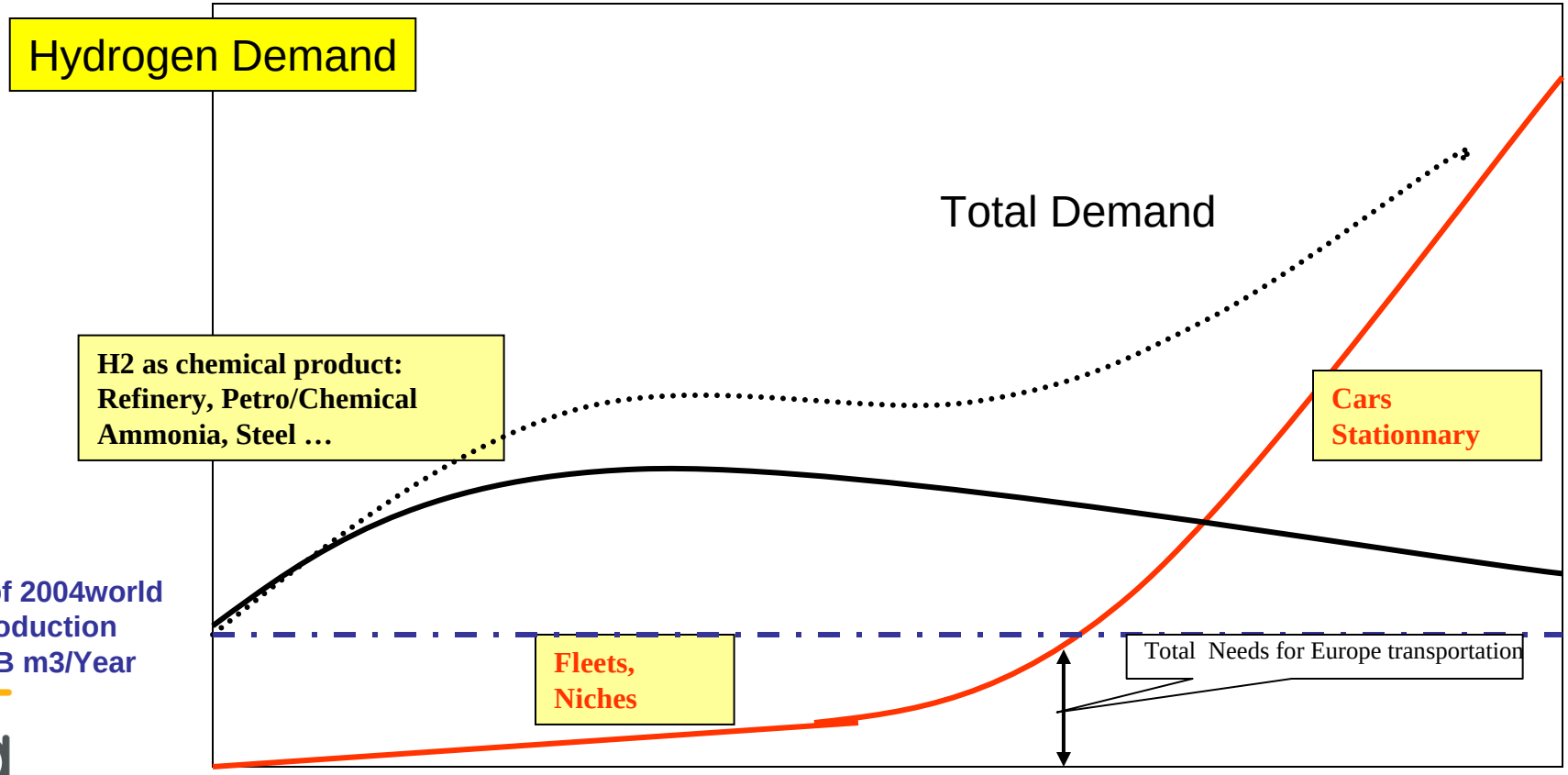
HYDROGEN PRODUCTION SCOPING PAPER: R&D for Alternative production processes

Short summary and propositions

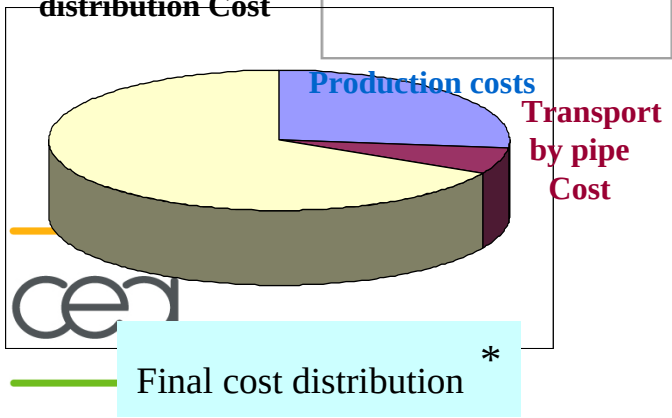
Paul Lucchese
CEA, France
With the contribution of Australia, Brazil, Canada, Germany, Iceland, Italy, USA, Japan, Korea, Norway, EC

Hydrogen Supply : a key point of future H2 Economy



Hydrogen Production Today : a Hydrogen Chain issue

Process	Production	Primary energy cost	H2 production cost $/GJ	Final cost for end user (Infrastruture & delivery included)
Reference: gasoline 2003	Extraction Refinery		Gasoline : 6 $/GJ	gasoline : 8 $/GJ
Natural Gas reforming	Centralized 3 M m3/day	3$/GJ (8 $/GJ)	5-8 $/GJ (9-14 $/GJ)	22-30 $/GJ
Natural gas reforming	decentralized	4-5 $/GJ	7-12 $/GJ	28-33 $/GJ
Coal gasification	Centralized	1,2 $/GJ	13-16 $/GJ	32-37 $/GJ
Biomass gasification	Intermediate	2,4 $/GJ	17-22 $/GJ	33-40 $/GJ
Electrolyse	Décentralized	14$/GJ (5 c$/kWh)	18-25 $/GJ	35-40 $/GJ



- Needs to Alternative production processes
- Needs to reduce Hydrogen Chain costs !!!!!

Hydrogen production Issues (1)

- **Situation of Hydrogen production: opposite of fuel cells situation**:
  - Hydrogen production processes exists today at relatively cheap conditions (less than 1€/kg in large plant) and in massive quantity (550 Billions M3/year) but not largely distributed (industrial use only)
  - In the future, Hydrogen will become probably more and more expensive than today; new energy economy in the next decades will be characterized by
    - High cost for fossil fuels
    - Taken into account externalities such CO2 emissions (CO2 taxes)
  - Clean, sustainable processes for relatively cheap and massive hydrogen do not exist today: electrolysis with renewable electricity exists today but very expensive

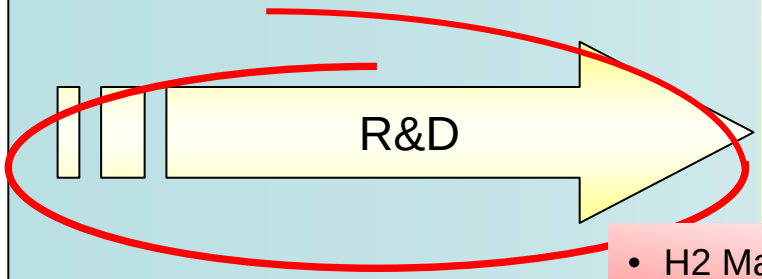
Hydrogen production Issues (2)

- **Objectives of International R&D Collaborative projects**
  - Propose no so expensive Hydrogen for customers or at least tolerable costs in a new and sustainable energy economy.
  - Propose clean processes and chain including primary energy sources
  - Use other energy sources than too sensitive or limited energy like oil, natural gas
  - Propose different **transition phases** to pass from one step to another step during next decades and to test at industrial scale different solutions, components
- **Medium/long term R&D effort is needed:**
  - Hydrogen production linked with Primary energy and Energy policy
    - ORDER OF MAGNITUDE OF TIME SCALE IN ENERGY IS DECADES
  - We have to start now to be ready in 30 years for new processes
    - R&D, demonstration, prototype, deployment phase
- Take into account transport/distribution Chain
- Evaluation on multi criteria basis

Hydrogen Production Road Map

Phase 1	Phase 2	Phase 3	Phase 4
Carbon Content Processes	Fossils & Sequestration	Clean Energy	Sustainable Development

Strategy for sustainable H2 production



- H2 massive production by solar furnaces
- H2 massive production by nuclear plants (Gén IV)
- H2 massive production from other renewables biological/PEC processes ?

- H2 prod. by renewable energy (solar, geoth, ..)
- H2 massive production by fusion & fission nuclear

- H2 Massive production from coal
- gasification with CO2 sequestration

Demonstration

- H2 Production starting from hydrocarbons H2 with CO2 sequestration
- Delocalized production by renewable energies

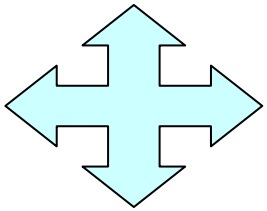
H_2 Production starting from hydrocarbons

Different criteria to classify Hydrogen production processes:

- **Temperature**: low (< 150°C), medium(200-400°C)-high (>500°C°) range;
- Use of **thermal** (gasification, thermochemical, cracking/decomposition, catalytic decomposition), **electricity** (electrolysis, plasma), **light** (photobiology, photoelectrochemistry), or hybrid energy (high temperature electrolysis, combined cycles…); **Hybrid system**
- **carbon**, or no carbon, containing feed stock;
- type of **primary energy** : renewables, fossils, nuclear; and
- **decentralized/ centralized** processes

Creation of a task force on Hydrogen production innovative processes

- Experts from all type of innovative processes
  - From Research/Academic and from Industry origin
- Taken into account all existing expert group and using results from them
  - For example: IEA/HIA Annexes on Photoelectrochemical, biological, high temperature processes

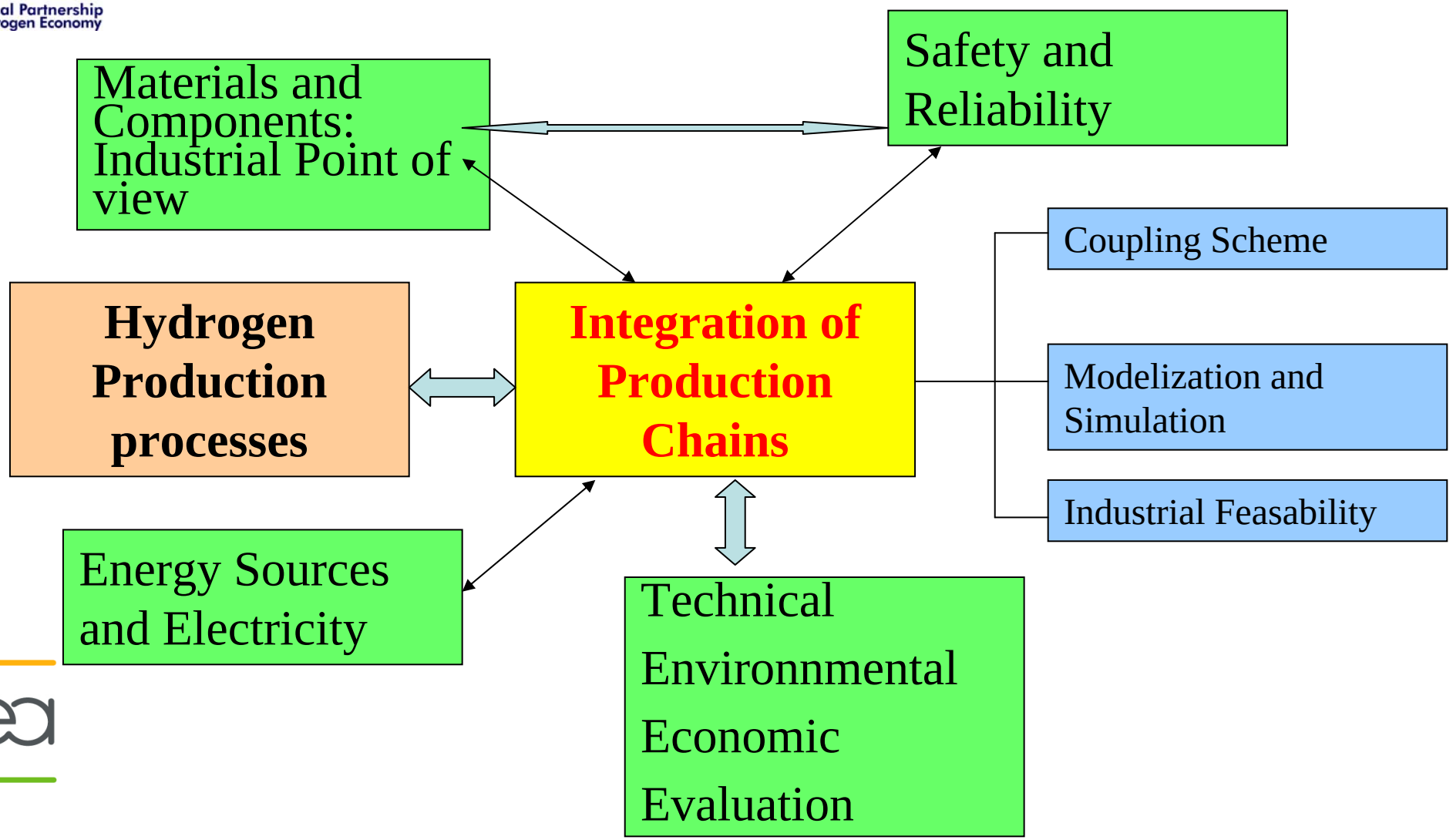


Bilateral cooperations
Gen IV Framework
Sushy Pro

Recommendations for IPHE collaboration on H2 production

- Focus Collaboration on **Innovative and pre competitive R&D processes:**
  - Short/medium term processes: Technological breakthroughs, innovations on classical processes or processes using Hydrocarbons
  - Medium/long term processes: Developping new processes with clean sources (renewables, nuclear)
    - **High temperature processes**
    - **Low temperature processes**
- **Define, promote and compare demonstrations/prototypes and « hybrid » or intermediate demonstrations:**
  - Example in Industrial needs : solar energy and natural gas, hydrogen for refinery, oil recovery
  - Cogeneration (H2/electricity) Heat ? experiments
  - Scale up processes: from lab to large scale for massive production
  - Tests of critical components, critical technologies
- **Develop a common evaluation and assessment of processes and give common perspectives**

Example of a global evaluation of processes



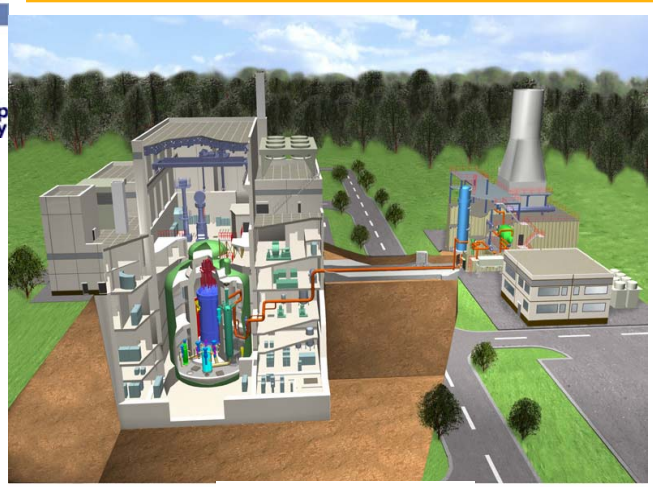
Actions and Deliverables of the Task Force(1)

- Creation of the task Force: mid 2005
- Annual report on R&D/Demonstration program/Experimental plat form/Facilities in the IPHE countries on Hydrogen Production innovative processes
- Compilation of reports and benchmark results (database)
- Conference in Sevilla, 18-20 October 2005 Hydrogen production from Renewables
- Experts Workshop in 2005
- Evaluation and link with others scientific fields/fundamental research to apply to hydrogen production

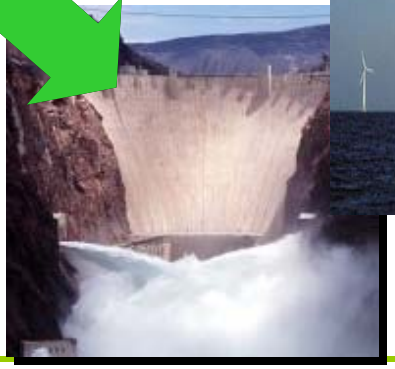
Actions and Deliverables of the Task Force (2)

- Definition of potential intermediate demonstration projects (2020-2030) and developping methodology to define such projects. Identify and promote large scale demonstration by 2010.
- Developping a common and agreed approach (methodology, criteria, data evaluation, benchmarking…) to assessing future innovative hydrogen production processes. Link with socio-economic task.
- Establishing bridge between hydrogen production processes and needs of the different countries of IPHE. Technology transfer conditions and early demonstrations

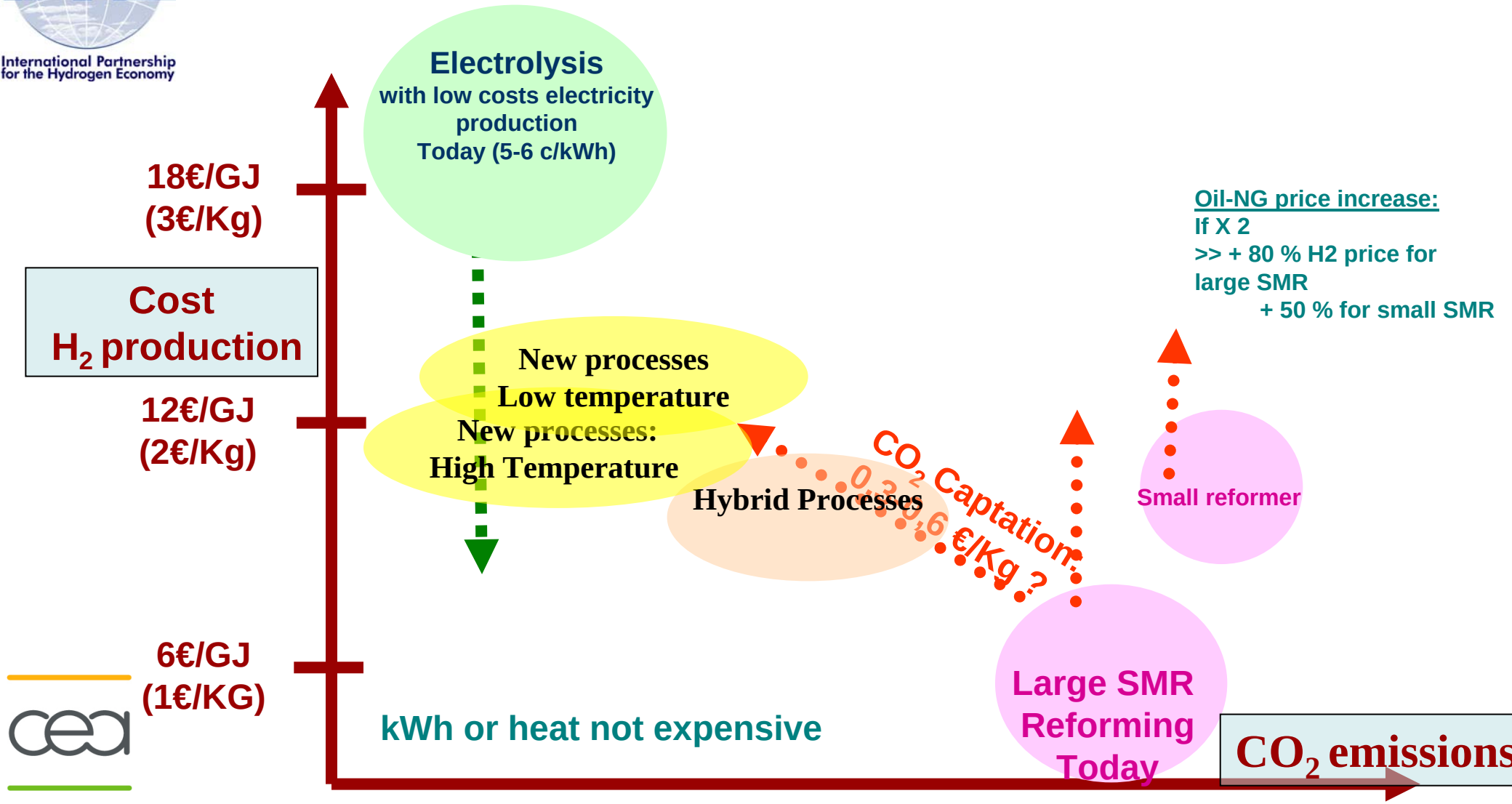
Production of hydrogen for the future



Thank You !!!

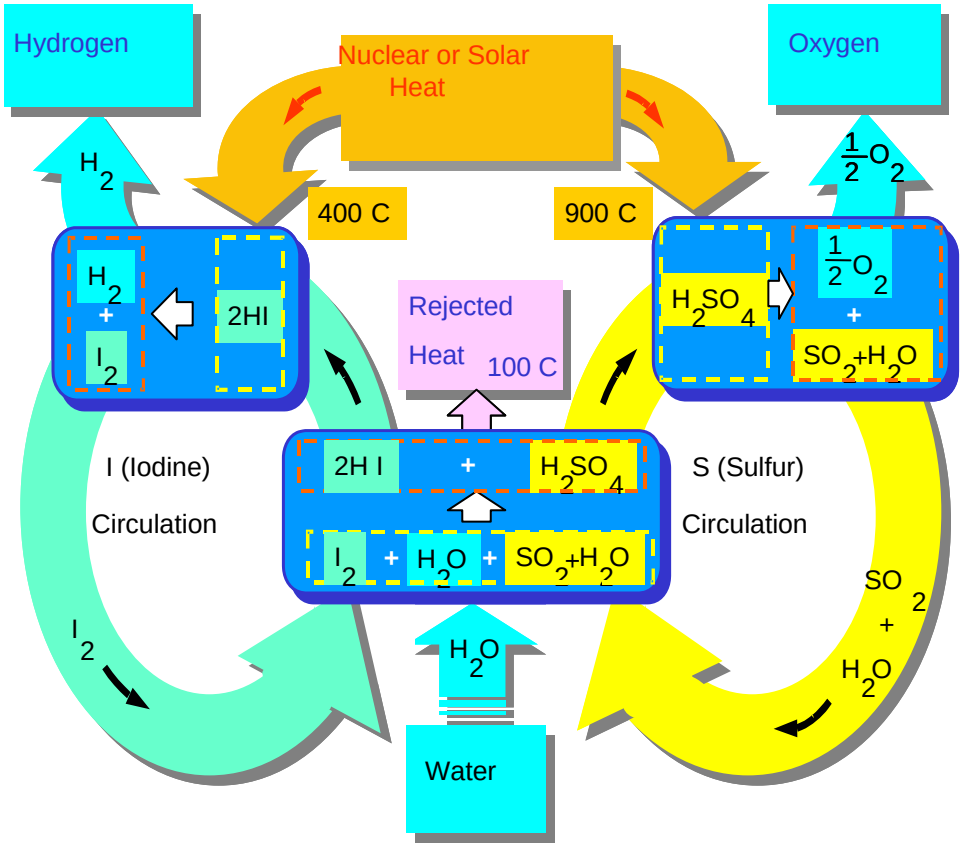


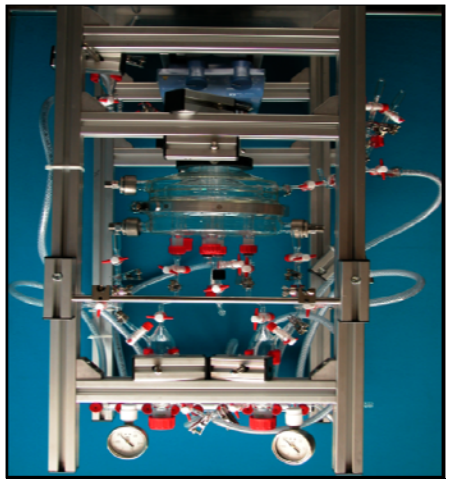
Hydrogen chain: economy of H2 production only



Example of a thermochemical cycle:

Iodine/sulfur Hydrogen water splitting process





- Lack of thermodynamic and kinetics data
- To reach energy efficiency (around 50 %)
- Material issues:
  - Corrosion
  - High temperature
- Distillation problems: needs for innovative membranes, study of distillative-reactive column concept
- Advanced heat exchangers
- Safety problem :
  - Chemical plant
  - Hydrogen
  - Nuclear
- Coupling with nuclear plant