HyWays

Handbook
Member State Energy Pathway Analysis
WP1, WP2 and WP3

Ulrich Bünger on behalf of the WP1 / WP2 partners

27 April 2004

Contents

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Background

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Introduction

A major task in identifying the roadmap towards hydrogen energy in Europe member state by member state is to choose relevant energy pathways along which hydrogen will be provided, distributed/transported and supplied to the end-user.

This task has been split in two work packages: WP1 - Data Provision and WP2 - Energy Pathway Analysis.

This handbook provides an introduction into the methodology and tools used for this process. It is meant as user guide for those member states which are observers in Phase I and will become full partners in Phase II.

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Issues to be Addressed

Which are the most relevant 5 - 6 member state specific hyrogen energy chains (WtW/StU or combined) and processes (**Phase I:** 6 member states, **Phase II:** further 6 member states) concerning

- individual geographical and climatic conditions,
- primary energy resource situation and
- policy orientation?

Which are the relevant regionalised processes and the specific techno-economic input data or regional limitations?

Which are the global energy chain and individual process efficiencies, GHG emissions and (micro-economic) hydrogen supply costs for the chains identified?

Which are common and different energy chains between member states?

Methodology

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The member states experts and stakeholders are „coached“ by the WP1/WP2 modelling partners CEA, ECN and LBST, iteratively comprising the following steps:

	Participants
1. Identification of relevant hydrogen energy pathways Well-to-Wheel (WtW) for road transport and Source-to-User (StU) for all other applications	MS experts, industry
2. Structuring of the hydrogen energy pathways	WP1 / WP2 partners
3. Identification of data gaps	WP1 partners
4. Data provision	WP1 partners, external*
5. Incorporation of data in relational database	WP1 partners
6. Calculation of CO_2 equivalent emissions and costs	CEA, ECN, LBST
7. Interpretation of results and screening of pathways	WP2 partners

* Original dataset based on CONCAWE, EUCAR, JRC WtW study in E3 Database

Choice of Potential Hydrogen Energy Chains

Choice of Potential Hydrogen Energy Chains (1)

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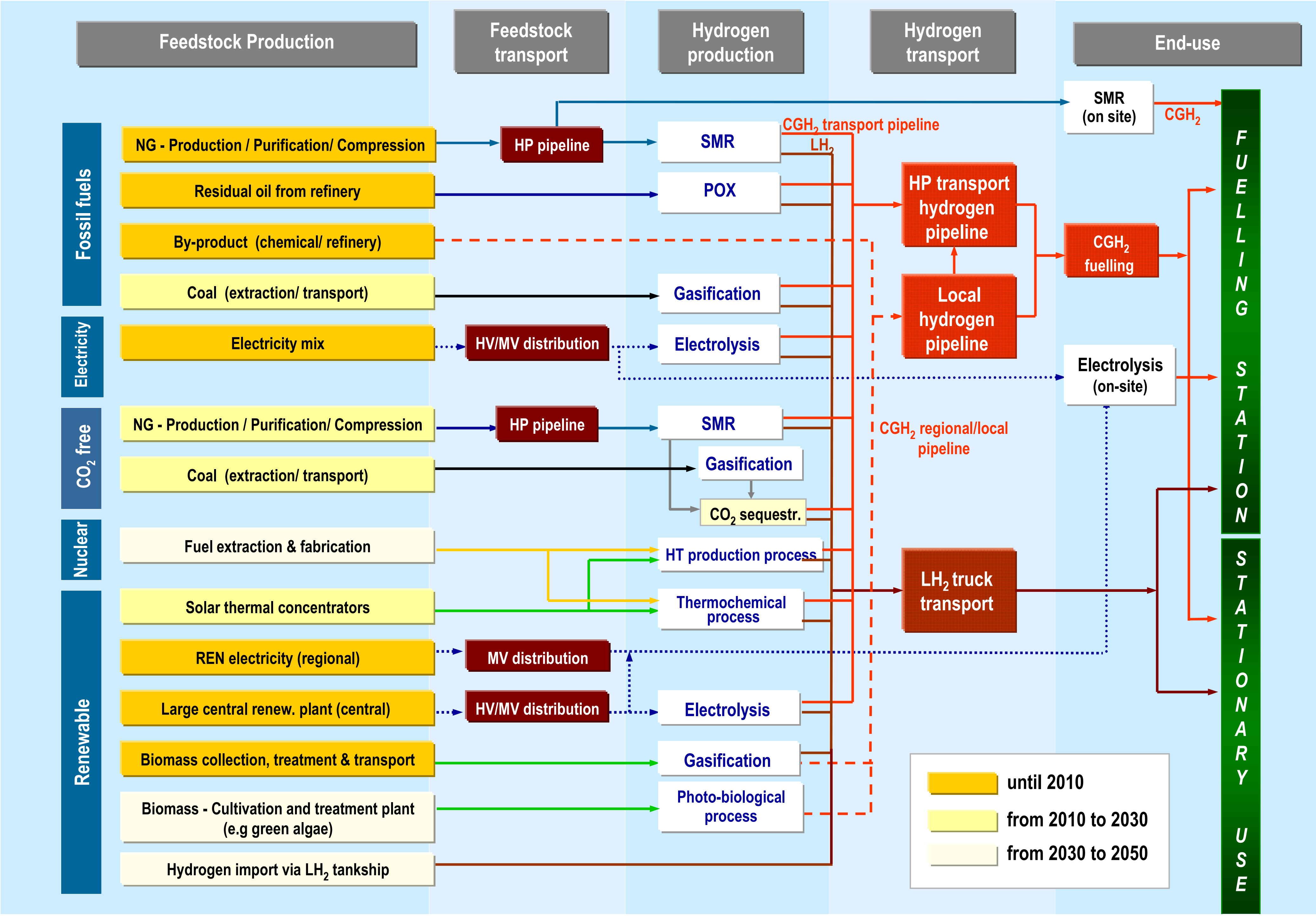
About 5 - 7 individual major hydrogen energy chains, characterised by their hydrogen provision, should be proposed by each member state.

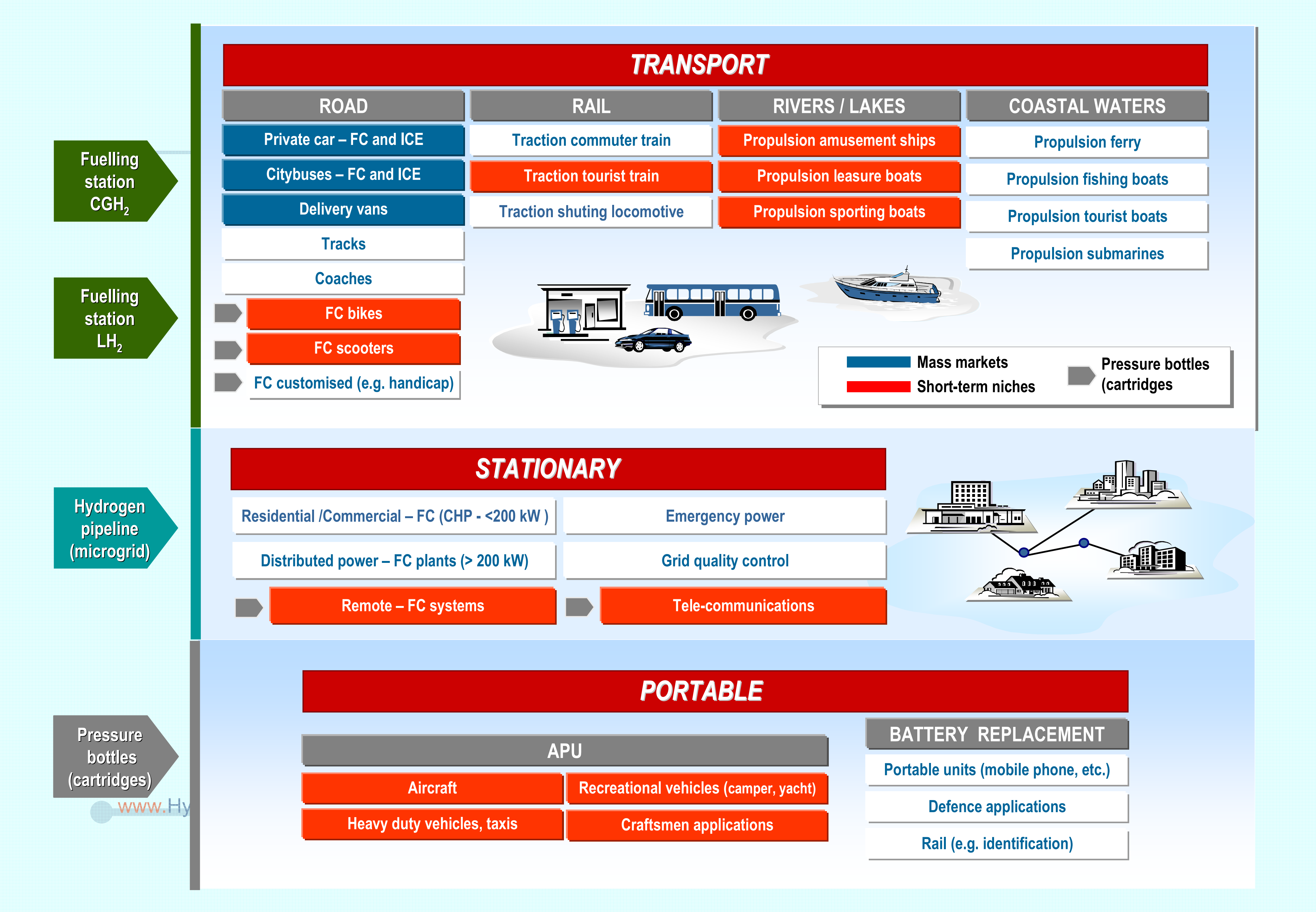
To choose possible hydrogen energy chains new HyWays member state partners are advised to study the following pages:

- Overview graph of potential chains from fossil, electricity mix, CO_2-free or -reduced and renewable energy (slide 10)
- Overview graph of potential hydrogen end-use applications (slide 11)
- Tables on potential pathways for the periods < 2010 (slide 13 - 14), 2010 - 2030 (slide 15 - 17) and 2030 - 2050 (slide 18 - 20) for the different energy sources

The energy chains under consideration in each member state should be grouped accordingly.



Feedstock Production
Feedstock transport
Hydrogen production
Hydrogen transport
End-use
Fossil fuels
Electricity
CO2 free
Nuclear
Renewable
NG - Production / Purification/ Compression
Residual oil from refinery
By-product (chemical/ refinery)
Coal (extraction/ transport)
Electricity mix
NG - Production / Purification/ Compression
Coal (extraction/ transport)
Fuel extraction & fabrication
Solar thermal concentrators
REN electricity (regional)
Large central renew. plant (central)
Biomass collection, treatment & transport
Biomass - Cultivation and treatment plant (e.g green algae)
Hydrogen import via LH2 tankship
HP pipeline
HV/MV distribution
HP pipeline
MV distribution
HV/MV distribution
SMR
POX
Gasification
Electrolysis
SMR
Gasification
CO2 sequestr.
HT production process
Thermochemical process
Electrolysis
Gasification
Photo-biological process
CGH2 transport pipeline
LH2
HP transport hydrogen pipeline
Local hydrogen pipeline
CGH2 regional/local pipeline
LH2 truck transport
SMR (on site)
CGH2
CGH2 fuelling
Electrolysis (on-site)
FUELLING STATION
STATIONARY USE
until 2010
from 2010 to 2030
from 2030 to 2050



Fuelling station CGH_2
Fuelling station LH_2
Hydrogen pipeline (microgrid)
Pressure bottles (cartridges)
TRANSPORT
ROAD
Private car – FC and ICE
Citybuses – FC and ICE
Delivery vans
Tracks
Coaches
FC bikes
FC scooters
FC customised (e.g. handicap)
RAIL
Traction commuter train
Traction tourist train
Traction shuting locomotive
RIVERS / LAKES
Propulsion amusement ships
Propulsion leasure boats
Propulsion sporting boats
COASTAL WATERS
Propulsion ferry
Propulsion fishing boats
Propulsion tourist boats
Propulsion submarines
Mass markets
Short-term niches
Pressure bottles (cartridges
STATIONARY
Residential /Commercial – FC (CHP - <200 kW)
Emergency power
Distributed power – FC plants (> 200 kW)
Grid quality control
Remote – FC systems
Tele-communications
PORTABLE
APU
Aircraft
Recreational vehicles (camper, yacht)
Heavy duty vehicles, taxis
Craftsmen applications
BATTERY REPLACEMENT
Portable units (mobile phone, etc.)
Defence applications
Rail (e.g. identification)

Definitions

For the location of the plants 3 cases are distinguished at this stage:

- **Remote plants**, involving HVDC electricity transport or LH_2 ship transport
- **Large plants,** including
  - central (500 km average truck transport distance)*
  - regional (150 km average truck transport or 50 km pipeline distribution distance)*
- **On-site plants,** including small hydrogen microgrids (max. 5 km)* from hydrogen production (e.g. biomass gasifier at city border) to end-use location

* Indicative only. Specific transport distances can vary as a result of the member state specific infrastructure analysis (parallel assessment in WP3)

Choice of Potential Hydrogen Energy Chains (5)

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Hydrogen Energy Chains < 2010: Fossil

No[1]	Energy in[2]	Fuel	Primary processes[3]	Intermediate fuel	Secondary H_2 processes[3]	Remarks[4]	Reference
1. Fossil							
1.1.1	NG	CGH_2	NG production, purification, compression, HP pipeline transport	NG	steam reforming (large), H_2 compression, MP pipeline, CGH_2 fuelling station		
1.1.2		LH_2			steam reforming (large), H_2 liquefaction, truck distribution, $LCGH_2$ fuelling station	All LH_2 stations also supply CGH_2	
1.1.3		CGH_2			steam reforming (on-site), CGH_2 fuelling station		
1.1.4			NG production, purification, liquefaction (LNG), ship transport, HP pipeline transport		steam reforming (large), H_2 compression, MP pipeline, CGH_2 fuelling station		
1.1.5		LH_2			steam reforming (large), H_2 liquefaction, truck distribution, $LCGH_2$ fuelling station	All LH_2 stations also supply CGH_2	
1.1.6		CGH_2			steam reforming (on-site), CGH_2 fuelling station		
1.2.1	Mineral oil	CGH_2	(Oil production, transport by ship,) residual oil from refinery	Residual oil	Partial oxidation (large), H_2 compression, MP pipeline, CGH_2 fuelling station	Realistically, only residual oil will be converted to hydrogen	
1.2.2		LH_2			Partial oxidation (large), H_2 liquefaction, truck distribution, $LCGH_2$ fuelling station	All LH_2 stations also supply CGH_2	
1.4.1	By-product	CGH_2	GHG-emissions equivalent with e.g. NG, possibly purification and compression	GH_2	MP distribution pipeline, CGH_2 fuelling station	By-product supply is depending inherently on the underlying process	

[1] 1 – fossil; 2 – CO_2-reduced or -free; 3 – renewable
[2] E.g. mineral oil, MS specific natural gas mix or NG from well, nuclear electricity, MS specific electricity mix, residual wood
[3] Major processes (if relevant with intermediate flows)
[4] CONCAWE/EUCAR/JRC well to wheel study by LBST

Choice of Potential Hydrogen Energy Chains (6)

Hydrogen Energy Chains < 2010: Electricity Mix, Reduced CO_2, Renewable

2. Electricity Mix							
2.1.1	Electricity mix (depending on spec. MS situation)	CGH_2	Electricity production mix, HV/MV transport and distribution	Electricity	H_2O electrolysis, CGH_2 fuelling station	Electricity from a mix of fossil, nuclear and renewable sources	
2.1.2		LH_2			H_2O electrolysis, H_2 liquefaction. , truck distribution , $LCGH_2$ fuelling station	All LH_2 stations also supply CGH_2	
2.1.3		CGH_2			H_2O electrolysis, H_2 liquefaction. , truck distribution , $LCGH_2$ fuelling station	All LH_2 stations also supply CGH_2	
3. Reduced CO_2							
4. Renewable							
4.1.1	Renewable electricity	CGH_2	Electricity production (e.g. hydropower), MV transport and distribution	Electricity	H_2O electrolysis, H_2 microgrid, CGH_2 fuelling station	Dedicated electricity	
4.1.2	Large central renewable electricity		Electricity production (e.g. wind-offshore), HV/MV transport and distribution		H_2O electrolysis, H_2 microgrid, CGH_2 fuelling station	Dedicated electricity	
4.1.3		$LCGH_2$			H_2O electrolysis, H_2 liquefaction, truck distribution, $LCGH_2$ fuelling station	Dedicated electricity	
4.2.4	Biomass gasification	CGH_2	Biomass collection, treatment (e.g. drying) and transport (e.g. 50 km radius)	Pre-trearted biomass	Gasification, hydrogen microgrid (e.g. 5 km), CGH_2 fueling station		

[1] 1 – fossil; 2 – CO_2-reduced or -free; 3 – renewable
[2] E.g. mineral oil, MS specific natural gas mix or NG from well, nuclear electricity, MS specific electricity mix, residual wood
[3] Major processes (if relevant with intermediate flows)
[4] CONCAWE/EUCAR/JRC well to wheel study by LBST

Choice of Potential Hydrogen Energy Chains (7)

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Hydrogen Energy Chains 2010 - 2020: Fossil

No[1]	Energy in[2]	Fuel	Primary processes[3]	Intermediate fuel	Secondary H_2 processes[3]	Remarks[4]	Reference
1. Fossil							
1.1.1	NG	CGH_2	NG production, purification, compression, HP pipeline transport	NG	steam reforming (large), H_2 purification & compression, MP pipeline, CGH_2 fuelling station		
1.1.2		LH_2			steam reforming (large), H_2 purification & liquefaction, truck distribution, $LCGH_2$ fuelling station	All LH_2 stations also supply CGH_2	
1.1.3		CGH_2			steam reforming (on-site), CGH_2 fuelling station		
1.1.4		CGH_2	NG production, purification, liquefaction (LNG), ship transport, HP pipeline transport		steam reforming (large), H_2 purification & compression, MP pipeline, CGH_2 fuelling station		
1.1.5		LH_2			steam reforming (large), H_2 purification & liquefaction, truck distribution, $LCGH_2$ fuelling station	All LH_2 stations also supply CGH_2	
1.1.6		CGH_2			steam reforming (on-site), CGH_2 fuelling station		
1.2.1	Mineral oil	CGH_2	(Oil production, transport by ship,) residual oil from refinery	Residual oil	Partial oxidation (large), H_2 purification & compression, MP pipeline, CGH_2 fuelling station	Only residual oil will be converted to hydrogen (possible decrease of available H_2 due to higher use of H_2 for refinery purposes)	
1.2.2		LH_2			Partial oxidation (large), H_2 purification & liquefaction, truck distribution, $LCGH_2$ fuelling station	All LH_2 stations also supply CGH_2	
1.3.1	Coal	CGH_2	Coal extraction, transport (ship or rail)	Coal	Partial oxidation (large), H_2 purification & compression, MP pipeline, CGH_2 fuelling station		
1.3.2		LH_2			Partial oxidation (large), H_2 purification & liquefaction, truck distribution, $LCGH_2$ fuelling station	All LH_2 stations also supply CGH_2	
1.4.1	By-product	CGH_2	GHG-emissions equivalent with e.g. NG, possibly purification and compression	GH_2	MP distribution pipeline, CGH_2 fuelling station	By-product supply is depending inherently on the underlying process	

[1] 1 – fossil; 2 – CO_2-reduced or -free; 3 – renewable
[2] E.g. mineral oil, MS specific natural gas mix or NG from well, nuclear electricity, MS specific electricity mix, residual wood
[3] Major processes (if relevant with intermediate flows)
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Hydrogen Energy Chains 2010 - 2020: Electricity Mix, Reduced CO_2

2. Electricity Mix							
2.1.1	Electricity mix (depending on spec. MS situation)	CGH_2	Electricity production mix, HV/MV transport and distribution	Electricity	H_2O electrolysis, CGH_2 fuelling station	Electricity from a mix of fossil, nuclear and renewable sources H_2 can be used in order to equalise the energy demand along the day	
2.1.2		LH_2			H_2O electrolysis, H_2 purification & liquefaction. , truck distribution , $LCGH_2$ fuelling station	All LH_2 stations also supply CGH_2	
3. Reduced or CO_2 free							
3.1.1	NG	CGH_2	NG production, purification, compression, HP pipeline transport	NG	steam reforming (large), CO_2 capture and sequestration (total or partial), H_2 purification & compression, MP pipeline, CGH_2 fuelling station	Plant can be built near sequestration sites, due to wide NG network	
3.1.2		LH_2			steam reforming (large), CO_2 capture and sequestration (total or partial), H_2 purification & liquefaction, truck distribution, $LCGH_2$ fuelling station	All LH_2 stations also supply CGH_2	
3.2.1	Coal	CGH_2	Coal extraction, transport (ship or rail)	Coal	Partial oxidation (large), CO_2 capture and sequestration (total or partial), H_2 purification & compression, MP pipeline, CGH_2 fuelling station	Different ways to transport CO_2 to sequestration sites, depending on the distance from plant	
3.2.2		LH_2			Partial oxidation (large), CO_2 capture and sequestration (total or partial), H_2 purification & liquefaction, truck distribution, $LCGH_2$ fuelling station	All LH_2 stations also supply CGH_2	
3.3.1	Nuclear	CGH_2	Nuclear fuel extraction and fabrication	Nuclear	Direct high temperature conversion, H_2 purification & compression, MP pipeline, CGH_2 fuelling station		
3.3.2		LH_2			Direct high temperature conversion, H_2 purification & liquefaction, truck distribution, $LCGH_2$ fuelling station	All LH_2 stations also supply CGH_2	

[1] 1 – fossil; 2 – CO_2-reduced or -free; 3 – renewable
[2] E.g. mineral oil, MS specific natural gas mix or NG from well, nuclear electricity, MS specific electricity mix, residual wood
[3] Major processes (if relevant with intermediate flows)
[4] CONCAWE/EUCAR/JRC well to wheel study by LBST

Choice of Potential Hydrogen Energy Chains (9)

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Hydrogen Energy Chains 2010 - 2020: Renewable

4. Renewable							
4.1.1	Renewable electricity	CGH_2	Electricity production (e.g. hydropower), MV transport to H_2 conversion plant	Electricity	H_2O electrolysis, H_2 micro grid, CGH_2 fuelling station		
4.1.2	Large central renewable electricity	CGH_2	Electricity production (e.g. wind-offshore), direct HV/MV transport to H_2 conversion plant		H_2O electrolysis, MP pipeline and/or H_2 micro grid , CGH_2 fuelling station	H_2 can be used in order to equalise the energy demand along the day, whenever renewable electricity production exceeds 15-20%	
4.1.3		$LCGH_2$			H_2O electrolysis, H_2 purification & liquefaction, truck distribution, $LCGH_2$ fuelling station		
4.2.1	Biomass	CGH_2	Biomass collection, treatment (e.g. drying) and transport to process plant	Biomass (wood residues, straw, cultivated plants, wastes)	H_2 production and purification, CGH_2 fuelling station		
4.2.2		LH_2			H_2 production and purification, H_2 purification & liquefaction, truck distribution, $LCGH_2$ fuelling station		
4.3.1	Solar	CGH_2	Solar collectors and thermal conversion	Solar energy	H_2 production, H_2 micro grid, CGH_2 fuelling station		

[1] 1 – fossil; 2 – CO_2-reduced or -free; 3 – renewable
[2] E.g. mineral oil, MS specific natural gas mix or NG from well, nuclear electricity, MS specific electricity mix, residual wood
[3] Major processes (if relevant with intermediate flows)
[4] CONCAWE/EUCAR/JRC well to wheel study by LBST

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Hydrogen Energy Chains 2030 - 2050: Fossil

No[1]	Energy in[2]	Fuel	Primary processes[3]	Intermediate fuel	Secondary H_2 processes[3]	Remarks[4]	Reference
1. Fossil							
1.1.1	NG	CGH_2	NG production, purification, compression, HP pipeline transport	NG	steam reforming (large), H_2 purification & compression, MP pipeline, CGH_2 fuelling station		
1.1.2		LH_2			steam reforming (large), H_2 purification & liquefaction, truck distribution, $LCGH_2$ fuelling station	All LH_2 stations also supply CGH_2	
1.1.3		CGH_2			steam reforming (on-site), CGH_2 fuelling station		
1.1.4		CGH_2	NG production, purification, liquefaction (LNG), ship transport, HP pipeline transport		steam reforming (large), H_2 purification & compression, MP pipeline, CGH_2 fuelling station		
1.1.5		LH_2			steam reforming (large), H_2 purification & liquefaction, truck distribution, $LCGH_2$ fuelling station	All LH_2 stations also supply CGH_2	
1.1.6		CGH_2			steam reforming (on-site), CGH_2 fuelling station		
1.2.1	Mineral oil	CGH_2	(Oil production, transport by ship,) residual oil from refinery	Residual oil	Partial oxidation (large), H_2 purification & compression, MP pipeline, CGH_2 fuelling station	Only residual oil will be converted to hydrogen (possible decrease of available H_2 due to higher use of H_2 for refinery purposes)	
1.2.2		LH_2			Partial oxidation (large), H_2 purification & liquefaction, truck distribution, $LCGH_2$ fuelling station	All LH_2 stations also supply CGH_2	
1.3.1	By-product	CGH_2	GHG-emissions equivalent with e.g. NG, possibly purification and compression	GH_2	MP distribution pipeline, CGH_2 fuelling station	By-product supply is depending inherently on the underlying process	
1.4.1	Coal	CGH_2	Coal extraction, transport (ship or rail)	Coal	Gasification (large), H_2 purification & compression, MP pipeline, CGH_2 fuelling station		
1.4.2		LH_2			Gasification (large), H_2 purification & liquefaction, truck distribution, $LCGH_2$ fuelling station	All LH_2 stations also supply CGH_2	

[1] 1 – fossil; 2 – CO_2-reduced or -free; 3 – renewable
[2] E.g. mineral oil, MS specific natural gas mix or NG from well, nuclear electricity, MS specific electricity mix, residual wood
[3] Major processes (if relevant with intermediate flows)
[4] CONCAWE/EUCAR/JRC well to wheel study by LBST

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Hydrogen Energy Chains 2030 - 2050: Electricity Mix, Reduced CO_2

2. Electricity Mix							
2.1.1	Electricity mix (depending on spec. MS situation)	CGH_2	Electricity production mix, HV/MV transport and distribution	Electricity	H_2O electrolysis, H_2 compression, MP pipeline, CGH_2 fuelling station	Electricity from a mix of fossil, nuclear and renewable sources H_2 can be used in order to equalise the energy demand along the day	
2.1.2		LH_2			H_2O electrolysis, H_2 liquefaction, truck distribution , $LCGH_2$ fuelling station	All LH_2 stations also supply CGH_2	
3. Reduced or CO_2 free							
3.1.1	NG	CGH_2	NG production, purification, compression, HP pipeline transport	NG	steam reforming (large), CO_2 capture and sequestration (total or partial), H_2 purification & compression, MP pipeline, CGH_2 fuelling station	Plant can be built near sequestration sites, due to wide NG network	
3.1.2		LH_2			steam reforming (large), CO_2 capture and sequestration (total or partial), H_2 purification & liquefaction, truck distribution, $LCGH_2$ fuelling station	All LH_2 stations also supply CGH_2	
3.2.1	Coal	CGH_2	Coal extraction, transport (ship or rail)	Coal	Gasification (large), CO_2 capture and sequestration (total or partial), H_2 purification & compression, MP pipeline, CGH_2 fuelling station	Different ways to transport CO_2 to sequestration sites, depending on the distance from plant	
3.2.2		LH_2			Gasification (large), CO_2 capture and sequestration (total or partial), H_2 purification & liquefaction, truck distribution, $LCGH_2$ fuelling station	All LH_2 stations also supply CGH_2	
3.3.1	Nuclear	CGH_2	Nuclear fuel extraction and fabrication	Nuclear	High temperature production process (large), H_2 compression, MP pipeline, CGH_2 fuelling station		
3.3.2		LH_2			High temperature production process (large), H_2 liquefaction, truck distribution, $LCGH_2$ fuelling station	All LH_2 stations also supply CGH_2	

[1] 1 – fossil; 2 – CO_2-reduced or -free; 3 – renewable
[2] E.g. mineral oil, MS specific natural gas mix or NG from well, nuclear electricity, MS specific electricity mix, residual wood
[3] Major processes (if relevant with intermediate flows)
[4] CONCAWE/EUCAR/JRC well to wheel study by LBST

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Hydrogen Energy Chains 2030 - 2050: Renewable

4. Renewable							
4.1.1	Renewable electricity	CGH_2	Electricity production (e.g. hydropower, minihydro), MV transport to H_2 conversion plant	Electricity	H_2O electrolysis, H_2 micro grid, CGH_2 fuelling station		
4.1.2	Large central renewable electricity	CGH_2	Electricity production (e.g. wind-offshore), direct HV/MV transport to H_2 conversion plant		H_2O electrolysis, MP pipeline and/or H_2 micro grid , CGH_2 fuelling station	H_2 can be used in order to equalise the energy demand along the day, whenever renewable electricity production exceeds 15-20%	
4.1.3		$LCGH_2$			H_2O electrolysis, H_2 purification & liquefaction, truck distribution, $LCGH_2$ fuelling station		
4.2.1	Biomass	CGH_2	Biomass collection, treatment (e.g. drying) and transport to process plant	Biomass (wood residues, straw, cultivated plants, wastes)	Gasification, H_2 purification & compression, MP pipeline, CGH_2 fuelling station		
4.2.2		LH_2			Gasification, H_2 purification & liquefaction, truck distribution, $LCGH_2$ fuelling station		
4.2.3	Biomass	CGH_2	Specific plant (e.g. green algae) cultivation and treatment (tbd)	Cultivated plants	Photo-biological production process, H_2 micro grid, CGH_2 fuelling station		
4.3.1	Solar	CGH_2	Solar collectors and thermal conversion	Solar energy	H_2 production, H_2 micro grid, CGH_2 fuelling station		

[1] 1 – fossil; 2 – CO_2-reduced or -free; 3 – renewable
[2] E.g. mineral oil, MS specific natural gas mix or NG from well, nuclear electricity, MS specific electricity mix, residual wood
[3] Major processes (if relevant with intermediate flows)
[4] CONCAWE/EUCAR/JRC well to wheel study by LBST

E3database

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Glossary (1)

CO_2-Factors	*CO_2-Factors* are factors, how many times more effective a specified gaseous emission is with regard to global warming than carbon dioxide (CO_2) (IPCC 2001: CO_2 = 1; CH_4 = 23, N_2O = 296, etc.)
Energy chain	(also „fuel pathway“) well-to-wheel WtW (transport), source-to-use StU (stationary) or combined *energy chains* from energy source to final energy end-use, consisting of several *Processes* linked by *Material* flows, called *Chain* in E3database.
GHG emissions	equivalent to *CO_2-equivalent* emissions (See *CO_2-Factors*)
„Grey“ energies	Energy for construction, maintenance and scrapping of plants/components
Handbook	A briefing in „presentation format“ about the methodology of WP1 and WP2

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Glossary (2)

Material	*Materials* are inputs and/or outputs of *Processes*, to build links between processes as either input or output of a process. A *Material* can be a material literally (e.g. steel, concrete, etc.) or an energy carrier (e.g. natural gas, crude oil, electricity, etc.) or also a non material entity like a service (e.g. vehicle-km, t-km, etc.).
Process	One element of an *energy chain*
Reference	*Reference* is used for documentation purposes. *Reference* was introduced to store further information about *Material* and *Process sources*. *Material* and *Process* can refer to the same *Reference*.
Regionalisation	Process to adapt *energy chains* to a member state/„political“ region
*Scenario**	List of relevant *energy chains* to be combined for one member state
Toolbox	Collection of guidelines, data and issues for the member state partners to carry out the work in WP1 and WP2

* In the context of E3 Database

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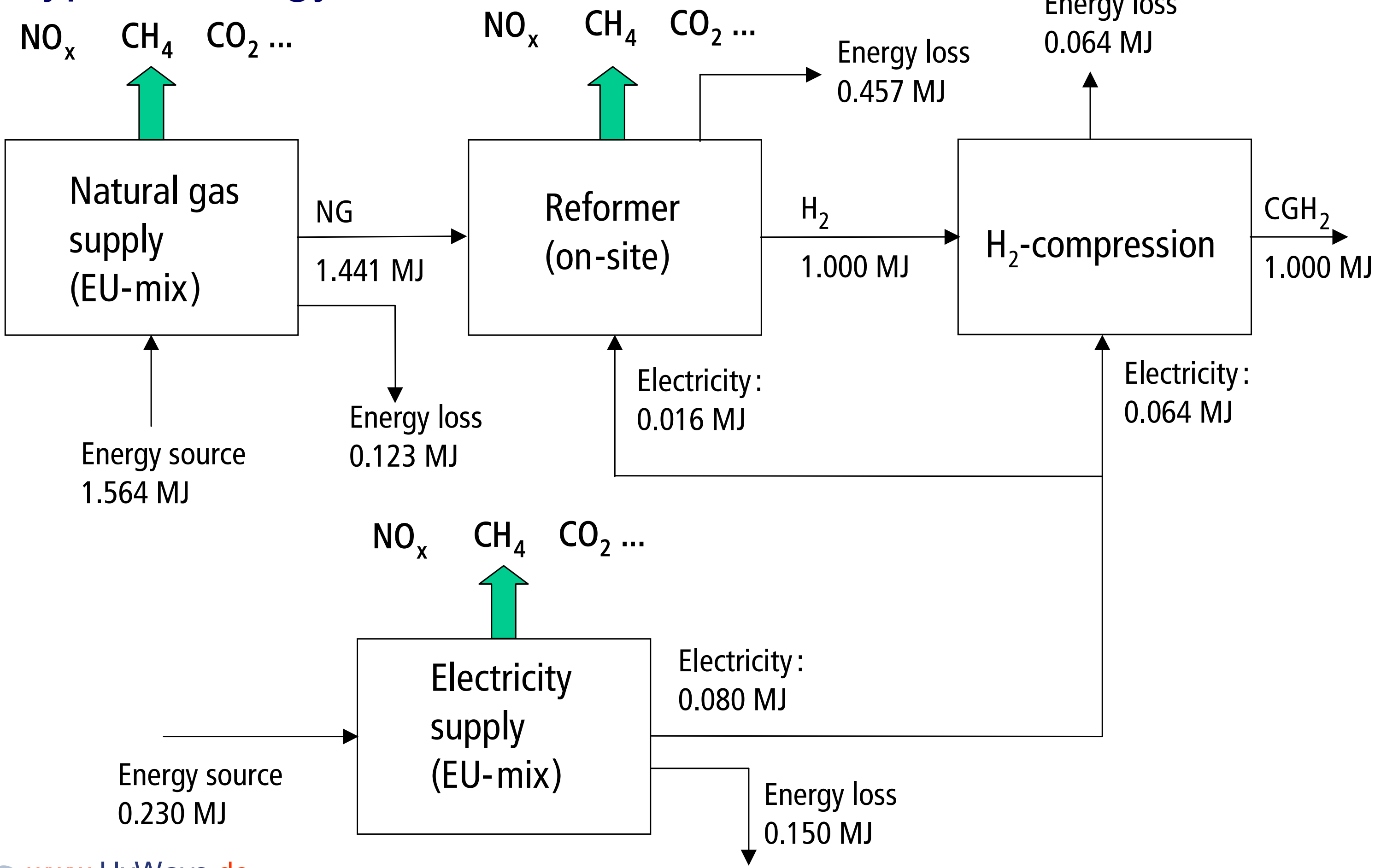
Typical Energy Chain



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Scope

Calculate total efficiency, local/global emissions and (complex) energy chains in iterative runs to accompany the regionalisation process

- use validated input data (harmonised datasets, e.g. CONCAWE/EUCAR/JRC)
- identify data gaps and distribute work load among WP1 / WP2 participants (mainly industry) to acquire data (partially MS specific)
- graphically present energy chains (WtW, StU)
- deliver output data in EXCEL format as interface to economic models (i.e. MARKAL)

E3database (5)

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Type of Input Data

Technology data

- *Material* name, unit (*material* type), *reference*, lower/higher heating value, density, time horizon, process scale, data range (bandwidth), major/secondary *Process* input(s) and output(s)

Emission-specific data

- CO_2-content (derived from carbon content), *CO_2-Factors, specific SO_2, NO_x,... emissions*

Economic data

- construction time, useful lifetime, dismantling time
- further data on separate page

E3database (6)

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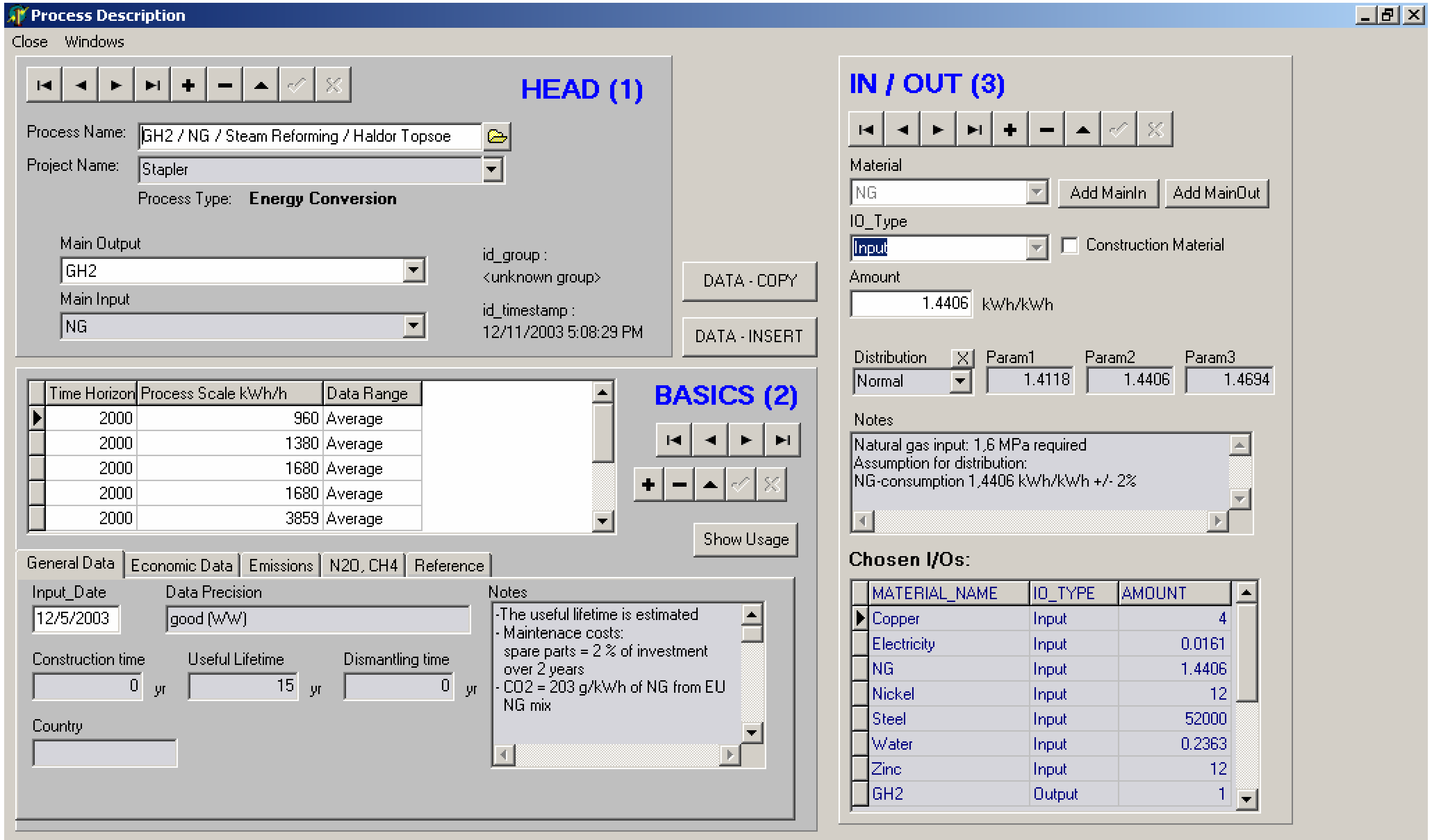
User Interface for Data Input



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Internal Data Organisation

- relational SQL-database
- high flexibility in creating *energy chains* from individual *processes*
- efficient data organisation by storing process variants with individual data modifications
- transparent and repeatable data and information storage

E3database (8)

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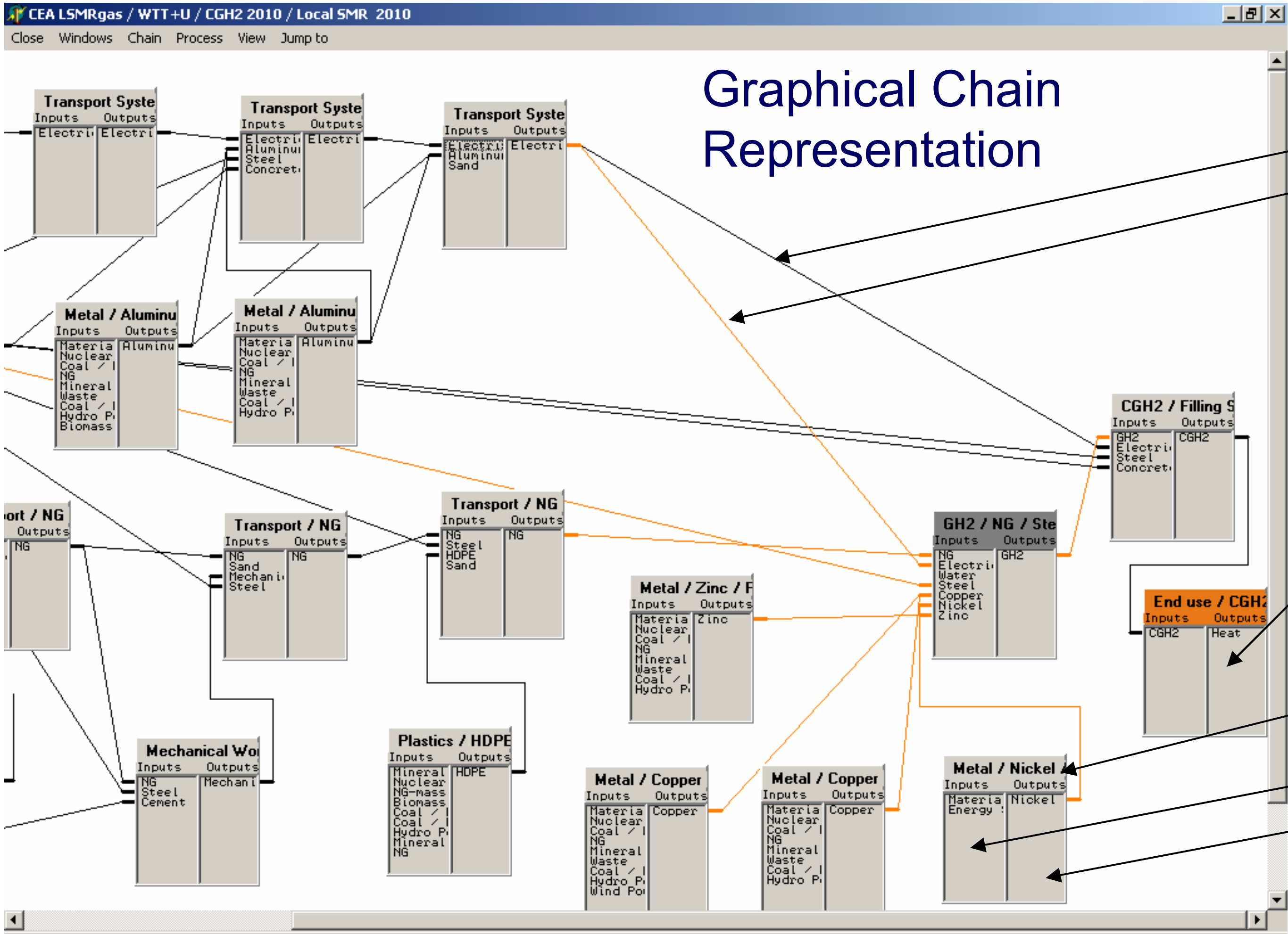

Process link
(Black: normal link
yellow: „detective"
blue: „credit" link)

Tail process
(End of chain)

Process head

Process box
(left: *Material* input,
right: *Material* output)

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Data Output (Extract)

Technological data

- Energy demand or efficiencies of individual processes and chains

Emission-specific data

- CO_2, CH_4, N_2O, SF_6, CF_4 .... emissions
- CO_2-equivalent emissions of energy chains (with or without “grey” energies): net + credit = gross CO_2-emissions
- SO_2, NO_x, ... emissions

Economic data

- specific „levelized“ hydrogen production costs from:
- total costs (construction, operation, dismantling) including:
  - investment costs, capital expenditure and overhead charges
  - operation and maintenance expenditures
  - energy and material supply expenditures

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Special Features

Statistical analysis

- Monte-Carlo analysis can be applied to quantify uncertainties by providing confidence bounds around best estimates
- parametric probability values are determined and then used to stochastically simulate the range of uncertainty for the overall pathway in question
- Every time an energy path is newly calculated certain parameters of some or all processes (i.e. for those processes where distributions are applied) shall assume random values according to predefined probability distributions (energy inputs, material inputs, CH_4-emissions, N_2O-emissions)

Scenario modelling

- mixed supply chains can be analysed to build regional hydrogen supply and demand scenarios

Both features are not applied for HyWays!

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Validity of Data

- E^2/E^3-Database development dates back to projects in ’95
- algorithm validation “by hand” in 1st version
- numerous cross-checks with other worldwide WtW projects
- quality of data output depends on quality of input data
- “industrially validated” database (transport/stationary fuel pathways)*

• Low emission drive systems for urban vehicles (I, P; Germany)	1995
• Transport Energy Strategy (TES) (I, P; Germany)	1998 - 2001
• TAB Fuel Cell Project (P, R; Germany)	1999
• Volkswagen SYNFUEL/SUNFUEL pathways (I; Germany)	2001
• GM WtW Study (I; Germany)	2001 - 2002
• CONCAWE/EUCAR/JRC Ispra (I; EU)	2002 - 2003
• FC-Ship (P, I; EU)	2003 - 2004
• LPG pathways (I; Germany)	2003
• Transport fuel matrix (P; Germany)	2004

* I – industry, P – politics, R – research institutes

Provision of Data

Provision of Data (1)

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Methodology

Each member state expert is coached by one of the WP1/WP2 modellers CEA, ECN and LBST.

1. Derive information gaps from pathways suggested by MSs and document them in structured format in GAPS FILE
2. Define possible data providers in industry (responsible individuals) and responsible modellers (one for each member state) in TASK ASSIGNMENT LIST
3. Use data from CONCAWE, EUCAR, JRC* as default
4. Collect and discuss data with providers and incorporate them in E3 Database, mirrored in TECHNOLOGY FACT SHEETS

* to be downloaded from: http://ies.jrc.cec.eu.int/Download/eh

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Tools

1. **TASK ASSIGNMENT LIST:** Structured task assignment by partner/individual (included in GAPS FILE)
2. **GAPS FILE:** document data requirements in WORD (input for data providers, dynamically updated and posted on HyWays website*)
3. **TECHNOLOGY FACT SHEETS*:** Mirror of techno-economic data used in E3 Database calculations in EXCEL (dynamically updated and posted on HyWays website*)

* to be accessed via: http://www.HyWays.de

Energy Chain Screening

HyWays

Introduction

The screening of energy chains is an **iterative process** moderated by the WP1/WP2 modellers aiming at a reduction of a larger number of alternative energy chains for one member state to a smaller number to be finalised for input to the economic models in WP3.

It will involve HyWays partners from WP1, WP2, WP3 and the member state experts. The member state experts should engage in involving other member state stakeholders in the discussion.

To invoke the process with member state stakeholders and as assistance to the member state experts **central issues** have been raised here.

To alert the E3database modellers the **analysis tasks** and possible **consequences for the Hydrogen Energy Pathways Analysis** have been documented here.

Energy Chain Screening (2)

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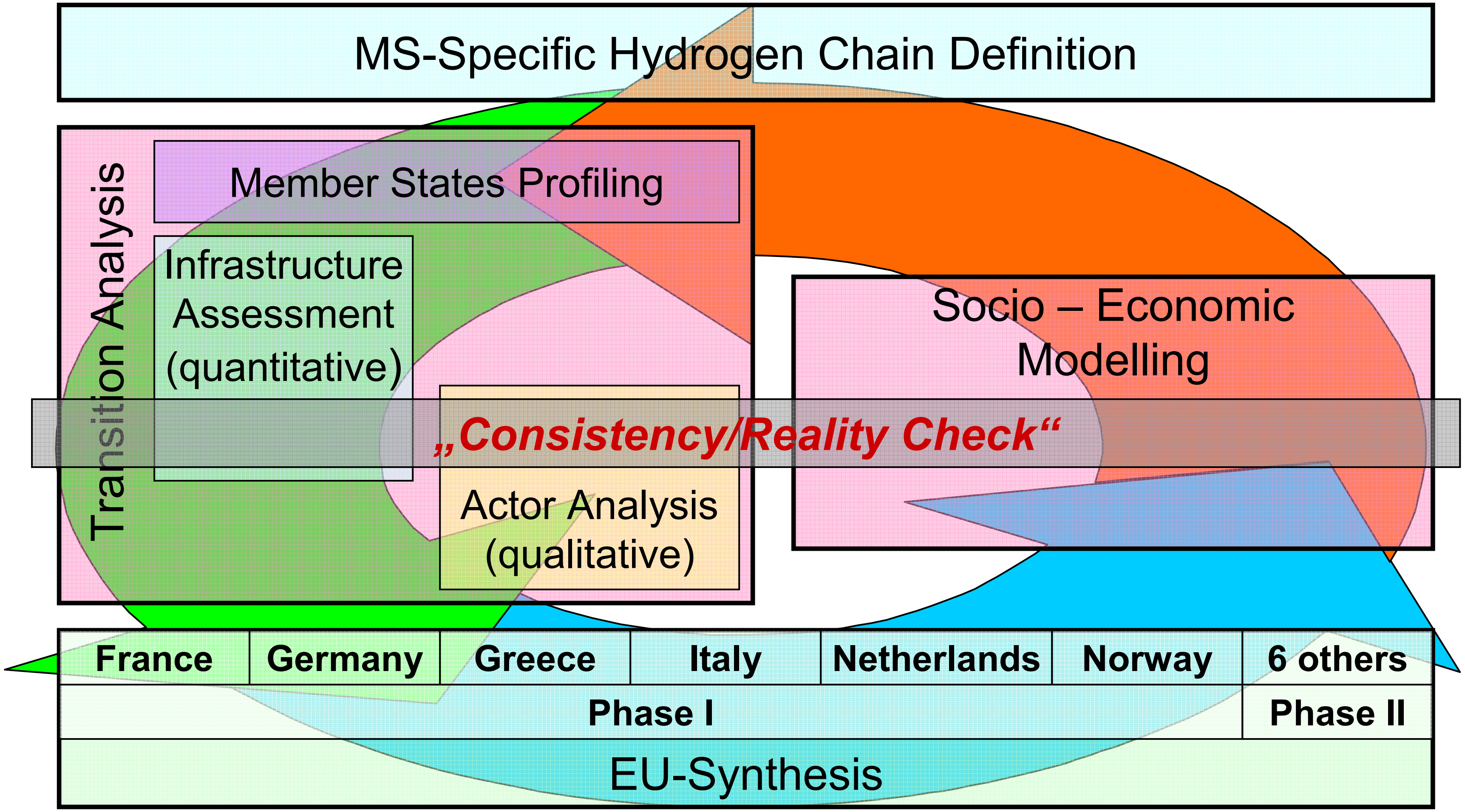

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Issue A: Hydrogen transport infrastructure (Imperial College)

„What determines how hydrogen will be distributed/transported within a specific member state or region?“

or

„Under what condition will a specific infrastructure for distribution/transport of hydrogen be able to develop and what consequences does it have for the hydrogen energy system?“

Issue B: Hydrogen production (IST)

„How will the transition from fossil based hydrogen to renewable hydrogen take place? What are the drivers? What are the barriers?“

or

„If hydrogen technology and infrastructure is introduced mainly based on fossil fuels, how will the transition to renewable based hydrogen take place?“

Issue C: Actor analysis (IST)

„Which actors are involved in building the infrastructure and hydrogen end-use market?"

or

„What is their role, responsibility and commitment?"

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Considerations to identify differences between member states:

- **supply chain** (availability of resources, cost of primary energies and energy transport...)
- **hydrogen transport** (geographical barriers, can existing infrastructure be used, presence of regions with a concentration of potential hydrogen end-users)
- **matching supply and demand** (what is necessary* to make hydrogen follow demand, how flexible is the existing energy infrastructure, **infrastructure build-up:** how is the hydrogen system integrated into the existing energy system)
- **fleet characteristics**** (what mix of vehicles is on the road and how do the specific conditions in the member state affect performance charateristics)
- **stationary system characteristics**** (heat/electricity demand for CHP systems, electricity grid and mix charactersitics influence the type of system to be used in each member state)

* in terms of storage or introduction of flexible production options

** To initiate the discussion the HyWays Scoping Report provides data (www.HyWays.de)

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Analysis Task: Hydrogen Transport Infrastructure

- What is the level of demand in a specific region which is necessary to sustain such a pipeline infrastructure?
- Will hydrogen transport through pipelines be used for "interregional" transport?
- In regions where such a pipeline infrastructure is not feasible, will hydrogen be transported by other methods (e.g. as trucked LH_2) or will it be generated on-site?
- More general, what influence do different methods of transport have on the economic feasibility of end-use sytems (in particular on stationary systems?).
- If hydrogen is to be distributed/transported by pipeline, what intermediate steps are there in building such an infrastructure?

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Energy Chain Consequences: Hydrogen Transport Infrastructure

- To be able to contribute to answering these questions, the chain analysis focuses on comparing different options for transport of hydrogen.
- The discussion of results should not only focus on the total energy chain, but also explicitly report the different steps in the chain. It is important to show explicitly how much cost, emissions and energy losses are associated with transport.
- It is necessary to perform some form of "sensitivity analysis" on the transport section of the chain. How are costs affected by (under-) utilisation of the infrastructure? How are costs influenced by synergy with other chains?

Analysis Task: Hydrogen Production

- How does availability of resources affect the chains.
- Is the infrastructure for hydrogen transport and distribution the same for fossil based as with renewable?
- Will there be a shift in end-use if the system is based on renewable energy instead of fossil fueled? (for example: what stationary end-use makes sense if the system is based on renewable energy)

Energy Chain Consequences: Hydrogen Production

- The energy chain analysis needs to clarify the difference between renewable and fossil based energy chains (required infrastructure, potential and possible end-use).