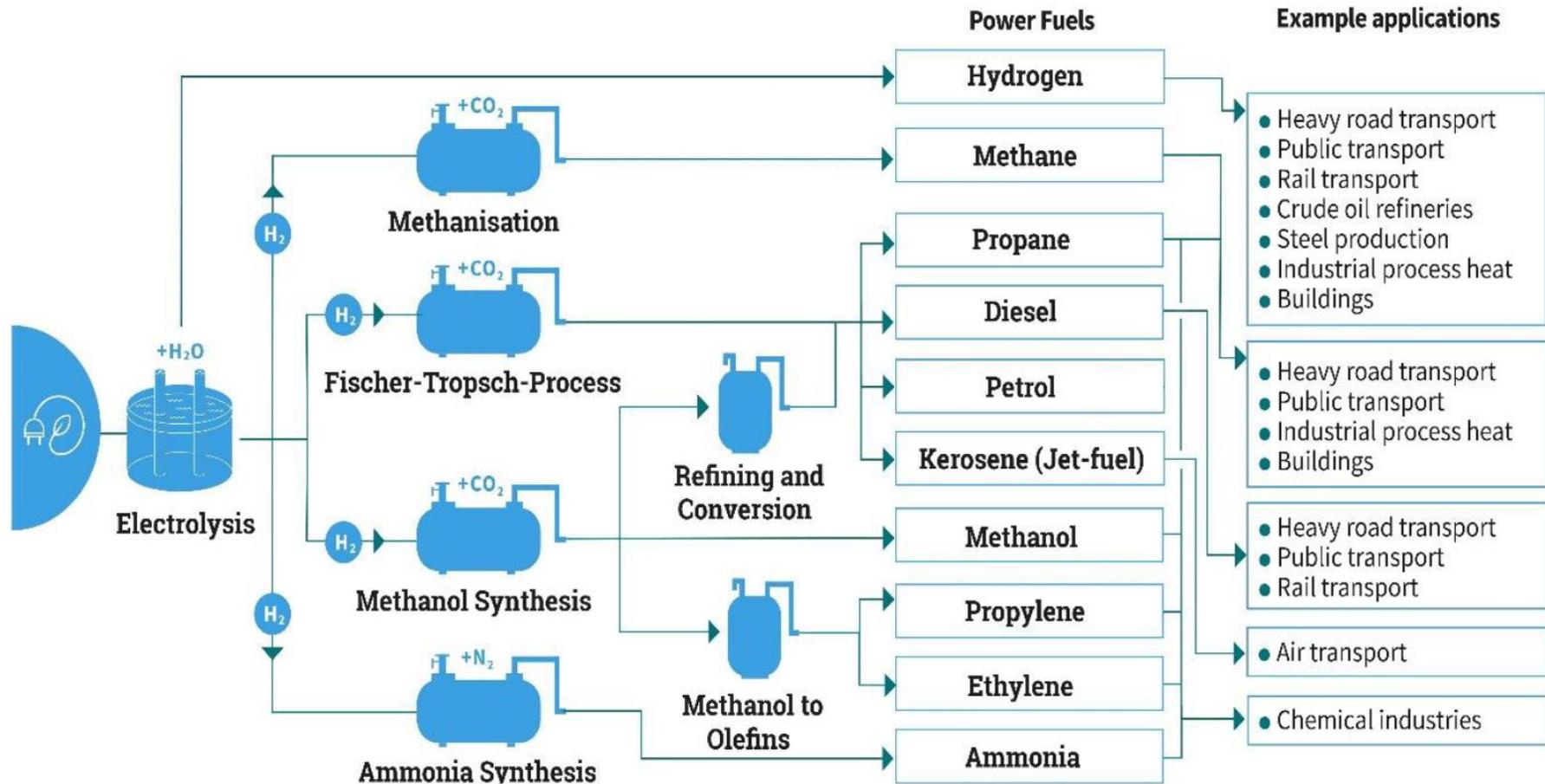
Modélisation économique pour le Québec



PEM Electrolyzer				
Scenarios	Base case	Aggressive	2030	Long-term
Hydrogen Production cost (2019 CAD/kg)	6.62	5.64	5.05	3.69
Load Factor (%)	90%	90%	90%	90%
Electricity Price at 2019 (¢/kwh)	4.5	4.5	3.5	3.5
CAPEX (\$/kWe)	1900	1400	1400	700

La production est rentable surtout avec une taxation du carbone

Typologie du Power-to-X



Électrification des transports

Weight
Tons

10,000+

1,000

100

10

1

0.1

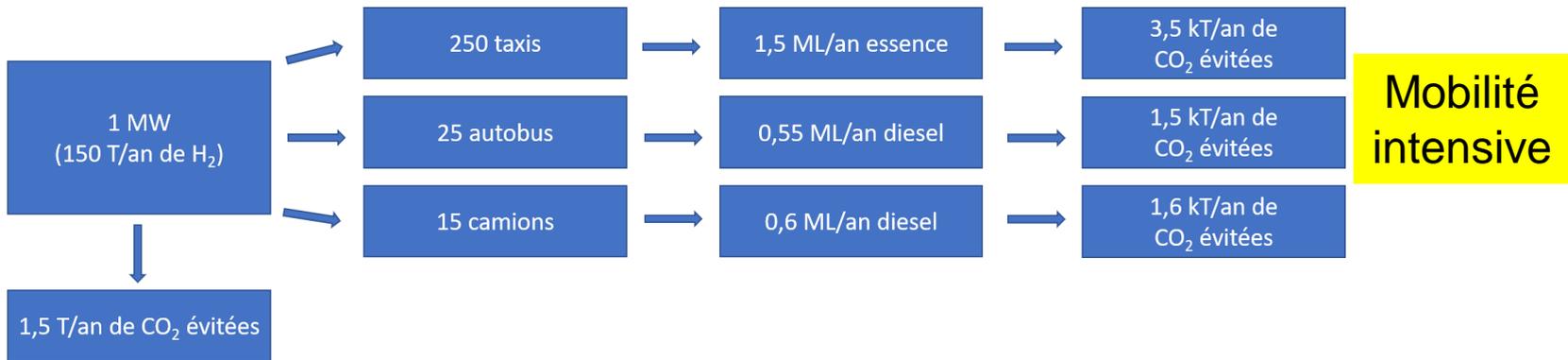


- BEV
- FCEV
- Bio- and (H₂-based) synthetic fuels

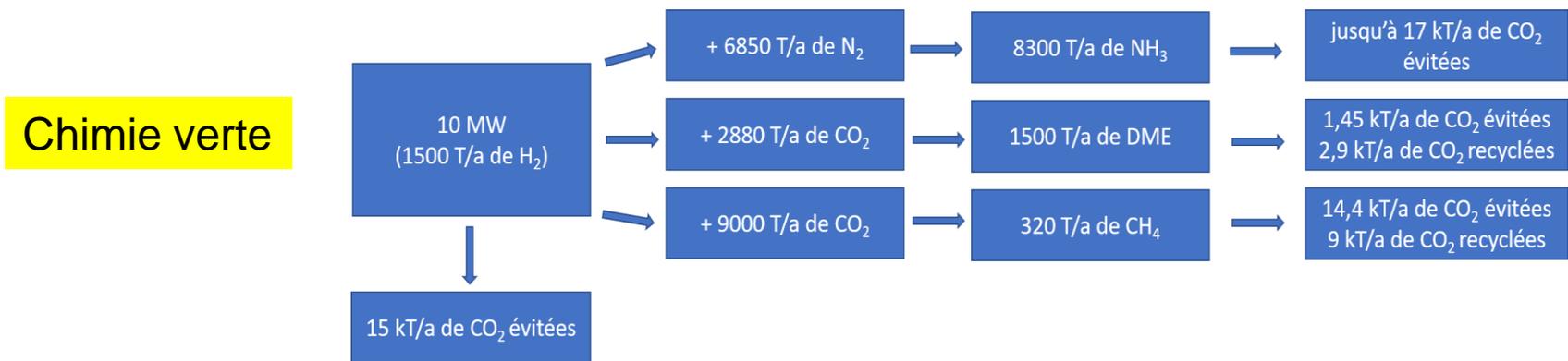
Medium to large cars²,
fleets and taxis

Average mileage per day/trip
Km

Quelques ordres de grandeur



Décarboner le camionnage lourd au Québec par l'hydrogène vert demanderait environ 900 kT/an d'hydrogène. Cela nécessiterait une capacité d'électrolyse de près de 6 GW (300 unités identiques à celle d'Air Liquide à Bécancour) et une consommation d'énergie de 50 TWh (6 fois la Romaine). À 1500 \$/kW, les coûts fixes seraient de 9 milliards de \$.



Plus de 20 feuilles de route déjà publiées

Goals in the Basic Hydrogen Strategy

Use

- Mobility**
 - FCV 200k by 2025, 800k by 2030
 - HRS 320 by 2025, 900 by 2030
 - BUS 1,200 by 2030
- Power**
 - Commercialize by 2030
 - Early realization of grid parity
- FC**

Set of targets to achieve

- Price difference between FCV and HV (¥3m → ¥0.7m)
- Cost of main FCV system (FC ¥20k/kW → ¥5k/kW, Hydrogen Storage ¥0.7m → ¥0.3m)
 - Construction cost: ¥350m → ¥200m
 - Operating cost: ¥34m → ¥15m
- Construction and operating costs
- Costs of components for HRS (Compressor ¥90m → ¥50m, Accumulator ¥50m → ¥10m)
- Vehicle cost of FC bus (¥105m → ¥52.5m)

Approach to achieving target

- Regulatory reform and developing technology
- Consideration for creating nation wide network of HRS
- Extending hours of operation
- Increasing HRS for FC bus
- Developing of high efficiency combustor etc.
- Developing FC cell/stack technology
- Scaling-up and improving efficiency of brown coal gasifier
- Scaling-up and improving thermal insulation properties
- Designated regions for public deployment tests utilizing the ox: the demonstration test in Namie.
- Development of electrolyzer with efficiency and durability

Early 2020s

- Efficiency of hydrogen power generation (26% → 27%)
- Realization of grid parity in commercial and industrial use
- Production: Production cost from brown coal gasification (¥several hundred/Nm3 → ¥12/Nm3)
- Scale-up of Liquefied hydrogen tank (thousands m³ → 50,000m³)
- Higher efficiency of Liquefaction (13.6kWh/kg → 6kWh/kg)
- Storage/Transport: ¥100m/kW → ¥50,000/kW

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Hydrogen Mobility (cumulative)

MOBILITY	2018		2022		2040	
	Domestic	Foreign	Domestic	Foreign	Domestic	Foreign
Hydrogen vehicles(FCEV)	1,800 (900)	1,800 (900)	81,000 (67,000)	81,000 (67,000)	6,200,000 + a (2,900,000)	6,200,000 + a (2,900,000)
Passenger Cars	-	-	-	-	5,900,000 (2,750,000)	5,900,000 (2,750,000)
Taxis	-	-	-	-	120,000 (80,000)	120,000 (80,000)
Buses	-	-	79,000 (65,000)	79,000 (65,000)	60,000 (40,000)	60,000 (40,000)
Trucks	2 (Test)	2 (Test)	-	-	120,000 (30,000)	120,000 (30,000)
Fueling Station	-	-	-	-	1,200 + a	1,200 + a
Trains, Ships, and Drones	14	14	2,000 (Test)	2,000 (Test)	-	-
Commercialization and export projects to be implemented before 2030 through R&D and demonstrations	-	-	310	310	-	-

* Domestic demand / Proportion of Hydrogen vehicles(FCEV) among all cars (cumulative)

Hydrogen Energy (cumulative)

ENERGY	2018		2022		2040	
	Domestic	Foreign	Domestic	Foreign	Domestic	Foreign
Fuel Cells	307.6MW	307.6MW	1.5GW (1GW)	1.5GW (1GW)	1.5GW + a (8GW)	1.5GW + a (8GW)
Households/Bus Idling	-	-	50MW	50MW	-	-
Hydrogen Gas Turbine	7MW	7MW	-	-	-	-

Technology development to be completed by 2030

Hydrogen Supply and Prices

	2030	2040
Hydrogen production (million tons/year)	5.26	5.26
By-product hydrogen production	①By-product hydrogen extraction	①By-product hydrogen extraction
Water electrolysis production	②Water electrolysis	②Water electrolysis
Overseas production	③Overseas production	③Overseas production
Price (KRW 3,000/kg)	④: 50%	④: 70%
	⑤: 50%	⑤: 30%

EERE AMO

- New NG reforming options
- Innovative manufacturing for fuel cells & electrolyzers, R2R
- Advanced composites for tanks (also with VTO)

EERE BETO

- H₂ from bio-waste-streams
- Circular-Carbon/H₂@Scale synergies in bio-fuels

EERE SETO

- H₂@Scale/Solar-Fuels synergy
- BOP for STCH H₂ production
- CSP-based solar NG reforming

EERE WETO, WPTO, GTO

- R&D to integrate electrolysis with renewables
- H₂@Scale leveraging of regional energy resources

DOE/EERE FCTO

Foundational Early-Stage R&D and H₂@Scale

- Hydrogen Fuel: production & storage
- Fuel Cells: for transportation & power
- Infrastructure R&D:
 - Technology Acceleration
 - Safety, Codes & Standards
 - Systems Analysis
- Research Consortia: H₂@Scale; H₂ materials compatibility; fuel cell catalysts & durability; advanced water splitting; H₂ storage materials & carriers

NSF

- Academia-based fundamental research relevant to hydrogen and fuel cell R&D (including co-funding with FCTO consortia)

NIST, DOT DOD, NASA, etc.

- Examples: standards in H₂ materials & services; next-generation military and space, buses, rail, marine, etc. applications

DOE/SC

- Fundamental processes of energy & matter relevant to H₂ manipulation
- Synergies

New NG & (including SOEC/SOF)

- Integrated for nuclear

H₂ for energy ancillary services

DOE/EE

- Innovative concepts for hydrogen and fuel cell

	2020	2025	2030
Overall objective	Small scale public sector demonstration in selected areas (5,000 FCVs)	Large-scale development of FC passenger cars and service vehicles in urban areas (50,000 FCVs)	Large-scale commercial deployment of passenger cars and commercial vehicles (one million FCVs)
Fuel cell system production capacity	>1,000 units per enterprise	>10,000 units per enterprise	>100,000 units per enterprise
Hydrogen fuel cell vehicles			
Functional requirements	Cold start -30°C, power system structure optimisation, FCV cost close to all-electric vehicles	Cold start -40°C, small volume production, FCV cost similar to hybrid vehicle	FCV overall performance comparable with traditional ICE vehicles - achieving competitive advantage
Commercial vehicle	Cost ≥ RMB 1.5 million	Cost ≥ RMB 1.0 million	Cost ≥ RMB 600,000
Passenger car	Max speed ≥ 160km/h Lifespan 200,000km Cost ≥ RMB 300,000	Max speed ≥ 170km/h Lifespan 250,000km Cost ≥ RMB 200,000	Max speed ≥ 180km/h Lifespan 300,000km Cost ≥ RMB 180,000
Hydrogen infrastructure			
H ₂ supply	Decentralised hydrogen production from renewable sources; industrial by-products such as coke-oven gas		Decentralised H ₂ production from renewable sources
H ₂ delivery	High pressure hydrogen storage and delivery	Cryogenic liquid + hydrogen delivery	High density organic liquid hydrogen storage** and delivery at normal pressure
HRS	100 stations	350 stations	1,000 stations

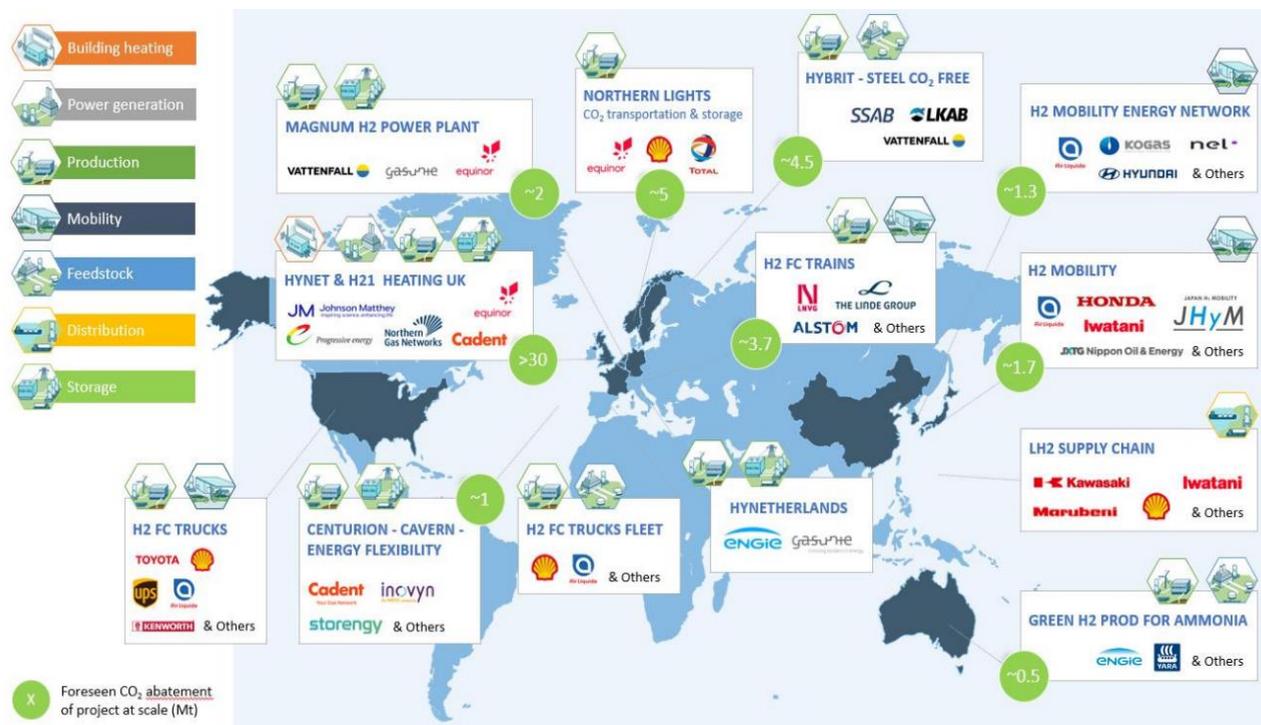
Création de l'*Hydrogen Council* en 2017



90 milliards de grands projets en cours

Coopération établie entre les principaux acteurs pour promouvoir le « 10-10-10 »

- 10 millions de véhicules fonctionnant à l'hydrogène
- 10000 points de ravitaillement
- en 10 ans



Propositions pour le Québec

Pour l'hydrogène direct (utilisé tel quel) :

- La mobilité avec un fort potentiel à long terme pour les véhicules lourds et le transport intensif
- Le stockage d'énergie incluant l'injection d'hydrogène dans les réseaux de gaz naturel

Pour l'hydrogène indirect :

- La décarbonation du raffinage et de la pétrochimie
- Le développement d'une chimie plus verte basée sur la valorisation du CO₂ industriel capté et comprenant en particulier les carburants synthétiques et d'autres produits chimiques à haute valeur ajoutée
- La diminution de l'empreinte carbone de la sidérurgie (réduction directe de l'oxyde de fer)

Un marché d'export?

International supply chains: Potential partner countries

Country	Shared characteristics
Canada, US, Australia, China	Likely future blue and green hydrogen producers and technology providers
Saudi Arabia, Russia	Resource-rich countries with potential of both blue and green hydrogen production
Peru, Iceland, Ethiopia	Potential supplier of low-cost green hydrogen; no incentive to use hydrogen domestically, enabling green hydrogen export
Ireland, Chile, UK	Potential supplier of low-cost green hydrogen; a need to enhance energy self-sufficiency, thus likely facing competition between domestic consumption and export of green hydrogen
Netherlands, UK, Switzerland, France, Germany, Spain, Portugal, Israel, Italy, Belgium, Korea, Japan	Potential demand for low-carbon hydrogen; high-income, high dependence on primary energy imports, and likely future users with technology competence

