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E3database

- A Tool for the Evaluation of Energy Chains -

Ludwig-Bölkow-Systemtechnik GmbH (LBST)

Ottobrunn

Tool developed by LBST in cooperation with CEA and IFP

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Overview

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- Aim of the tool
- Description of E3database tool
- Scope and limits of the tool
- Use of E3database

Aim of the tool

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Modelling of (hydrogen) energy chains from “well-to-wheel”.

Calculation of:

- Energy use
- GHG emissions (CO_2, N_2O, CH_4, CF_4, SF_6, HFC 134a)
- Air pollutant emissions (NO_x, SO_2, CO, NMVOC, Dust/PM)
- Costs (within the context of regional demand scenarios)

E3database: functionalities

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Definition of a regional Study Case by a "top-down" approach

Evaluation of regional hydrogen demand

Selection of required unit sizes of installations for hydrogen production

Selection of appropriate options for hydrogen chains

Costs calculation

Levelized costs for hydrogen processes and chains

Reference gasoline chain

Further externalities

Sensitivity analysis

Information on the most influential input parameters

E3database: functionalities

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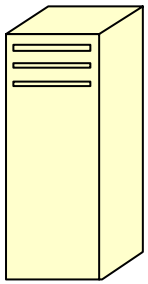
User-friendliness

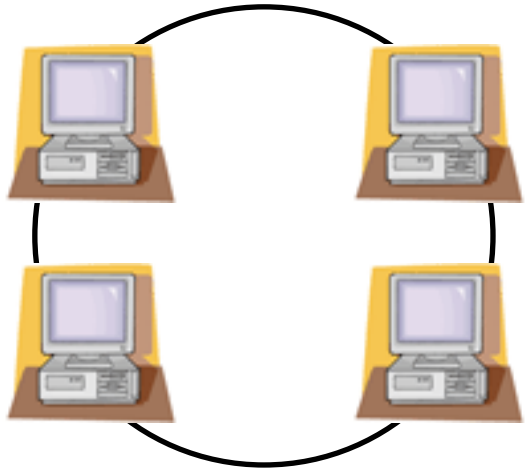
Guidance of the user in selection of energy chains meeting H2 regional demand

Display of easy readable results



Storage of regional study cases, partially (process) or totally (chain)

Remote utilization



Delivery of new versions of the tool

Exchange of selected data: processes, chains...

Description of E3database tool

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- Hardware and software requirements
- Modelling of processes
- Modelling of chains
- Calculation algorithm
- Presentation of results

Hardware and software requirements

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- Personal Computer
- Operating System MS Windows 2000 or XP
- Firebird SQL database management system
- E3database program (software based on Borland Delphi)
- ...

Modelling of processes

Process: biomass gasification “Blauer Turm” [DM2]

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Pilot plant “Blauer Turm” in Herten, North-Rhine-Westphalia, Germany

Process: biomass gasification “Blauer Turm” [DM2]

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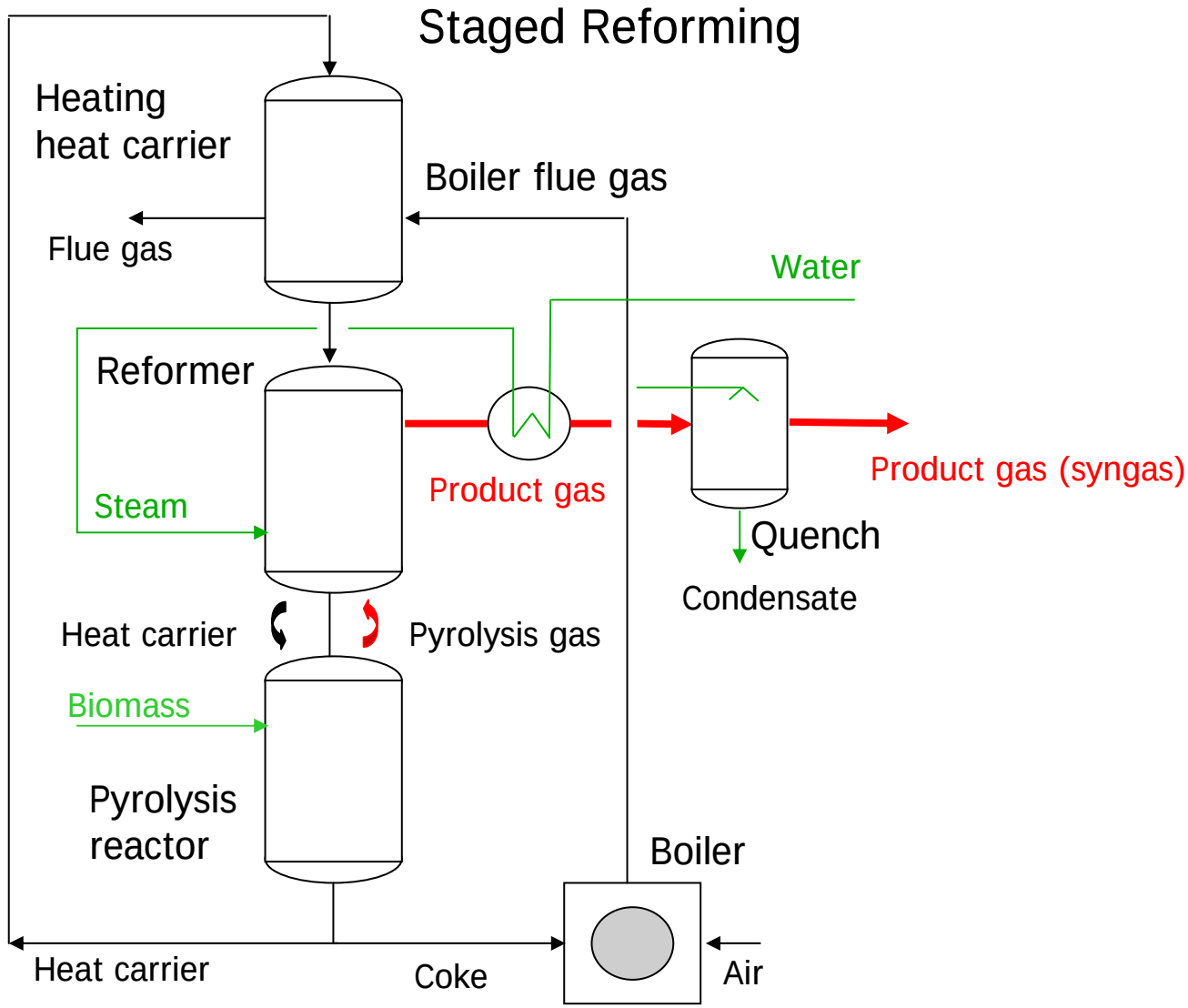
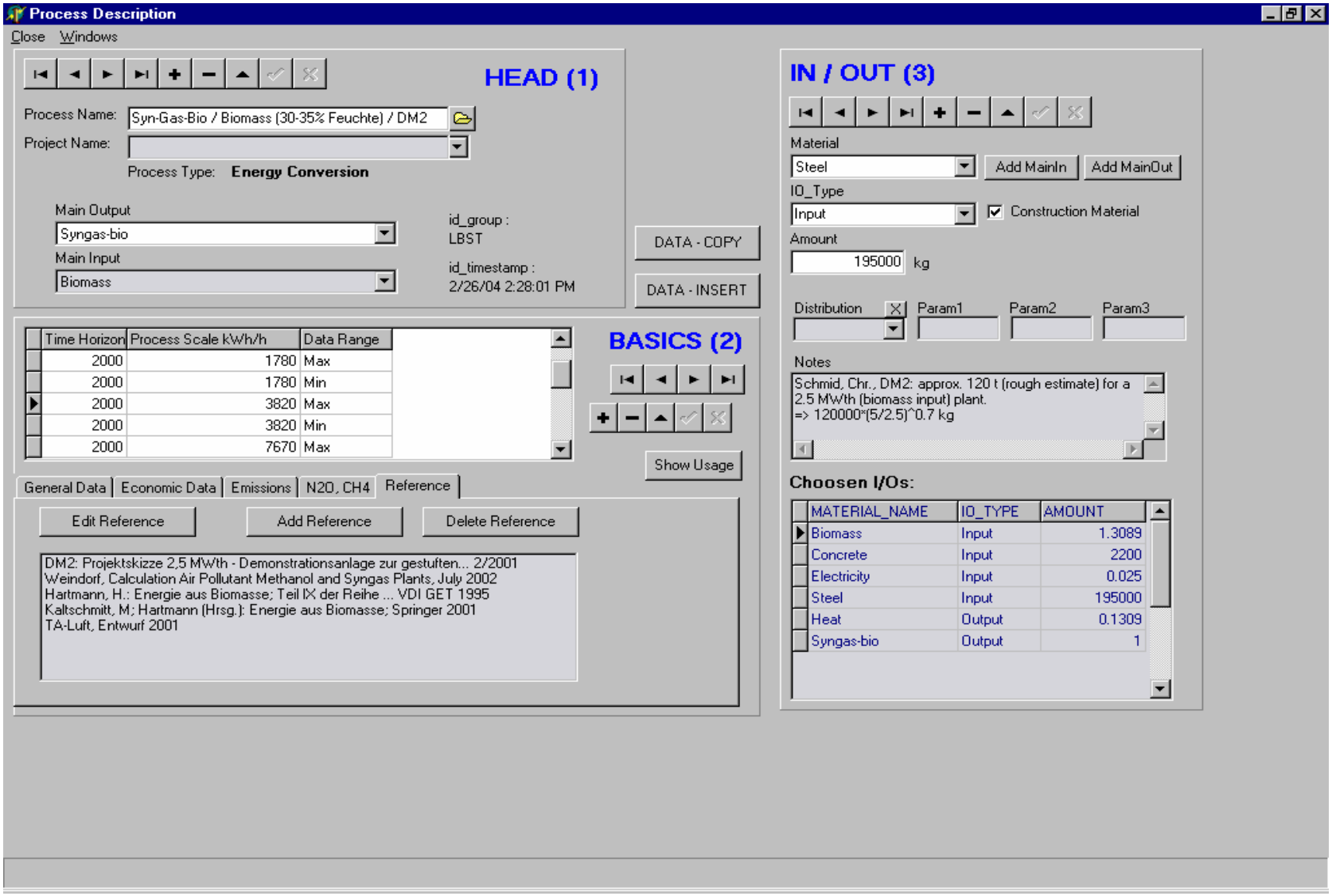


Process: biomass gasification



Process: biomass gasification

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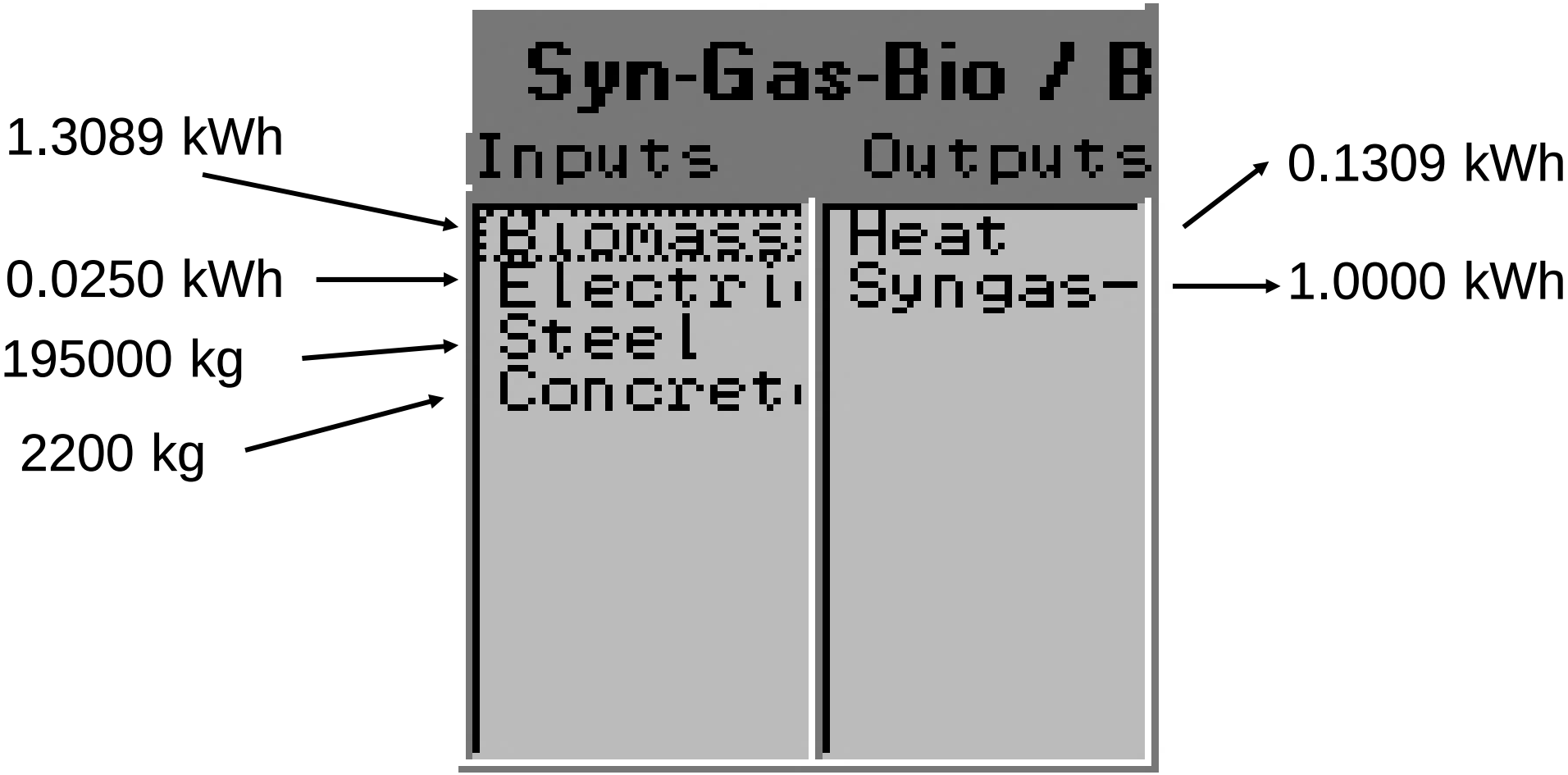

Modelling of chains

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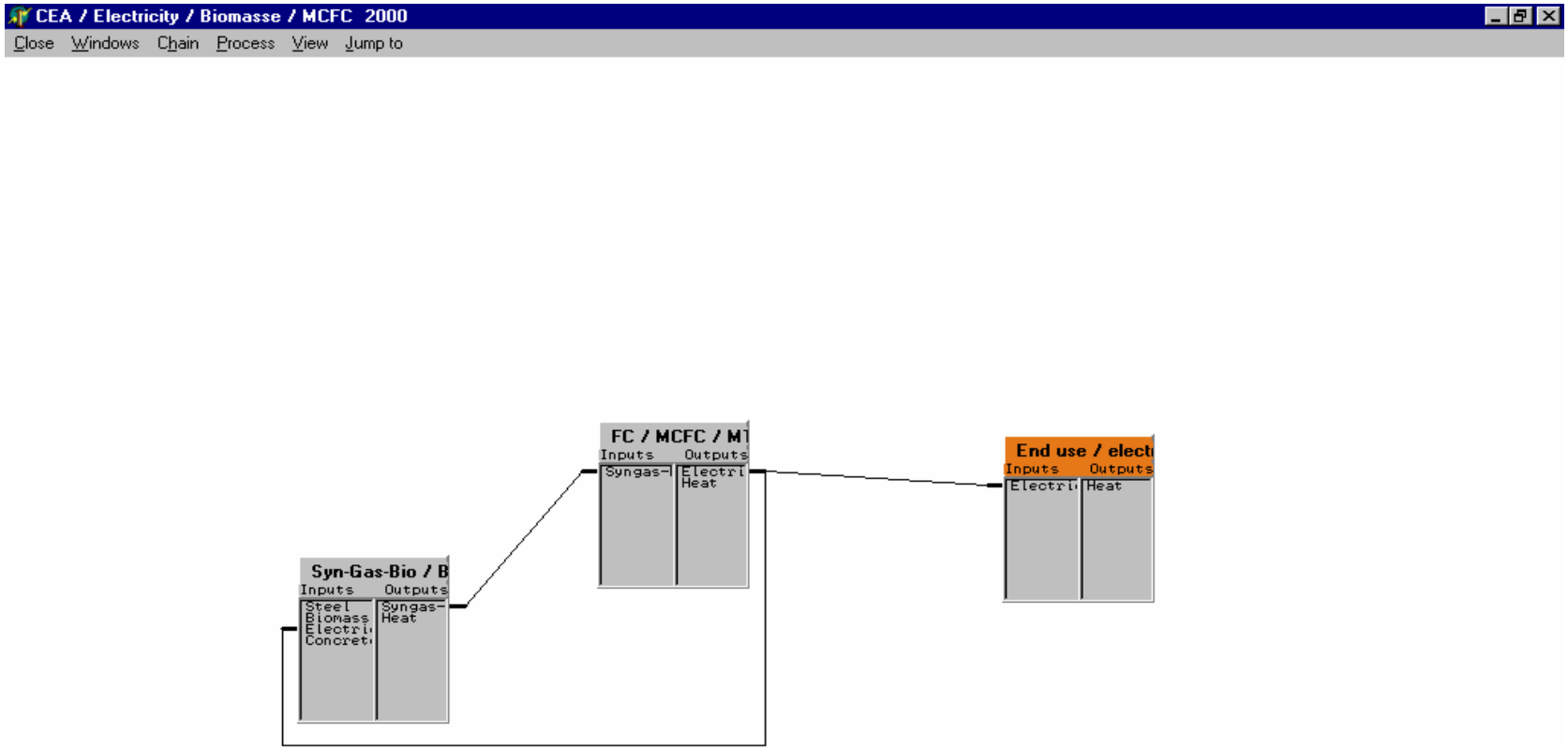
Electricity from biomass via gasification with downstream MCFC

Chain: electricity from biomass via MCFC without heat credit



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Chain: electricity from biomass via MCFC with heat credit from MCFC and gasifier

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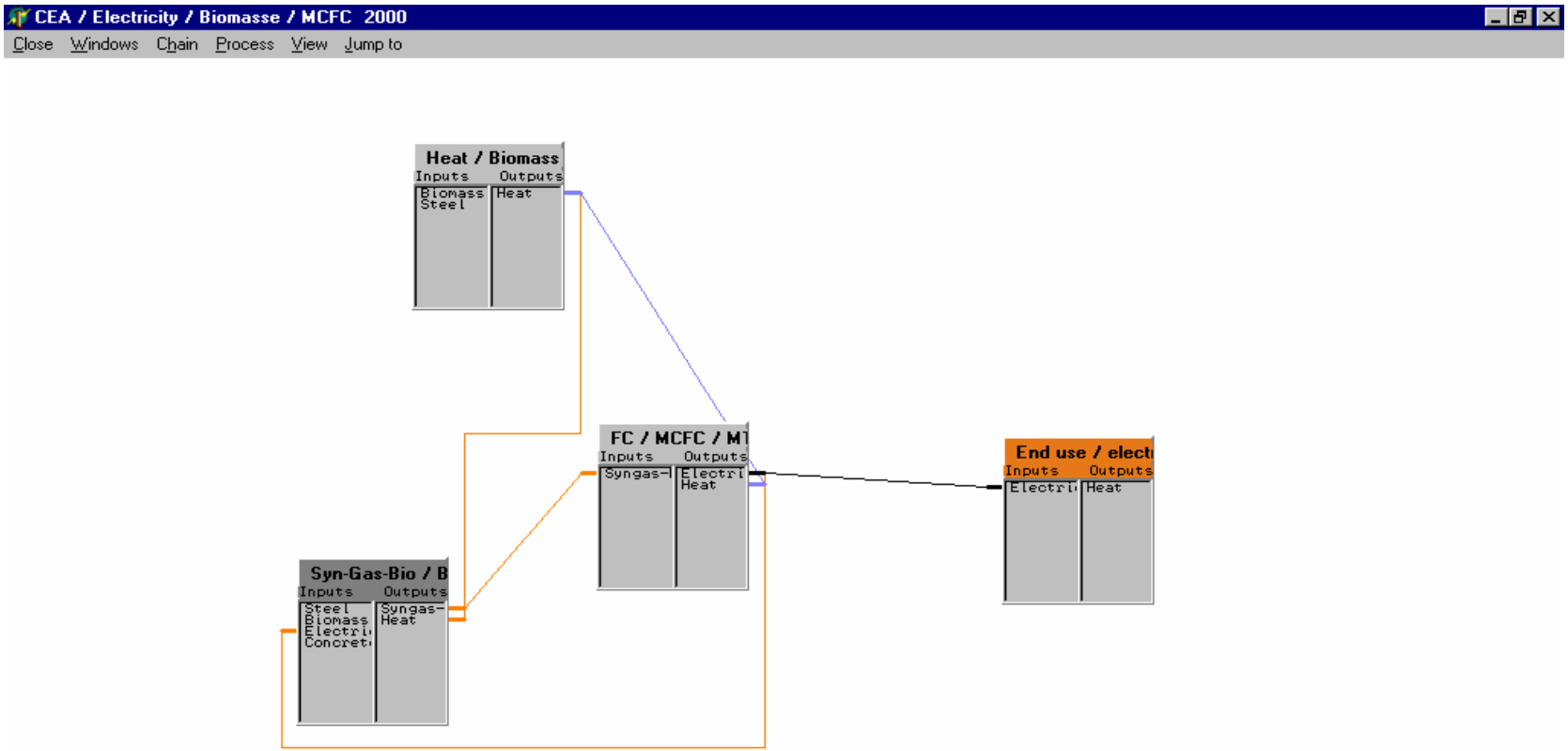

Chain: electricity from biomass via MCFC with heat credit from MCFC and gasifier including energy requirement for construction material

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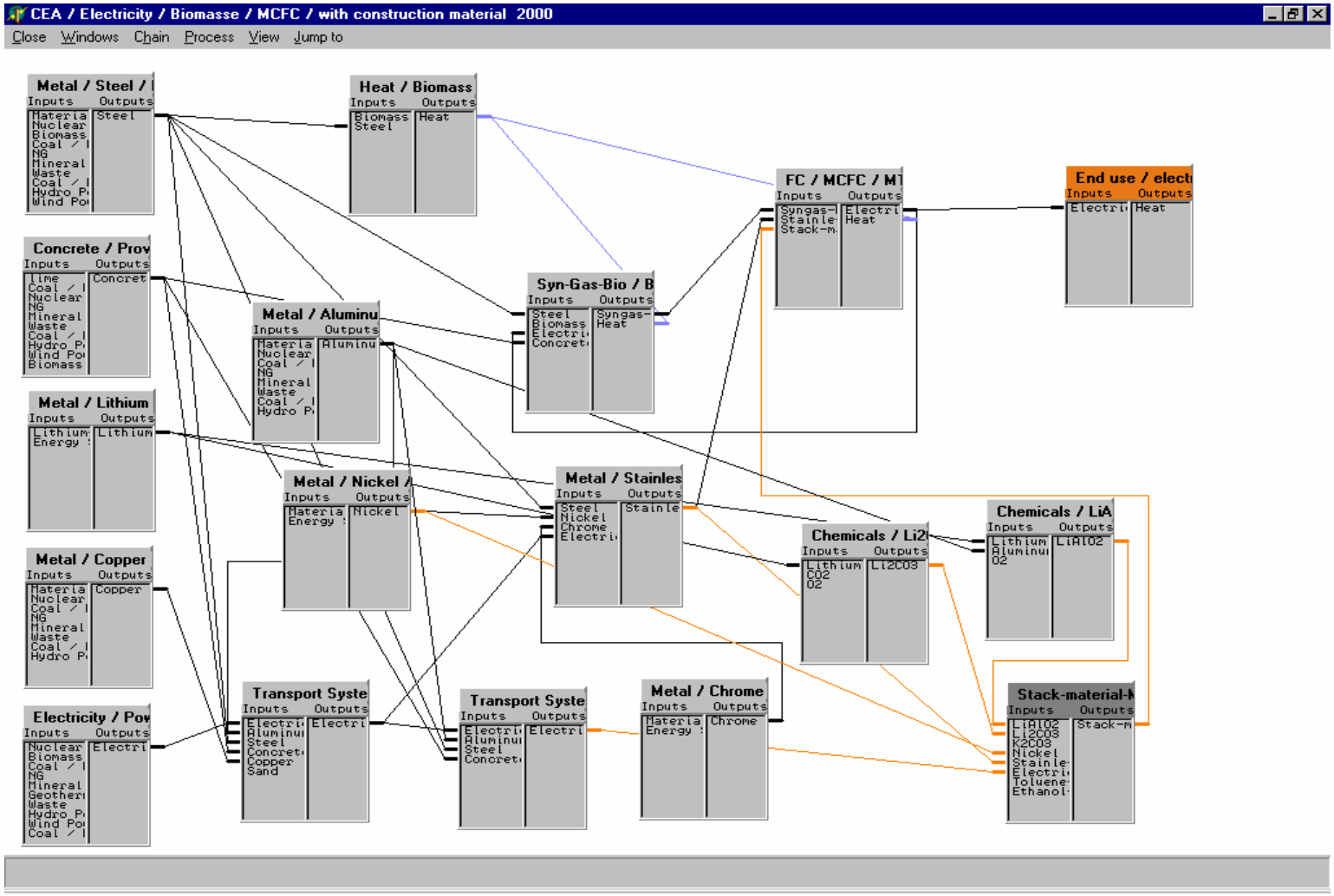
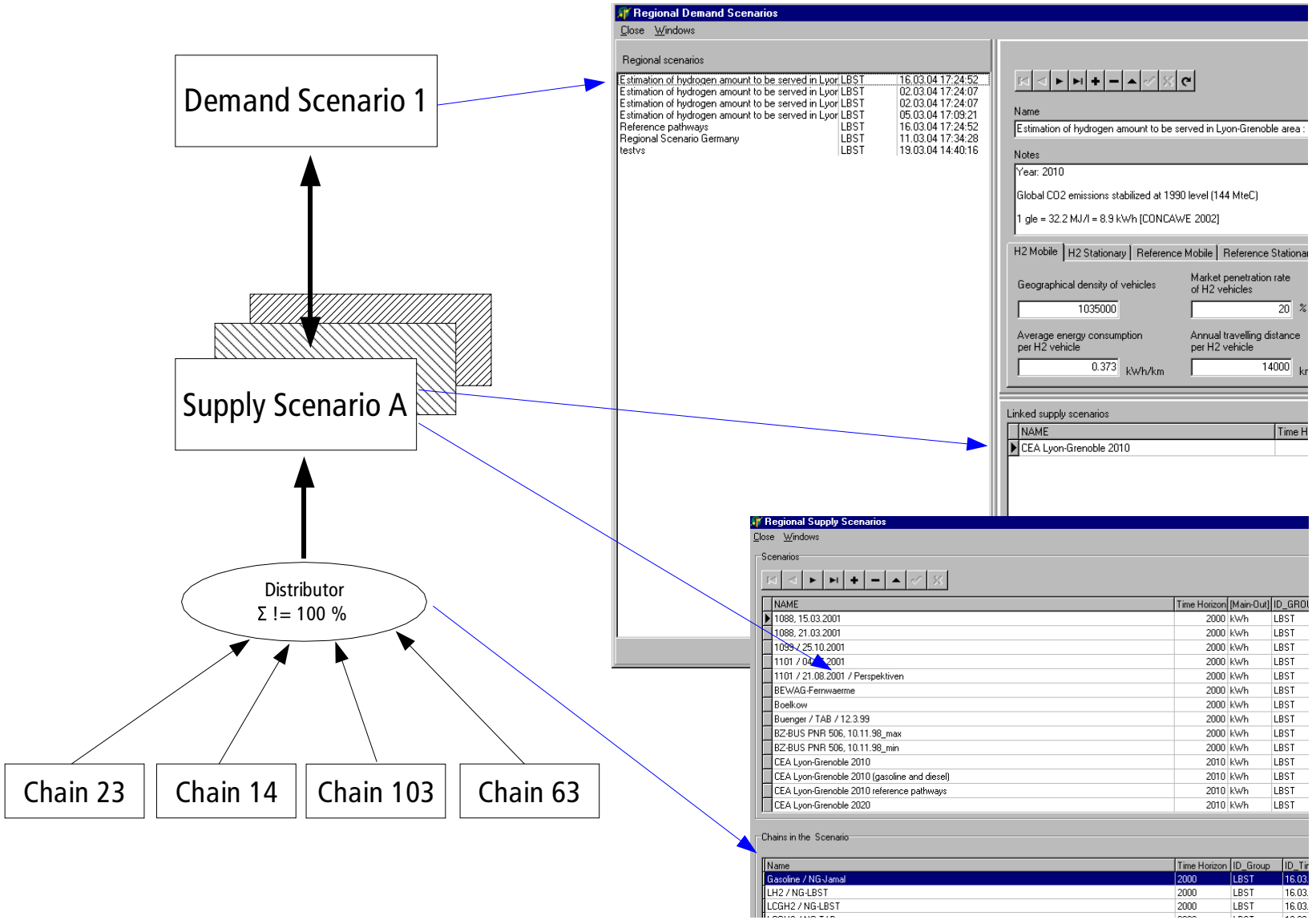


Modelling of regional scenarios



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Regional demand scenario

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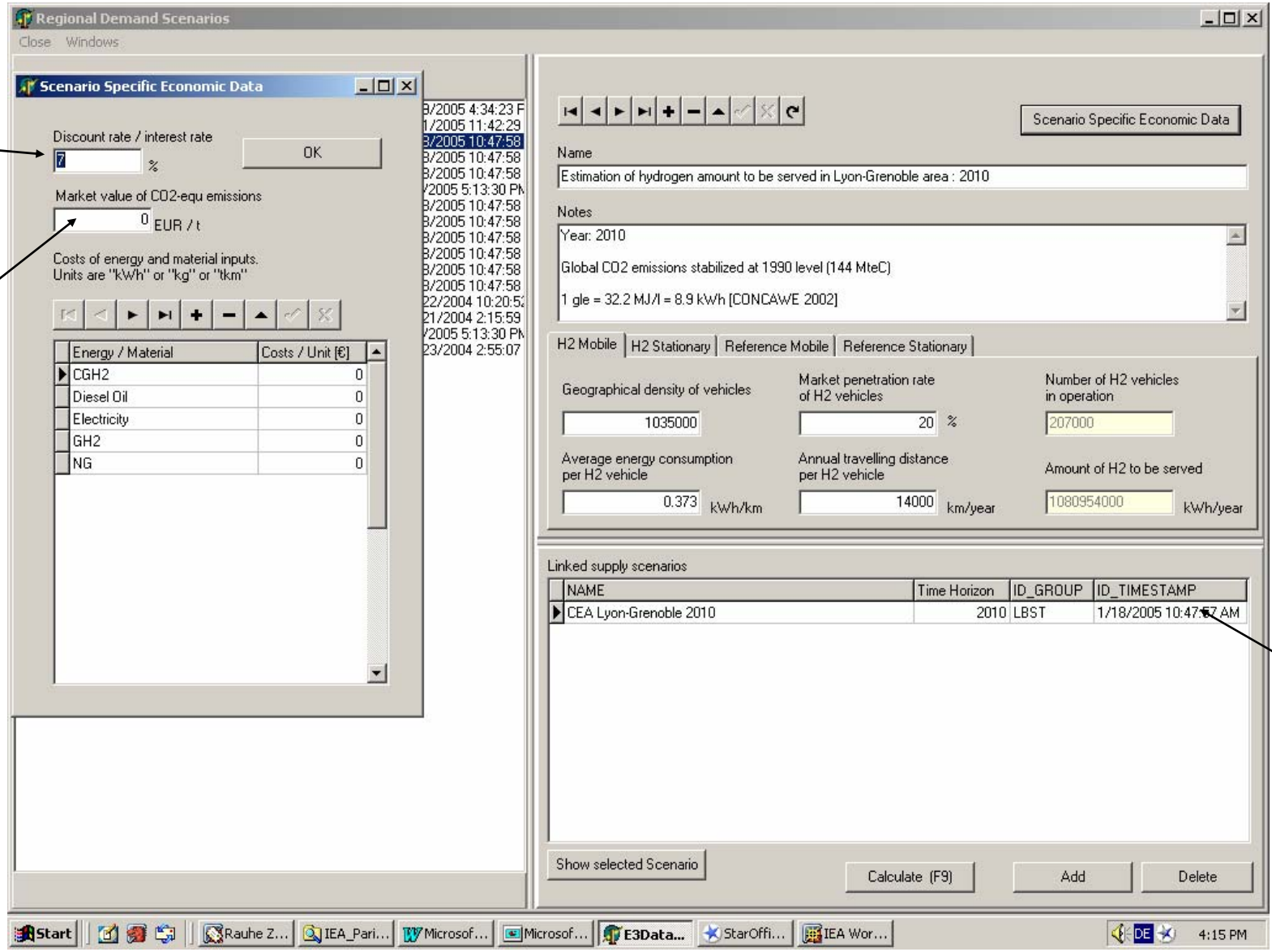
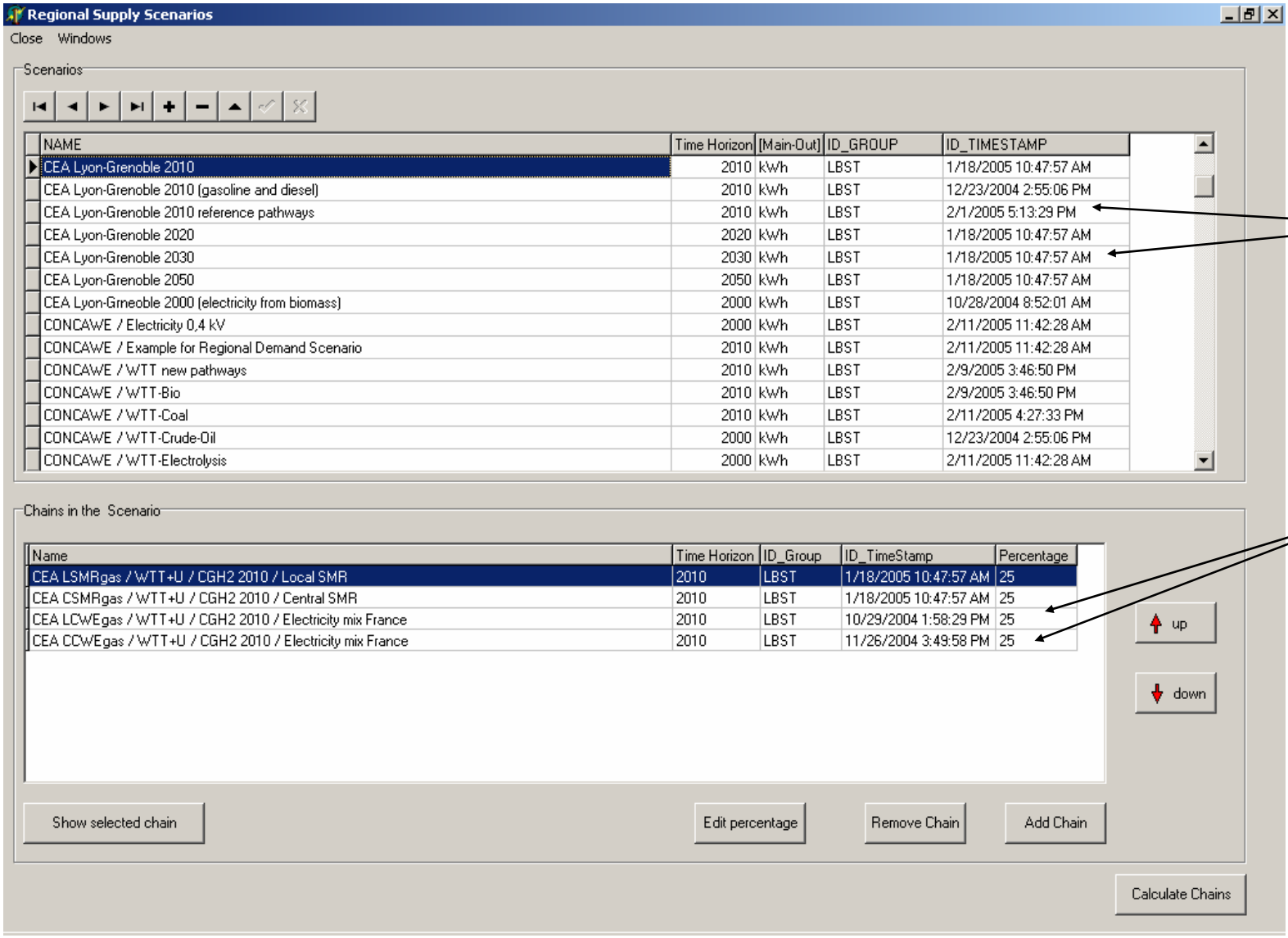
Interest rate

Market value of CO_2



Scenario

Regional supply scenario



Supply scenarios

Chains of a supply scenario and its percentage of a regional demand scenario

Calculation algorithm

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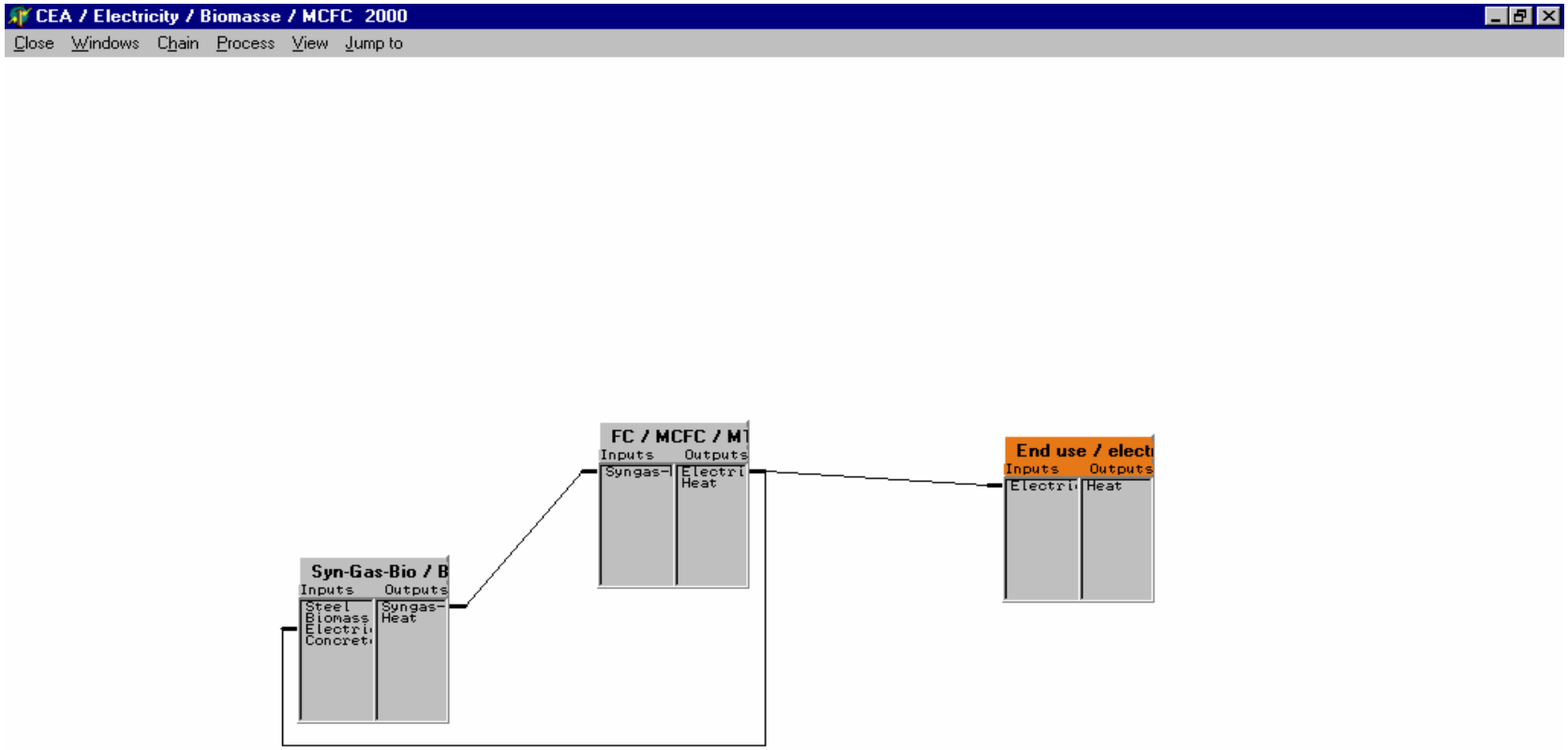
The Calculation algorithm:

- is implemented only once in the program
- is independent of the shape, size or complexity of a chain

Correctness of calculation results is guaranteed by the properties of the tool.

The user can concentrate on the empirical aspects of modelling !

Chain: electricity with biomass fueled MCFC



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Example for a recursion: Electricity generation with biomass fueled MCFC

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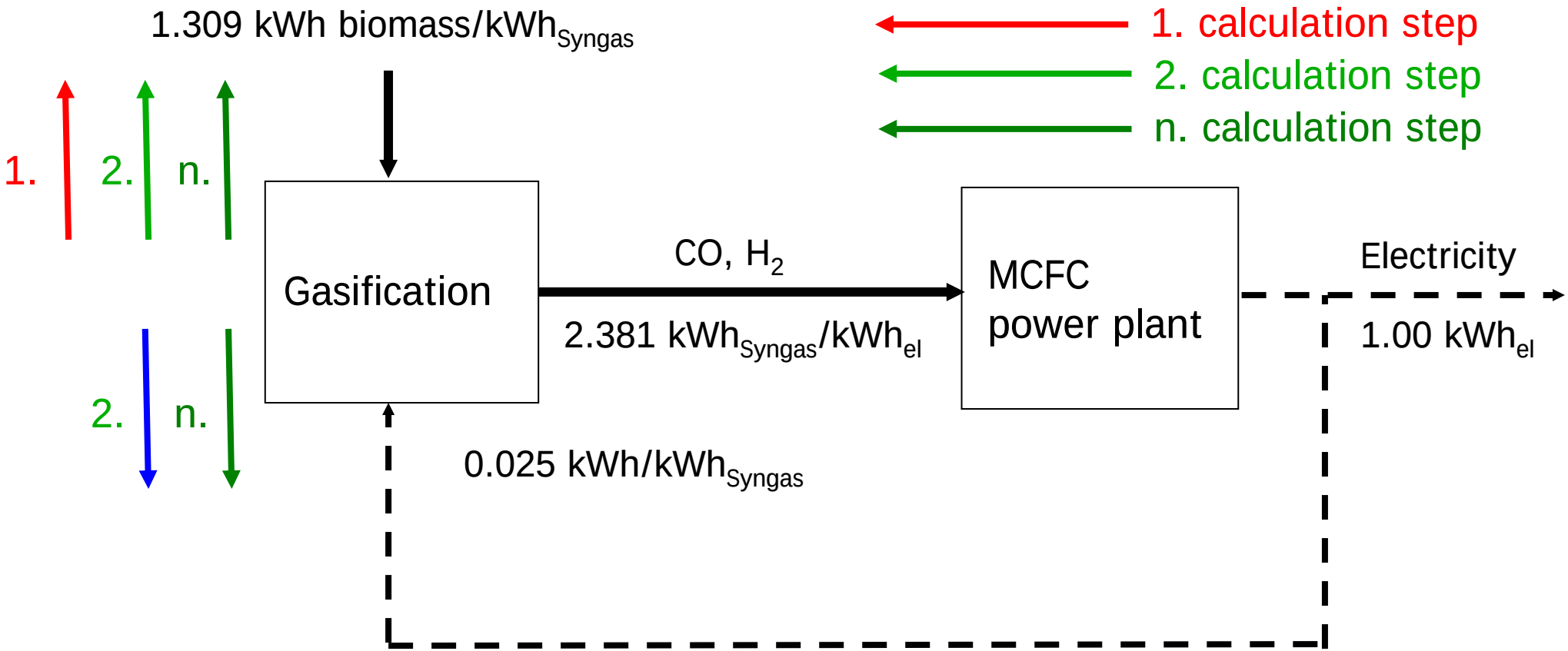

E = (1.309+0.025*2.381* (1. 309+0.025*2.381* (1. 309+0.025*2.381...))) *2.381 kWh/kWh$_{el}$= 3.313 kWh/kWh$_{el}$

Example for a recursion: Electricity generation with biomass fueled MCFC

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E = (1.309 + 0.025 * 2.381 *

* (1.309 + 0.025 * 2.381 *

* (1.309 + 0.025 * 2.381 *

* (1.309...)))) *2.381 kWh/kWh_{el}= 3.313 kWh/kWh_{el}

The calculation ends when the result change of the last recursion is smaller than a predefined value

Monte Carlo simulation

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Stochastic variations of input or output parameters

- Energy inputs
- Material inputs
- CH_4-emissions
- N_2O-emissions

Variation of output parameters as a function of varying energy inputs

- CO_2-emissions

Different probability distributions for randomization of parameters

- Normal (Gauss)
- Triangle
- Equal
- ... (to be defined)

Presentation of results

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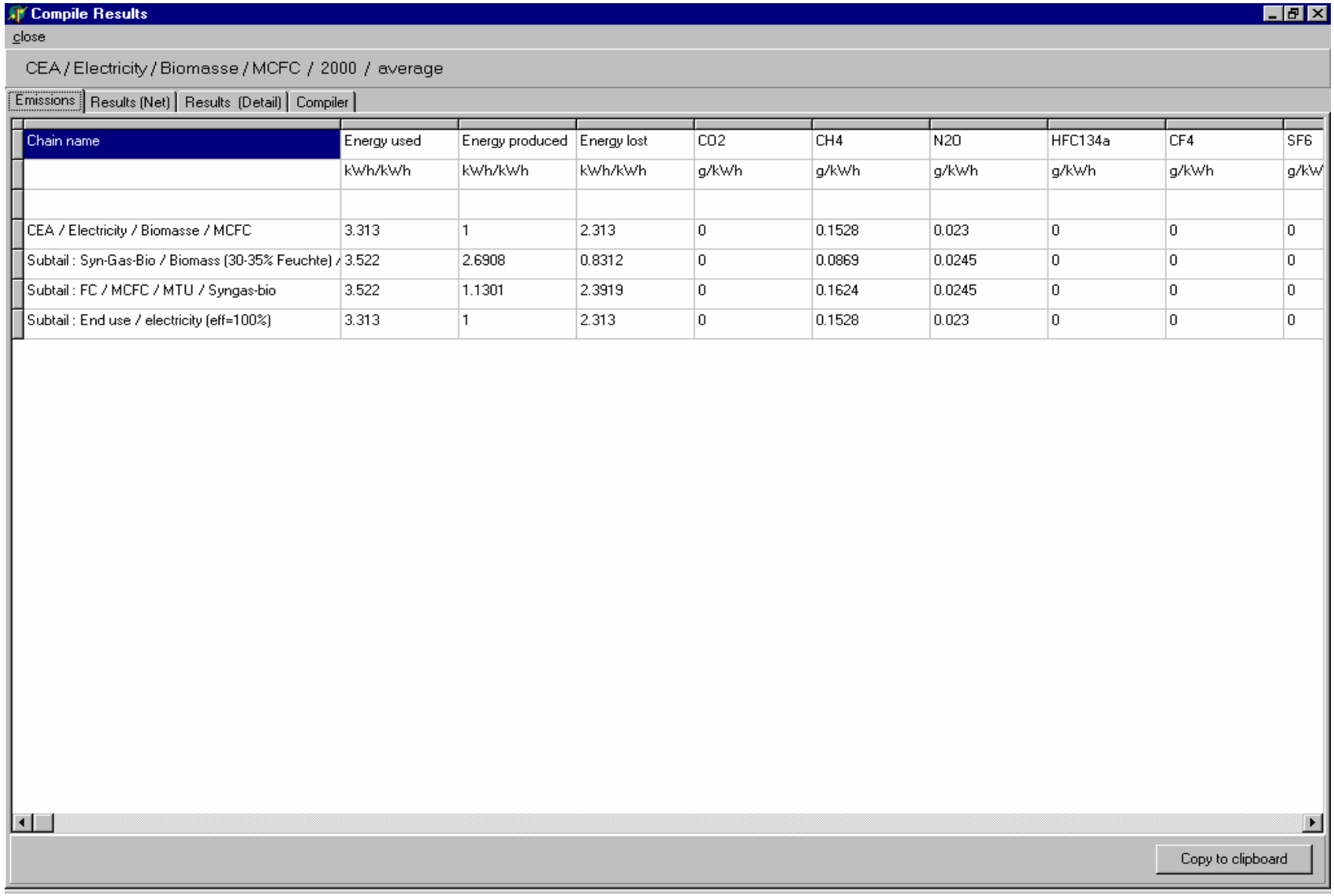
- Chain
- Regional supply scenario
- Regional demand scenario

Results: electricity from biomass via MCFC



Compile Results

close

CEA / Electricity / Biomasse / MCFC / 2000 / average

Emissions | Results (Net) | Results (Detail) | Compiler

Chain name	Energy used	Energy produced	Energy lost	CO2	CH4	N2O	HFC134a	CF4	SF6
	kWh/kWh	kWh/kWh	kWh/kWh	g/kWh	g/kWh	g/kWh	g/kWh	g/kWh	g/kW
CEA / Electricity / Biomasse / MCFC	3.313	1	2.313	0	0.1528	0.023	0	0	0
Subtail : Syn-Gas-Bio / Biomass (30-35% Feuchte) /	3.522	2.6908	0.8312	0	0.0869	0.0245	0	0	0
Subtail : FC / MCFC / MTU / Syngas-bio	3.522	1.1301	2.3919	0	0.1624	0.0245	0	0	0
Subtail : End use / electricity (eff=100%)	3.313	1	2.313	0	0.1528	0.023	0	0	0

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Typical Hydrogen Chains

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Typical hydrogen chains

- CGH_2 from NG via local steam methane reforming (LSMR)
- CGH_2 from NG via central steam reforming (CSMR)
- CGH_2 from French electricity mix via local conventional water electrolysis (LCWE)
- CGH_2 from French electriciy mix via central conventional water electrolysis (CCWE)

Results: regional supply scenario

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Compile Results

close

CEA Lyon-Grenoble 2010

Emissions

Chain name	Energy used	Energy produced	Energy lost	CO2	CH4	N2O	HFC134a	CF4	SF6
	kWh/kWh	kWh/kWh	kWh/kWh	g/kWh	g/kWh	g/kWh	g/kWh	g/kWh	g/kW
CEA LSMRgas / WTT+U / CGH2 2010 / Local SM	1.8321	1	0.8321	356.7209	0.8184	0.0023	0	0	0
CEA CSMRgas / WTT+U / CGH2 2010 / Central S	1.8058	1	0.8058	351.9623	0.8004	0.0021	0	0	0
CEA LCWEgas / WTT+U / CGH2 2010 / Electricit	5.6768	1	4.6768	140.5358	0.3595	0.0022	0	0	0
CEA CCWEgas / WTT+U / CGH2 2010 / Electricit	5.4679	1	4.4679	135.4255	0.3464	0.0021	0	0	0

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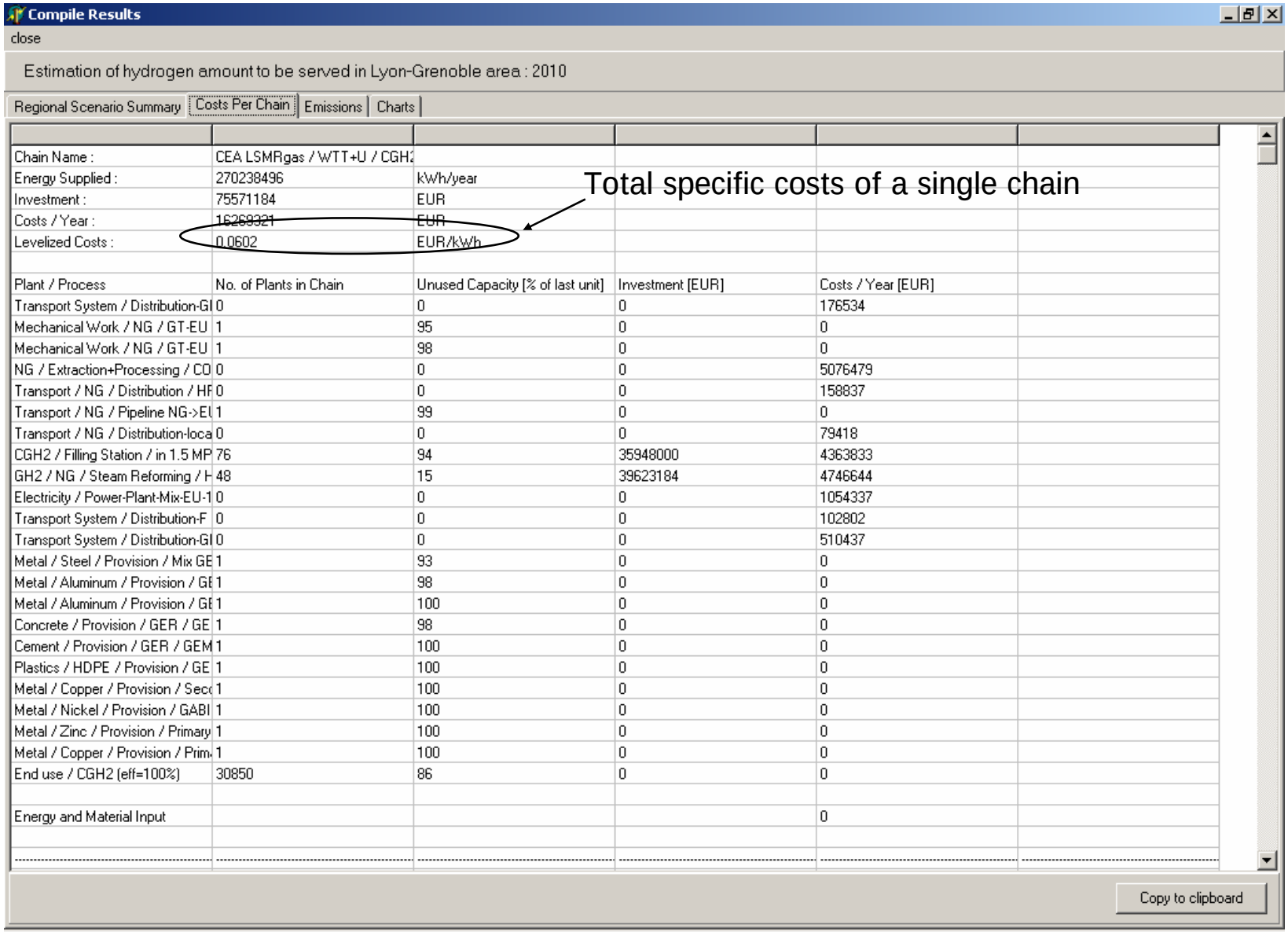
Calculation of the emissions, the energy use and the energy loss for different selected pathways and presentation of the results for every chain (percentage for the regional demand scenario not relevant here).

Results: costs per chain in a regional demand scenario



Chain Name :	CEA LSMRgas / WTT+U / CGH2				
Energy Supplied :	270238496	kWh/year			
Investment :	75571184	EUR			
Costs / Year :	16269321	EUR			
Levelized Costs :	0.0602	EUR/kWh			
Plant / Process	No. of Plants in Chain	Unused Capacity [% of last unit]	Investment [EUR]	Costs / Year [EUR]	
Transport System / Distribution-GI	0	0	0	176534	
Mechanical Work / NG / GT-EU	1	95	0	0	
Mechanical Work / NG / GT-EU	1	98	0	0	
NG / Extraction+Processing / CO	0	0	0	5076479	
Transport / NG / Distribution / HF	0	0	0	158837	
Transport / NG / Pipeline NG->EU	1	99	0	0	
Transport / NG / Distribution-loca	0	0	0	79418	
CGH2 / Filling Station / in 1.5 MP	76	94	35948000	4363833	
GH2 / NG / Steam Reforming / H	48	15	39623184	4746644	
Electricity / Power-Plant-Mix-EU-1	0	0	0	1054337	
Transport System / Distribution-F	0	0	0	102802	
Transport System / Distribution-GI	0	0	0	510437	
Metal / Steel / Provision / Mix GE	1	93	0	0	
Metal / Aluminum / Provision / GE	1	98	0	0	
Metal / Aluminum / Provision / GE	1	100	0	0	
Concrete / Provision / GER / GE	1	98	0	0	
Cement / Provision / GER / GEM	1	100	0	0	
Plastics / HDPE / Provision / GE	1	100	0	0	
Metal / Copper / Provision / Sec	1	100	0	0	
Metal / Nickel / Provision / GABI	1	100	0	0	
Metal / Zinc / Provision / Primary	1	100	0	0	
Metal / Copper / Provision / Prim	1	100	0	0	
End use / CGH2 (eff=100%)	30850	86	0	0	
Energy and Material Input				0	

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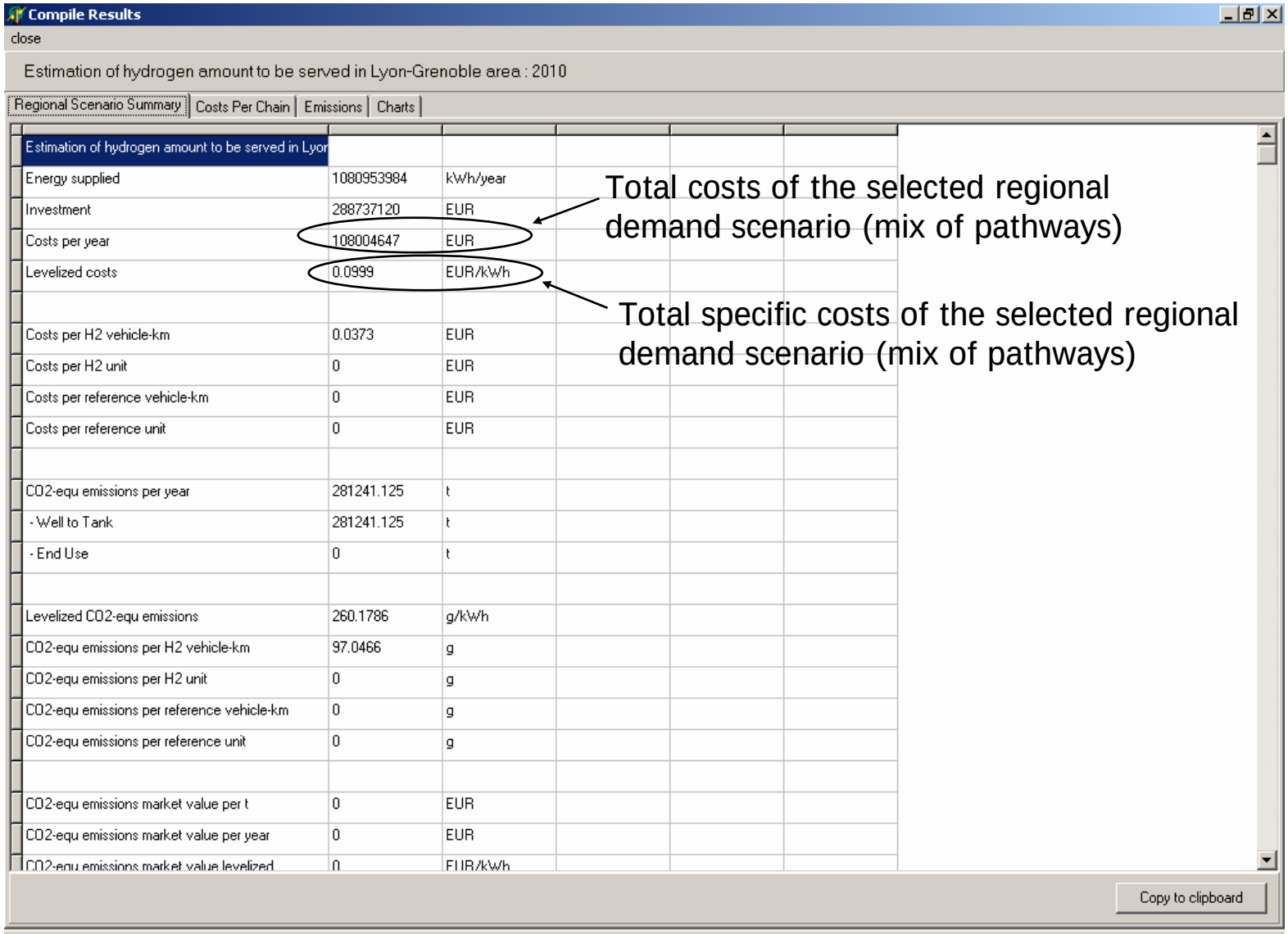
Results: costs of regional demand scenario

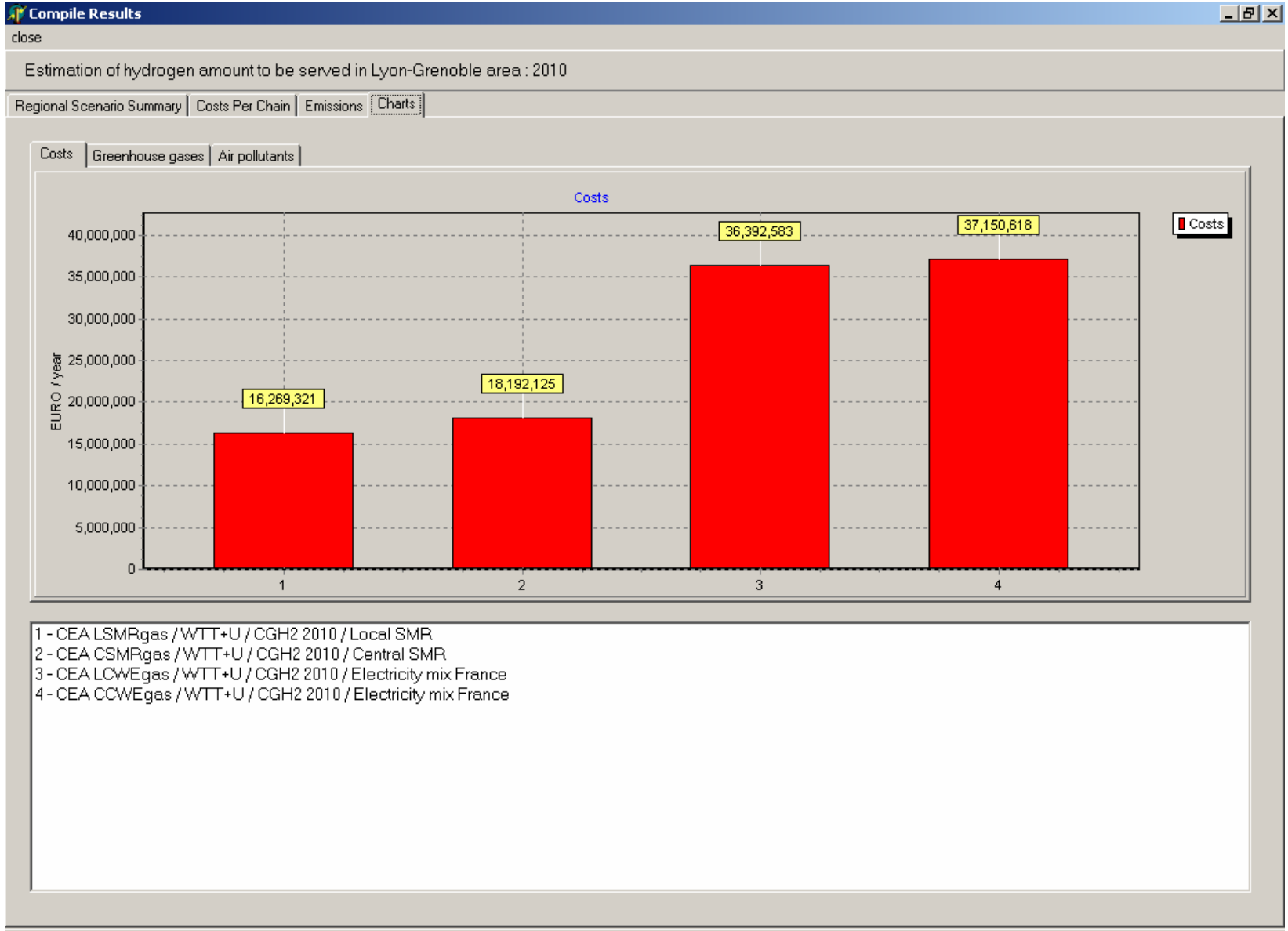


Estimation of hydrogen amount to be served in Lyon		
Energy supplied	1080953984	kWh/year
Investment	288737120	EUR
Costs per year	108004647	EUR
Levelized costs	0.0999	EUR/kWh
Costs per H2 vehicle-km	0.0373	EUR
Costs per H2 unit	0	EUR
Costs per reference vehicle-km	0	EUR
Costs per reference unit	0	EUR
CO2-equ emissions per year	281241.125	t
- Well to Tank	281241.125	t
- End Use	0	t
Levelized CO2-equ emissions	260.1786	g/kWh
CO2-equ emissions per H2 vehicle-km	97.0466	g
CO2-equ emissions per H2 unit	0	g
CO2-equ emissions per reference vehicle-km	0	g
CO2-equ emissions per reference unit	0	g
CO2-equ emissions market value per t	0	EUR
CO2-equ emissions market value per year	0	EUR
CO2-equ emissions market value levelized	0	EUR/kWh

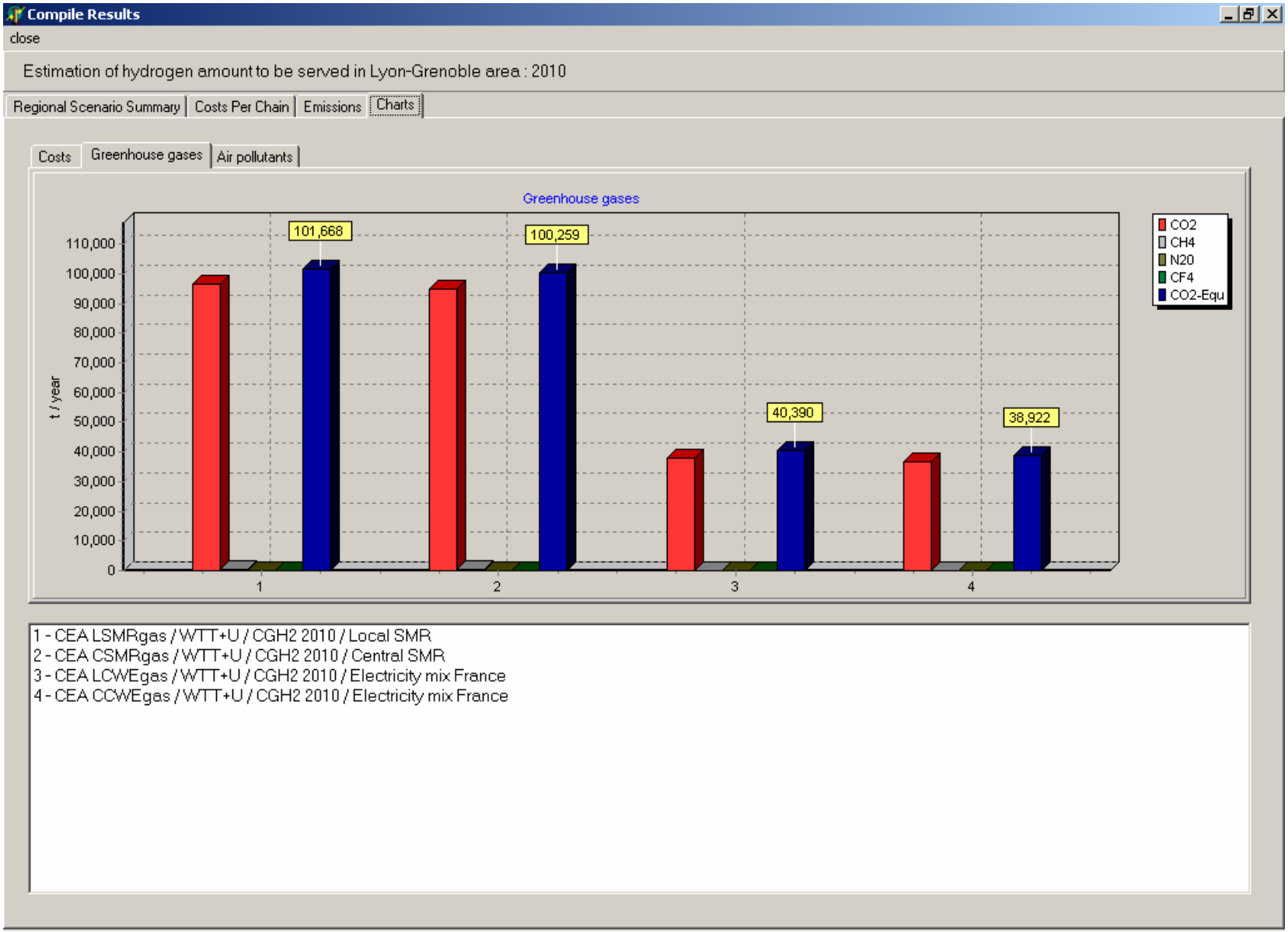
Total costs of the selected regional demand scenario (mix of pathways)

Total specific costs of the selected regional demand scenario (mix of pathways)

Results: costs of regional demand scenario



Results: GHG emissions of a regional demand scenario



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Results: Air pollutant emissions of a regional demand scenario

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Compile Results

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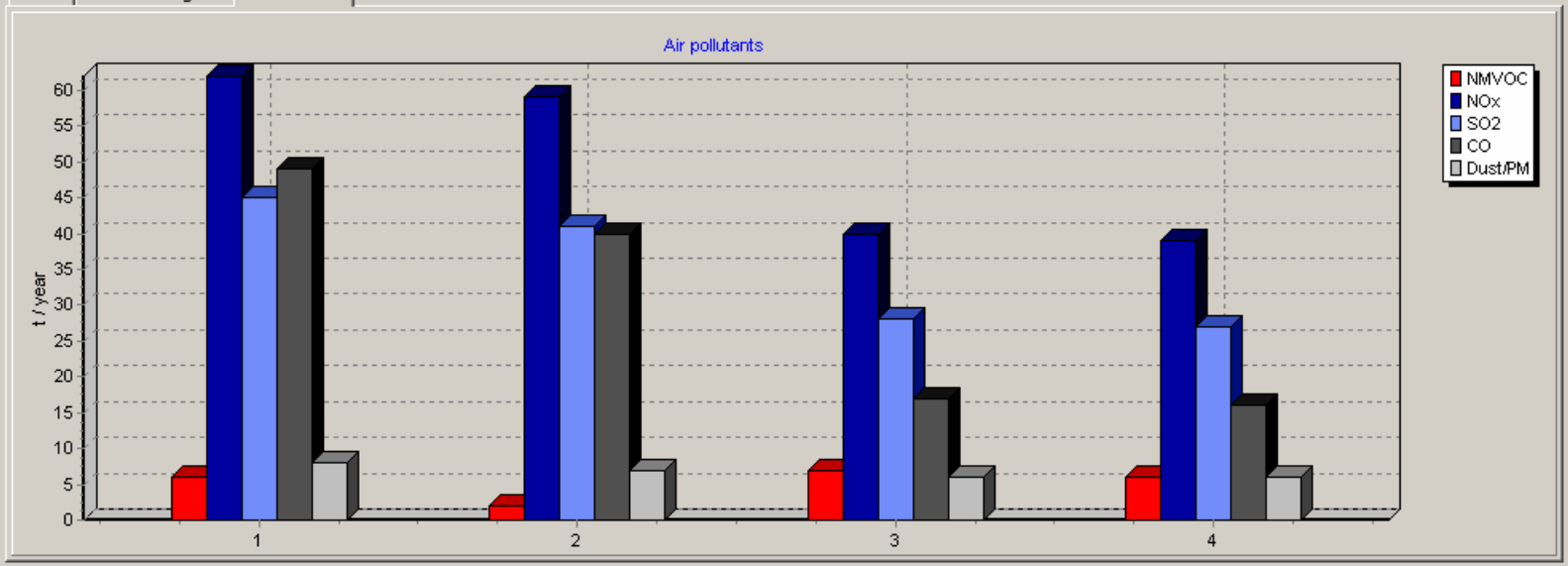
Estimation of hydrogen amount to be served in Lyon-Grenoble area : 2010

Regional Scenario Summary | Costs Per Chain | Emissions | Charts

Costs | Greenhouse gases | Air pollutants



1 - CEA LSMRgas / WTT+U / CGH2 2010 / Local SMR
2 - CEA CSMRgas / WTT+U / CGH2 2010 / Central SMR
3 - CEA LCWEgas / WTT+U / CGH2 2010 / Electricity mix France
4 - CEA CCWEgas / WTT+U / CGH2 2010 / Electricity mix France

Limits of E3database

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E3database is a TOOL and not a MODEL (like e.g. MARKAL)

- The tool does not perform any optimizations
- No trade offs between different criteria can be carried out
- No modelling of evolution over time is possible

E3database supplies basic data for a more comprehensive evaluation of energy chains and regional scenarios by the user.

Scope of the tool

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The tool ensures

- physical and technical viability and correctness of chain formulation
- correct calculation results in accordance with implemented calculation algorithms

The user is responsible for

- the validity and correctness of all data describing the basic processes in an energy chain
- the technical rationale behind the modelling of an energy chain

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E3database was/is used in recent major studies

- Transport Energy Strategy (1998-2001)
- GM European Well-to-Wheel Study (2002)
- CONCAWE/EUCAR/JRC Well-to-Tank contribution (2003-2004)
- HyWays (2003- ..)