ISO/TC 197
« HYDROGEN TECHNOLOGIES »

FRENCH HYDROGEN ROADMAP

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The French programme framework

The French State-oriented research and innovation system is based on:

- Dedicated public agencies:
  - For research policy (ANR)
  - To support businesses (OSEO)
  - For priority challenges (ADEME for energy and the environment)
- Public research bodies (CNRS, CEA, universities, etc)
- Companies (AIR LIQUIDE, AREVA, GDF SUEZ, MICHELIN, etc)
- Mixed structures (competitive clusters, initiatives by local and regional authorities, etc)
- Other private research organizations or associations under contract

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The tool kit

Since the national Grenelle Environment Forum (2007), France has made significant efforts and has commissioned ADEME to develop low carbon energy technologies:

- Investments
  - For research demonstration projects > €400M (2008-2009)
  - For investments in the future > €2.85G
- Strategic roadmaps
  - To construct the programme and define the priorities for application of these exceptional budgets
  - Dedicated strategic roadmap on H2-energy and fuel cells
- Call for expressions of interest on H2
  - For H2-fuel cell > issued in April 2011
  - For H2-dedicated mobility > issued end of 2011-beginning of 2012
  - Possibility to propose H2-fuel cell solutions in other calls (electric power train, heavy goods vehicles, etc)

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The strategic roadmap on H2-energy and fuel cells - Context

National roadmap objectives:

- Agree on the challenges
- Participate in the creation of shared visions
- Identify R&D priorities and needs in terms of demonstration

Method:

- Consultation work > 30 experts and players in the field grouped together in the HyPaC hydrogen and fuel cell hub (researchers, industry players, small and medium-sized companies, regional and local authorities)
- Publication > April 2011

Content:

- Research scope / Challenges / Key parameters
- 2020 visions and goals / 2050 visions / Barriers and levers
- R&D priorities and demonstration project requirements

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The strategic roadmap on H2-energy and fuel cells - Scope

Research subjects:

- H2-energy
- Fuel cells
- Industrial H2 excluded

Applications targeted:

- Stationary (building, industry, networks)
- Mobile (CNG, fuel cell only or hybrid vehicles)
- Niche or early (mobile and backup power supplies)

Two hydrogen-energy designations, depending on the source and/or production process:

- “Low carbon hydrogen”:
  - Steam reforming of natural gas + CCSR (carbon capture, storage and re-use)
  - Electrolysis with nuclear or renewable sources
  - Biomass processes (gasification, steam reforming of biogas, etc.)
- “Renewable hydrogen”:
  - Electrolysis with renewable sources
  - Biomass processes (gasification, steam reforming of biogas, etc

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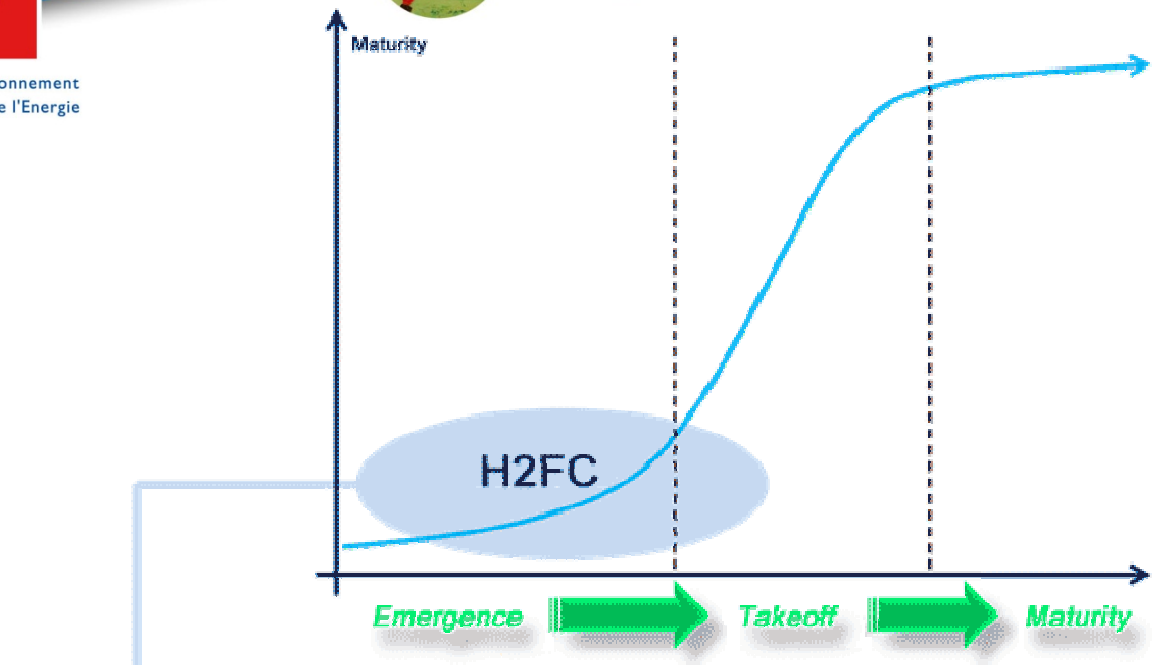

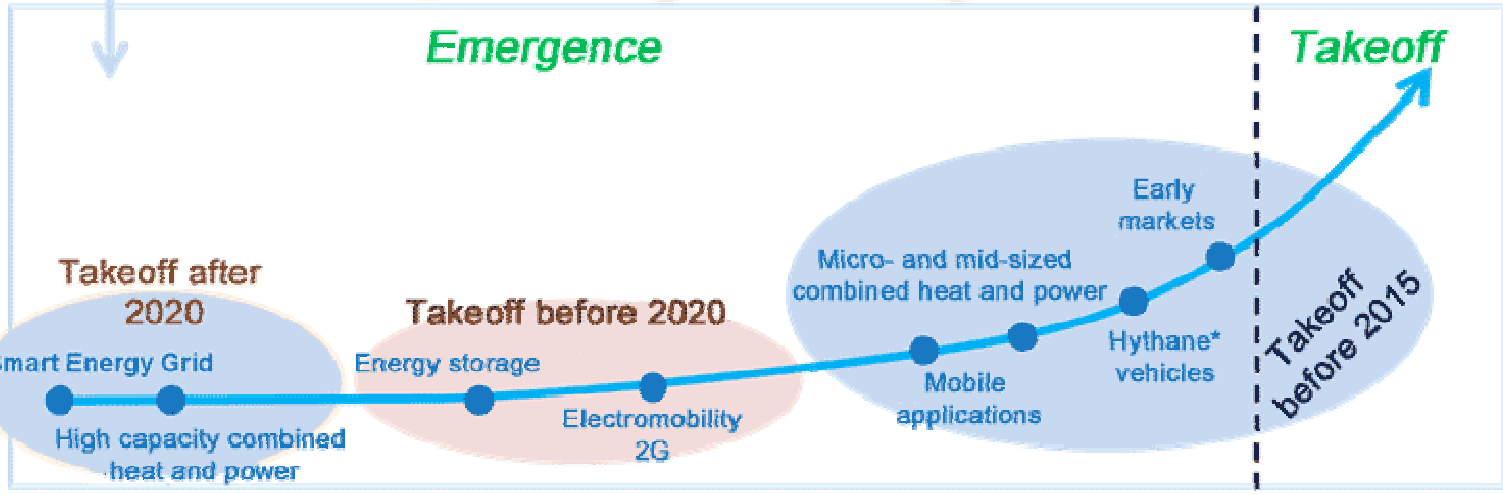

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Energy and environmental challenges

Five challenges:

- To contribute to conserving resources by encouraging the use of renewable energies
  - Means of storage, transport, distribution and use of diffuse and intermittent renewable energies
- To contribute to reducing CO_2 emissions in diffuse uses
- To support the development of energy grids
  - Management of intermittent electricity supplies, connections between electricity and gas networks
- To reduce nuisance related to energy use in an urban environment
  - Vehicles with zero particulate, NOx and VOC emissions
- To contribute to improving energy efficiency in the construction field
  - Decentralized, efficient power generation by fuel cells

Benefits actually depend on the efficiency of the entire H_2 chain

Optimization is a crirerion

H2 systems and fuel cell may not be always relevent (static storage for french electric grid)

Competing technologies do exist

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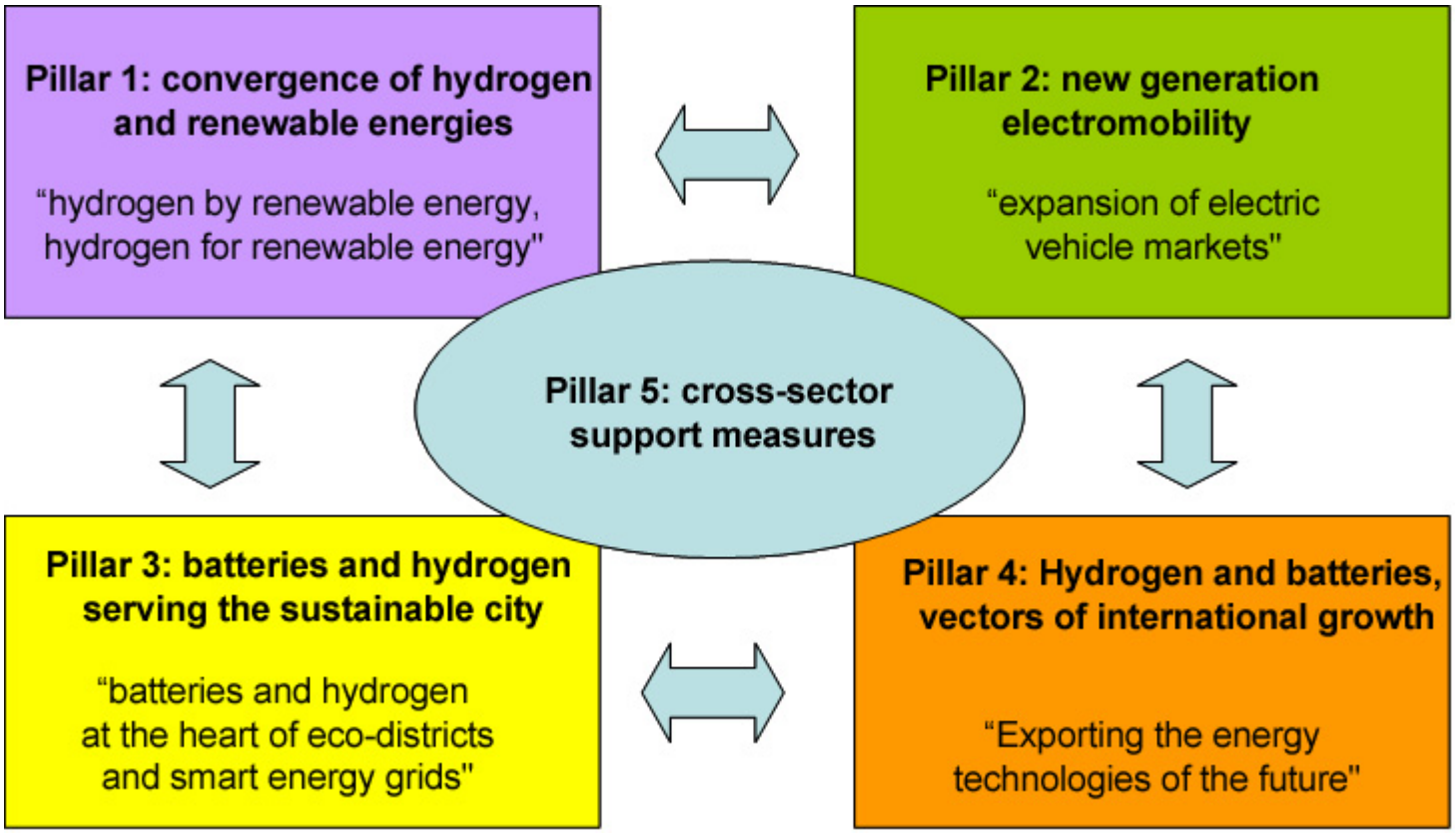
2020 visions and goals



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R&D priorities and pre-industrial demonstration project requirements

Pillar 1 H2 and renewable energy convergence	- R&D hydrogen production (all sectors) - Technico-economic studies of systems and smart grid feasibility study - Demonstration of renewable H2 and secondary hydrogen use
Pillar 2 New generation electromobility	- R&D on PEM fuel cells, onboard storage and systems - Technico-economic studies on deployment of an H2 infrastructure for automobiles - Phase 1: demonstration on captive fleet (2 to 5 cities) - Phase 2: pre-commercial demonstration on large captive fleets
Pillar 3 Fuel cells and H2 and the sustainable city	- R&D on SOFC (solid oxide fuel cells) - Coordinated tests of stationary systems: micro- and mid-sized combined heat and power production, storage and generation of H2 in buildings - Demonstration of H2 injection in natural gas pipelines - 10 to 15 complete renewable H2 chains in local loops (production, distribution and uses) - Demonstration of the smart energy grid on the scale of a city or an eco-district - Deployment of Hythane® type vehicle fleets
Pillar 4 H2 and fuel cells, international growth	- Demonstration of special off-road vehicle fleets - Demonstration of standby and power supply application for isolated sites

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Barriers and levers

Technico-economic barriers:

- Optimization of “technological building blocks” > until achievement of products suitable for industrialization
- H2 > CCSR, high and low voltage electrolysis, storage
- Fuel cell > integration in systems, extension of lifetime, reliability

Socio-economic barriers:

- Adapted regulatory and standardization framework
- The “fear of hydrogen”

Economic and industrial barriers:

- Convergence of multiple and/or new technological skills
- Long transition phase before maturity for H2

Three types of levers:

- Visible and sustainable political support
- Strong industrial leadership
- Support by society > acceptability and adoption