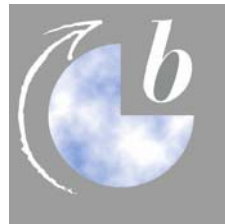




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E3database

- A Tool for the Evaluation of Energy Chains -

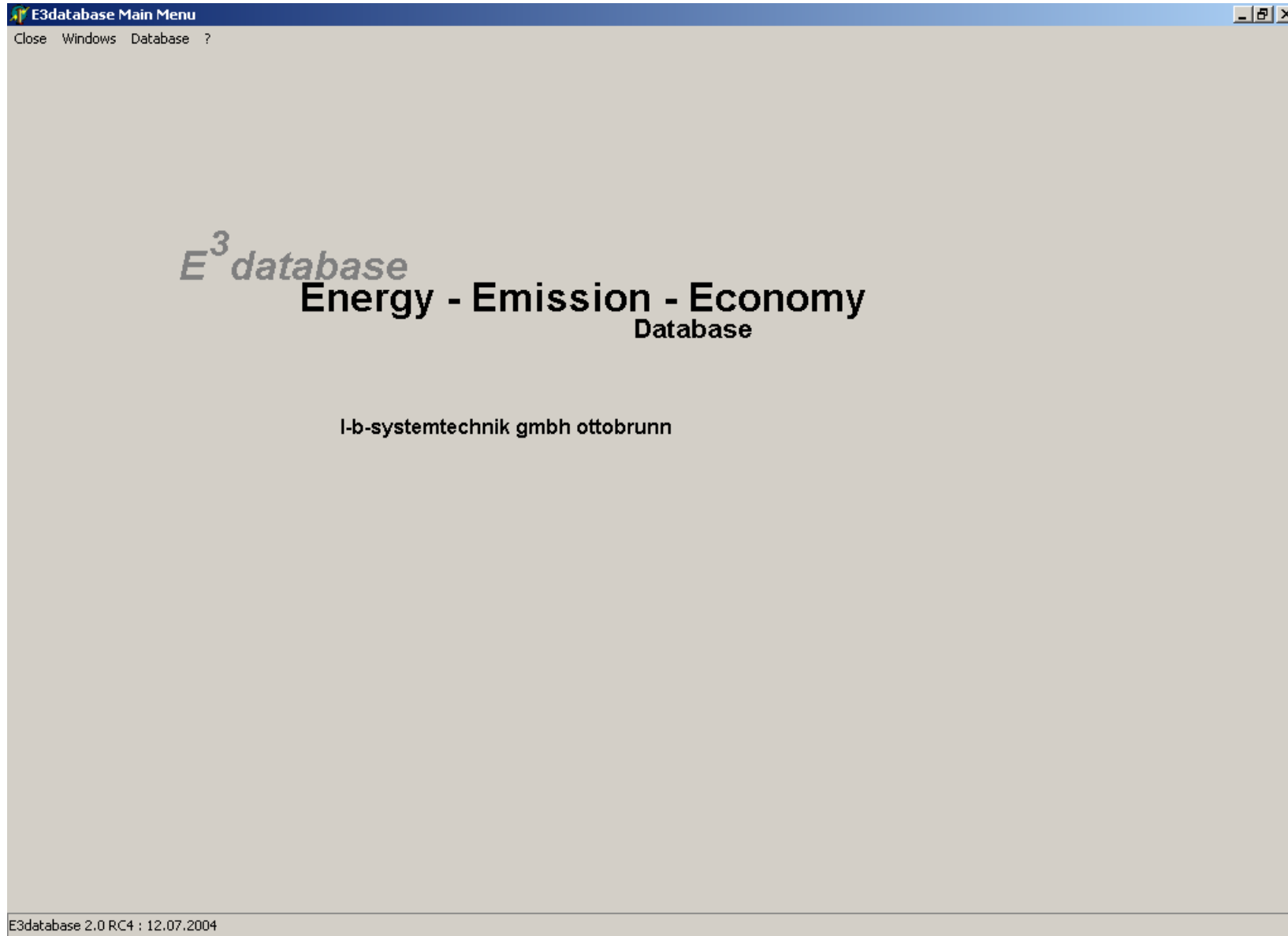


Ludwig-Bölkow-Systemtechnik GmbH (LBST)
Ottobrunn

Tool developed by LBST in cooperation with CEA and IFP



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



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)



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

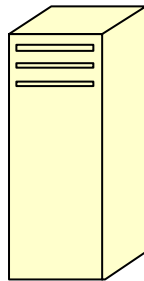
**Information on the most
influential input parameters**

User-friendliness



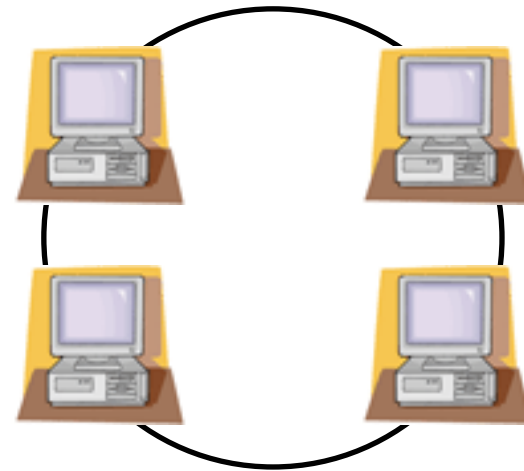
**Guidance of the user
in selection of energy
chains meeting H2
regional demand**

**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...**



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



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



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Modelling of processes

Process: biomass gasification “Blauer Turm” [DM2]



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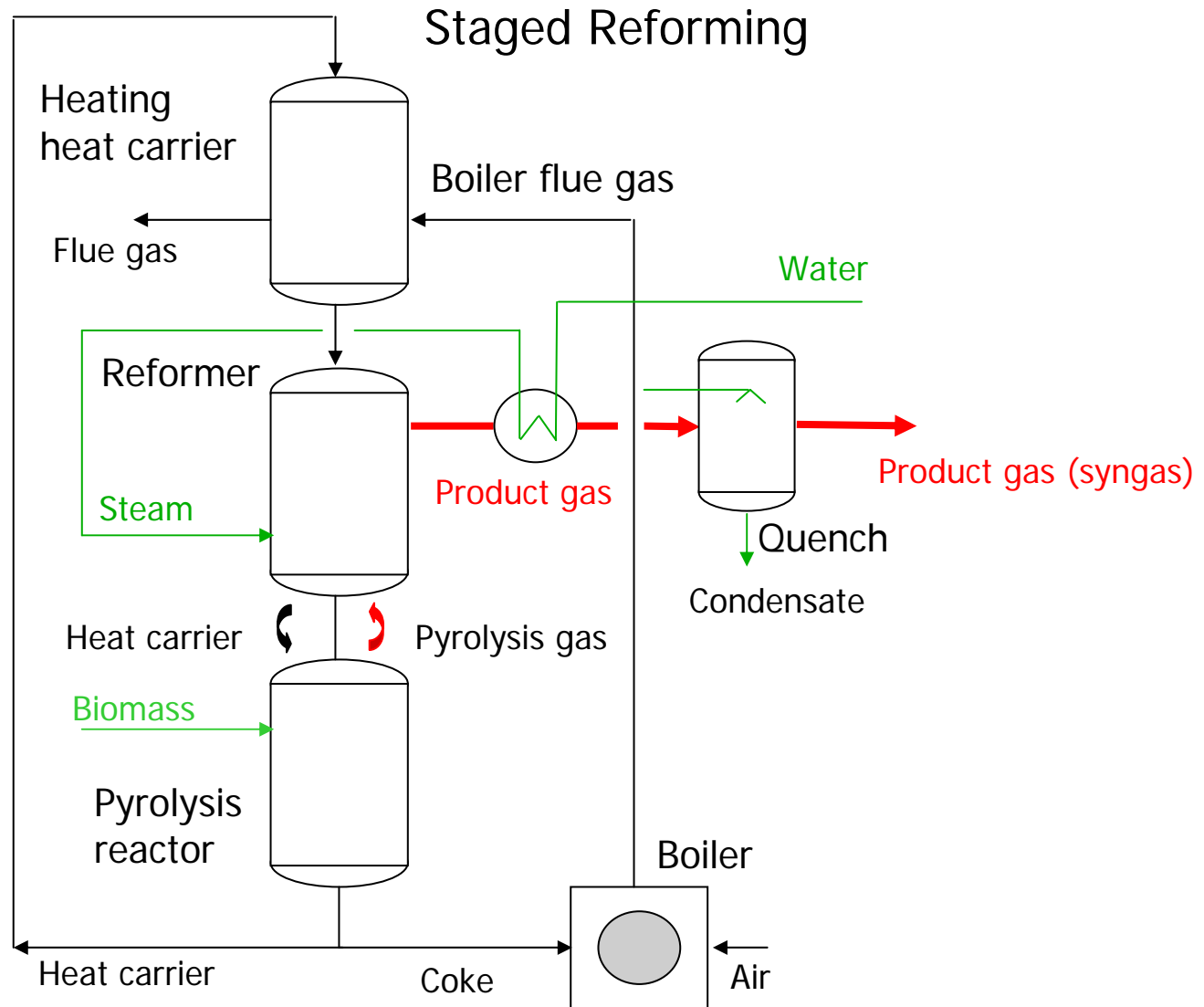


Pilot plant “Blauer Turm” in Herten, North-Rhine-Westphalia, Germany

Process: biomass gasification "Blauer Turm" [DM2]



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Process: biomass gasification



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Process Description
_ 6 x

Close Windows

HEAD (1)

Process Name:

Project Name:

Process Type: **Energy Conversion**

Main Output: id_group : LBST

Main Input: id_timestamp : 2/26/04 2:28:01 PM

DATA - COPY

DATA - INSERT

IN / OUT (3)

Material: Add MainIn Add MainOut

IO_Type: Construction Material

Amount: kg

Distribution: Param1 Param2 Param3

Notes:

Chosen I/Os:

MATERIAL_NAME	ID_TYPE	AMOUNT
Biomass	Input	1.3089
Concrete	Input	2200
Electricity	Input	0.025
Steel	Input	195000
Heat	Output	0.1309
Syngas-bio	Output	1

BASICS (2)

Time Horizon	Process Scale kWh/h	Data Range
2000	1780	Max
2000	1780	Min
2000	3820	Max
2000	3820	Min
2000	7670	Max

Show Usage

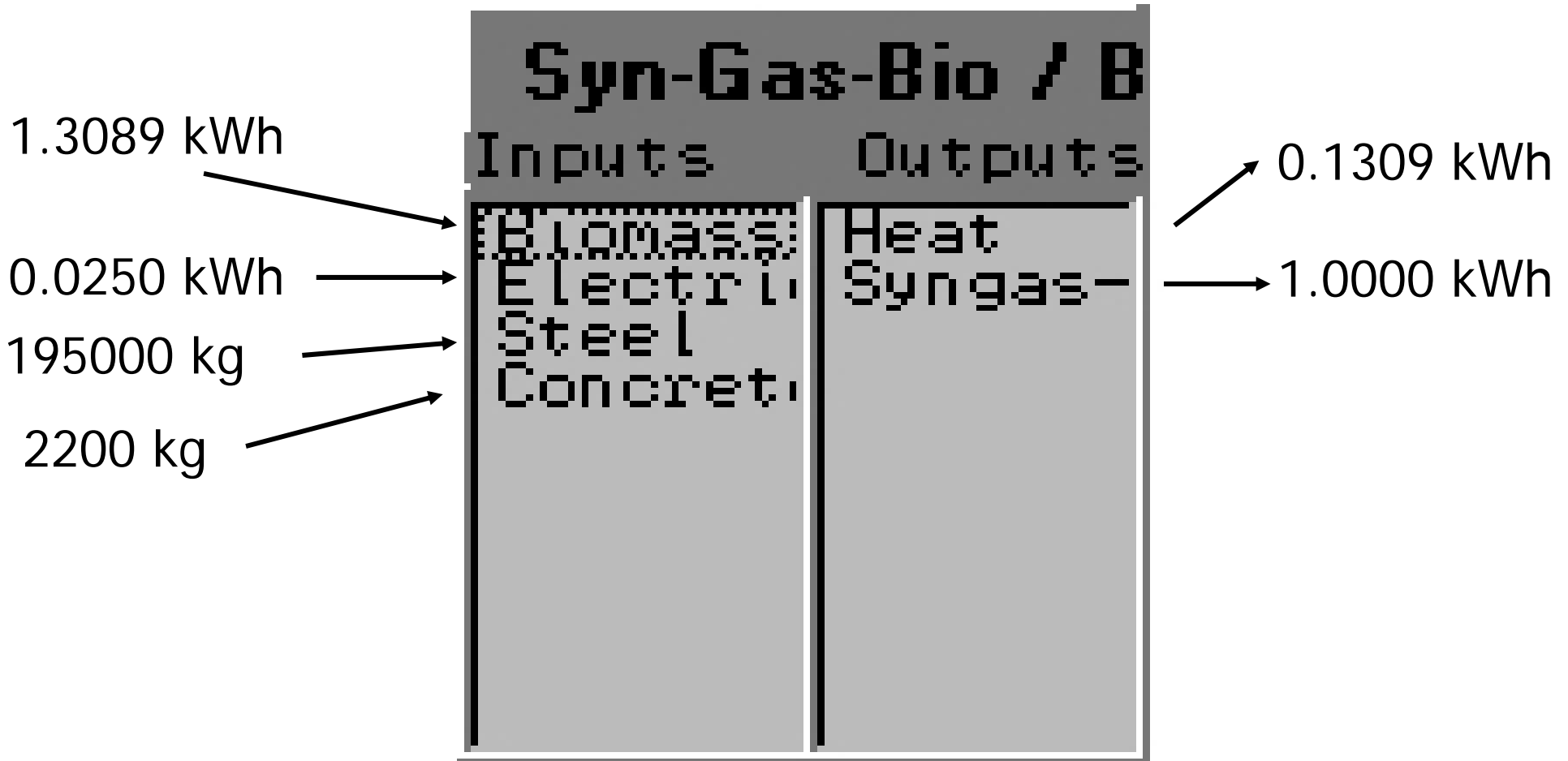
General Data | Economic Data | Emissions | N2O, CH4 | Reference

DM2: Projektskizze 2,5 MWth - Demonstrationsanlage zur gestuften... 2/2001
 Weindorf, Calculation Air Pollutant Methanol and Syngas Plants, July 2002
 Hartmann, H.: Energie aus Biomasse; Teil IX der Reihe ... VDI GET 1995
 Kaltschmitt, M.; Hartmann (Hrsg.): Energie aus Biomasse; Springer 2001
 TA-Luft, Entwurf 2001

Process: biomass gasification



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Modelling of chains



Electricity from biomass via gasification with
downstream MCFC

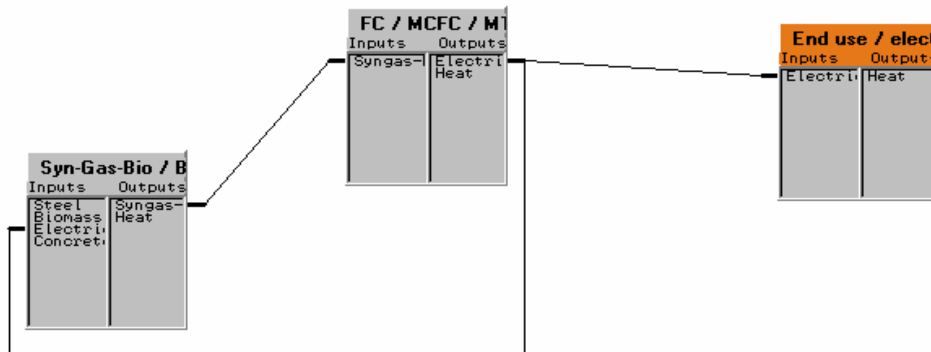
Chain: electricity from biomass via MCFC without heat credit



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CEA / Electricity / Biomasse / MCFC 2000

Close Windows Chain Process View Jump to

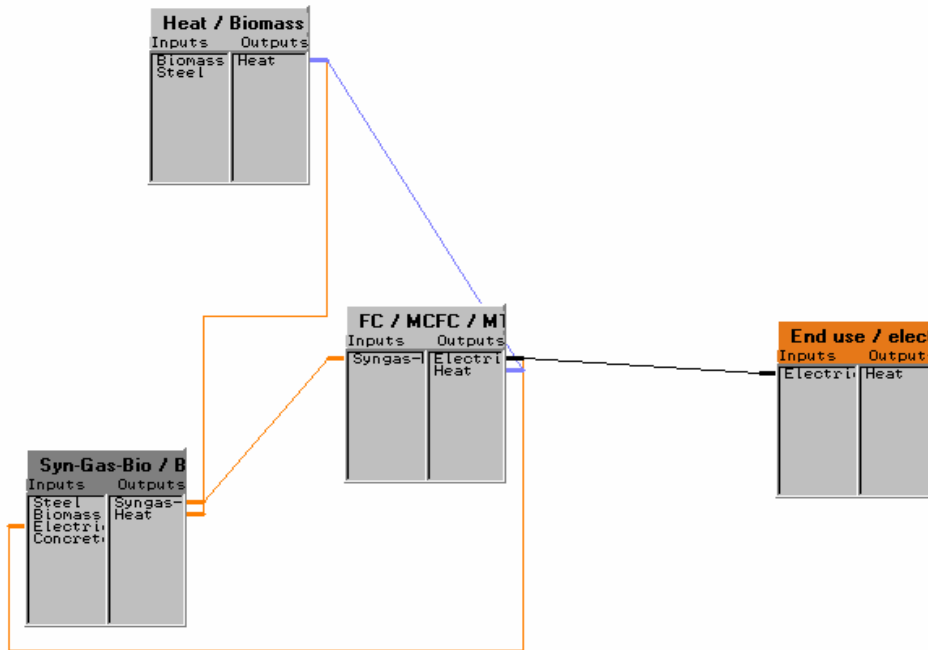


Chain: electricity from biomass via MCFC with heat credit from MCFC and gasifier



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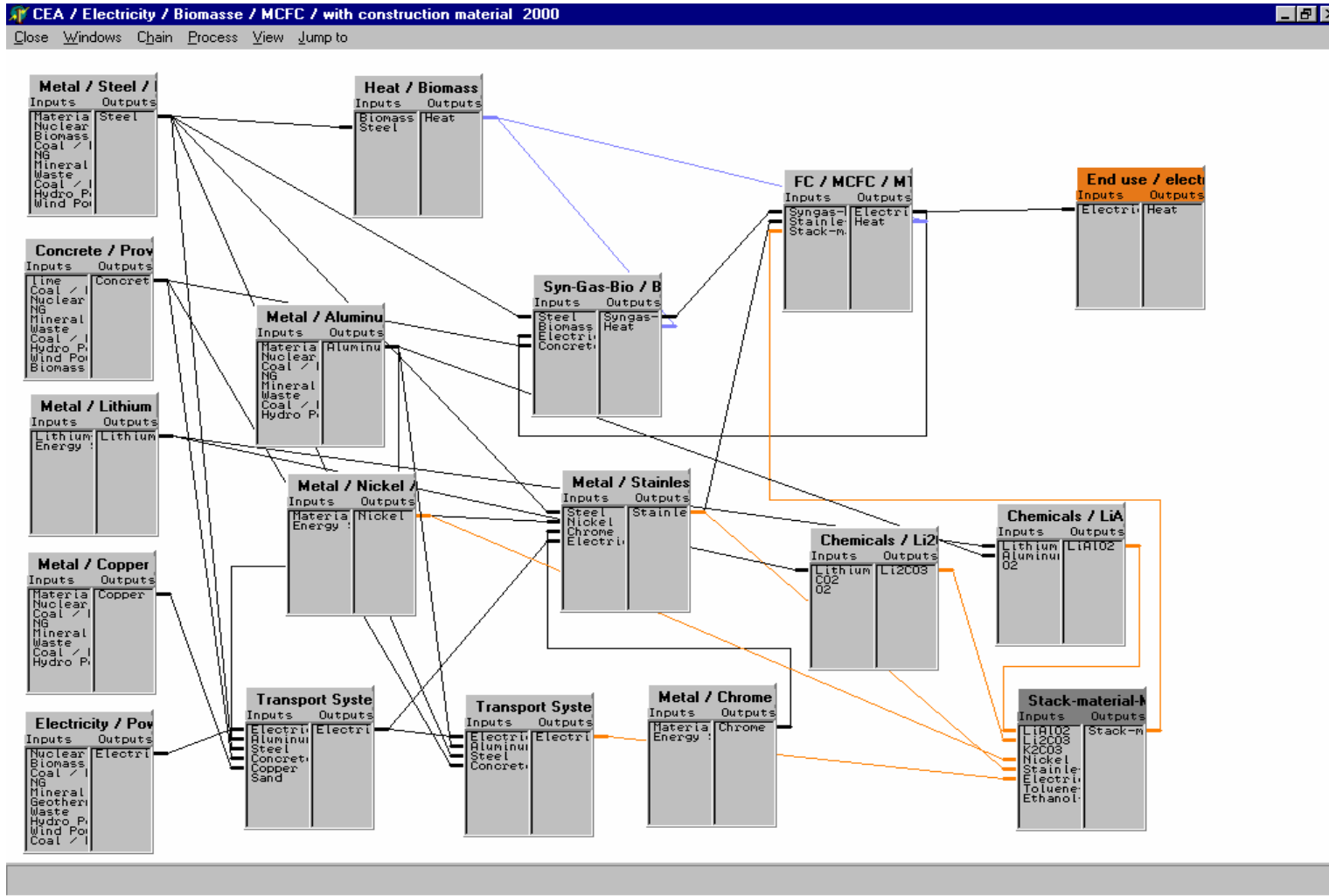
CEA / Electricity / Biomasse / MCFC 2000
Close Windows Chain Process View Jump to



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



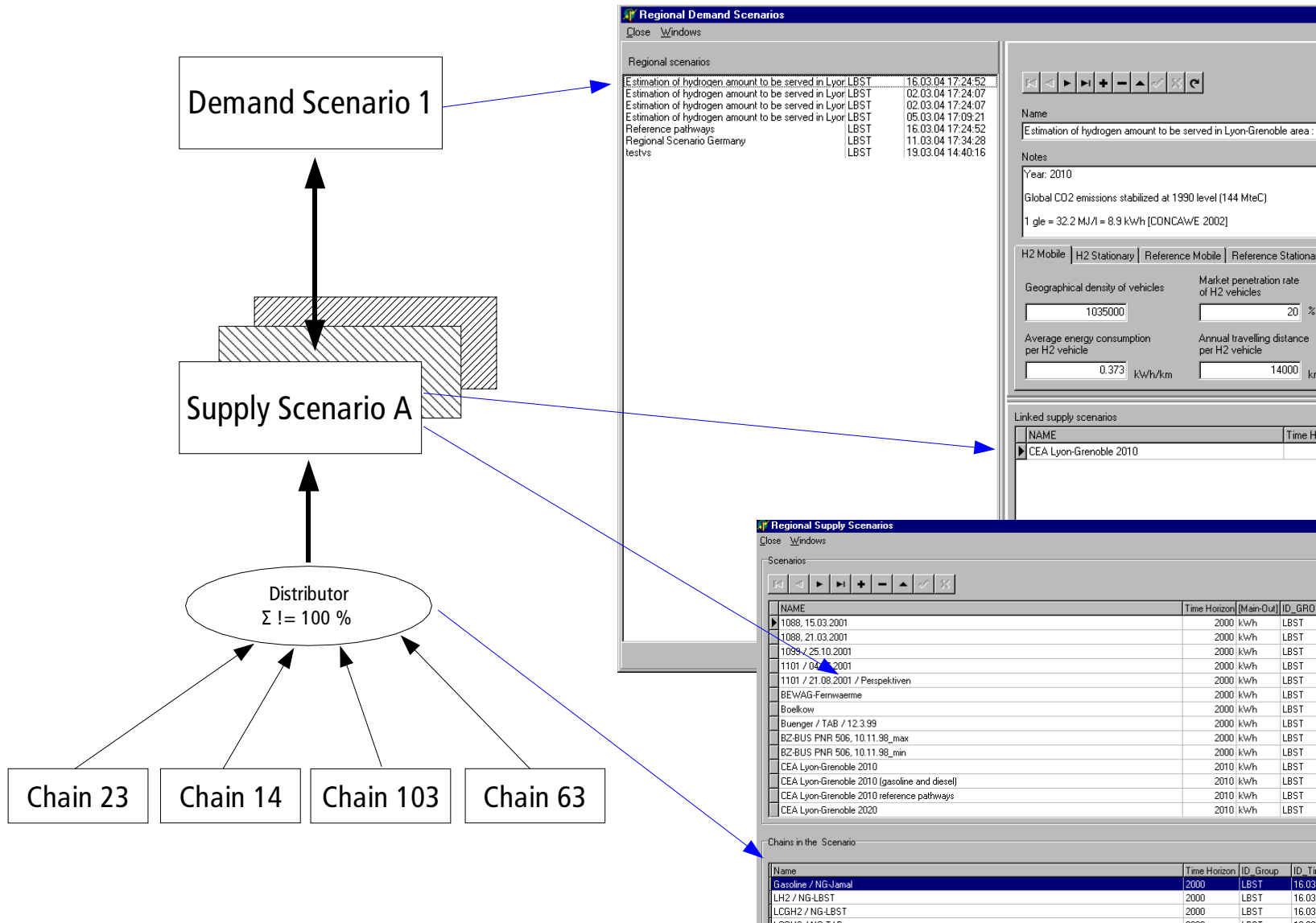
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Modelling of regional scenarios



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Regional demand scenario



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Interest
rate

Market
value
of CO₂

Regional Demand Scenarios

Scenario Specific Economic Data

Discount rate / interest rate: %

Market value of CO₂-equ emissions: EUR / t

Costs of energy and material inputs. Units are "kWh" or "kg" or "tkm"

Energy / Material	Costs / Unit [€]
CGH2	0
Diesel Oil	0
Electricity	0
GH2	0
NG	0

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

Notes: Year: 2010
Global CO₂ emissions stabilized at 1990 level (144 MteC)
1 gle = 32.2 MJ/l = 8.9 kWh [CONCAWE 2002]

H2 Mobile | H2 Stationary | Reference Mobile | Reference Stationary

Geographical density of vehicles	Market penetration rate of H2 vehicles	Number of H2 vehicles in operation
<input type="text" value="1035000"/>	<input type="text" value="20"/> %	<input type="text" value="207000"/>
Average energy consumption per H2 vehicle	Annual travelling distance per H2 vehicle	Amount of H2 to be served
<input type="text" value="0.373"/> kWh/km	<input type="text" value="14000"/> km/year	<input type="text" value="1080954000"/> kWh/year

Linked supply scenarios

NAME	Time Horizon	ID_GROUP	ID_TIMESTAMP
CEA Lyon-Grenoble 2010	2010	LBST	1/18/2005 10:47:57 AM

Show selected Scenario | Calculate (F9) | Add | Delete

Scenario

Regional supply scenario



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Regional Supply Scenarios

Close Windows

Scenarios

NAME	Time Horizon	[Main-Out]	ID_GROUP	ID_TIMESTAMP
CEA Lyon-Grenoble 2010	2010	kWh	LBST	1/18/2005 10:47:57 AM
CEA Lyon-Grenoble 2010 (gasoline and diesel)	2010	kWh	LBST	12/23/2004 2:55:06 PM
CEA Lyon-Grenoble 2010 reference pathways	2010	kWh	LBST	2/1/2005 5:13:29 PM
CEA Lyon-Grenoble 2020	2020	kWh	LBST	1/18/2005 10:47:57 AM
CEA Lyon-Grenoble 2030	2030	kWh	LBST	1/18/2005 10:47:57 AM
CEA Lyon-Grenoble 2050	2050	kWh	LBST	1/18/2005 10:47:57 AM
CEA Lyon-Grenoble 2000 (electricity from biomass)	2000	kWh	LBST	10/28/2004 8:52:01 AM
CONCAWE / Electricity 0.4 kV	2000	kWh	LBST	2/11/2005 11:42:28 AM
CONCAWE / Example for Regional Demand Scenario	2010	kWh	LBST	2/11/2005 11:42:28 AM
CONCAWE / WTT new pathways	2010	kWh	LBST	2/9/2005 3:46:50 PM
CONCAWE / WTT-Bio	2010	kWh	LBST	2/9/2005 3:46:50 PM
CONCAWE / WTT-Coal	2010	kWh	LBST	2/11/2005 4:27:33 PM
CONCAWE / WTT-Crude-Oil	2000	kWh	LBST	12/23/2004 2:55:06 PM
CONCAWE / WTT-Electrolysis	2000	kWh	LBST	2/11/2005 11:42:28 AM

Chains in the Scenario

Name	Time Horizon	ID_Group	ID_TimeStamp	Percentage
CEA LSMRgas / WTT+U / CGH2 2010 / Local SMR	2010	LBST	1/18/2005 10:47:57 AM	25
CEA CSMRgas / WTT+U / CGH2 2010 / Central SMR	2010	LBST	1/18/2005 10:47:57 AM	25
CEA LCWEgas / WTT+U / CGH2 2010 / Electricity mix France	2010	LBST	10/29/2004 1:58:29 PM	25
CEA CCWEgas / WTT+U / CGH2 2010 / Electricity mix France	2010	LBST	11/26/2004 3:49:58 PM	25

Show selected chain Edit percentage Remove Chain Add Chain Calculate Chains

up down

Supply scenarios

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



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 !

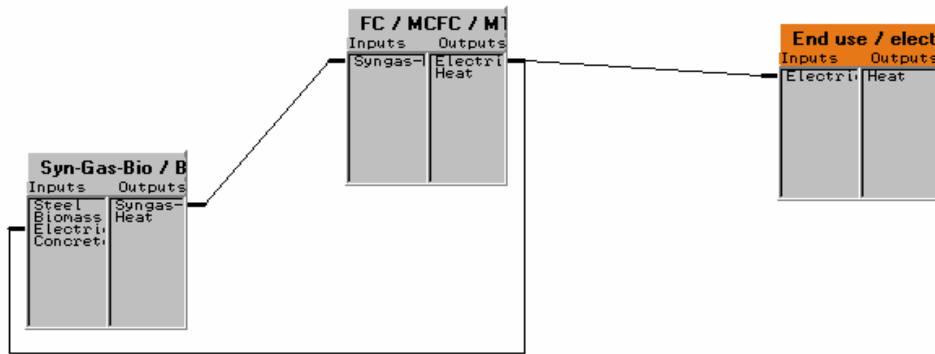
Chain: electricity with biomass fueled MCFC



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CEA / Electricity / Biomasse / MCFC 2000

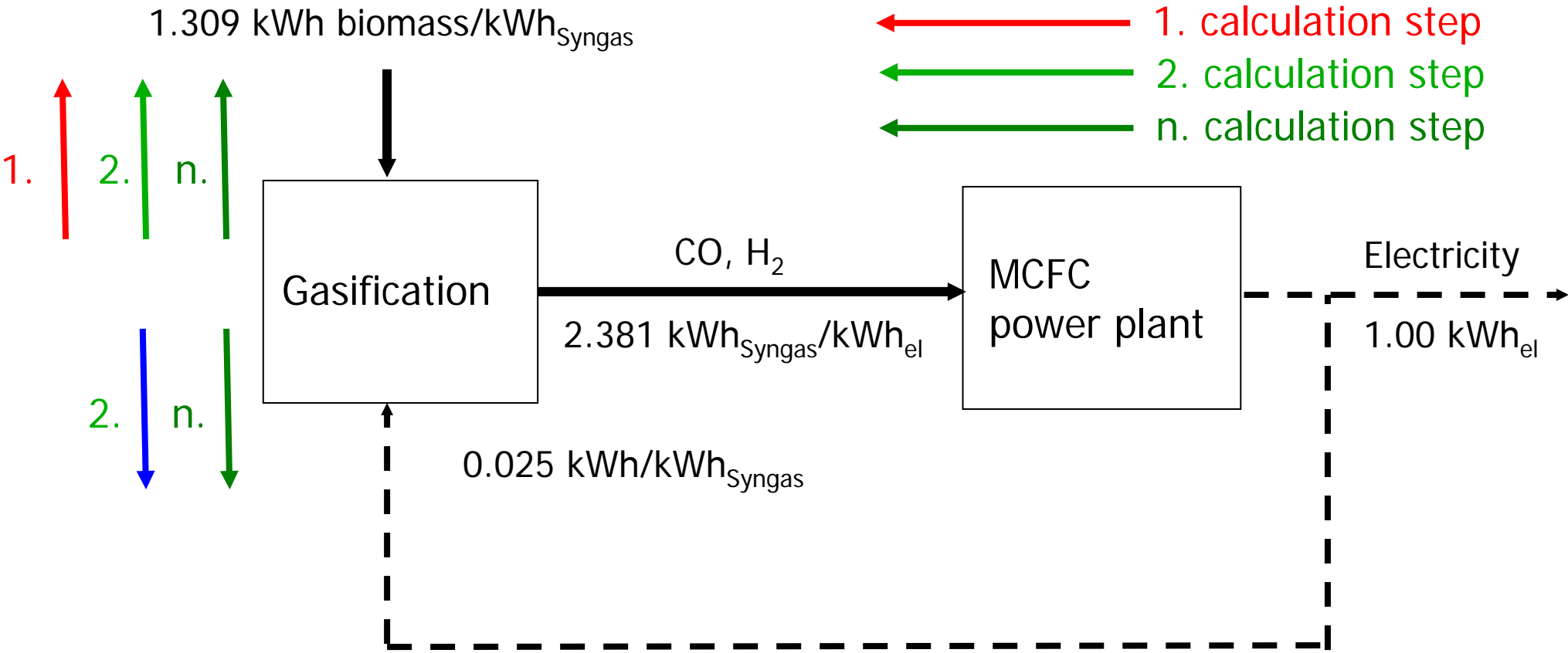
Close Windows Chain Process View Jump to



Example for a recursion: Electricity generation with biomass fueled MCFC



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$$E = (1.309 + 0.025 * 2.381 * (1.309 + 0.025 * 2.381 * (1.309 + 0.025 * 2.381 \dots))) * 2.381 \text{ kWh/kWh}_{\text{el}} = 3.313 \text{ kWh/kWh}_{\text{el}}$$

Example for a recursion: Electricity generation with biomass fueled MCFC



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

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

Stochastic variations of input or output parameters

- Energy inputs
- Material inputs
- CH₄-emissions
- N₂O-emissions

Variation of output parameters as a function of varying energy inputs

- CO₂-emissions

Different probability distributions for randomization of parameters

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



- Chain
- Regional supply scenario
- Regional demand scenario

Results: electricity from biomass via MCFC



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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/kWh
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

- 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 electricity 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/kWh
CEA L5MRgas / 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



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Compile Results

close

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

Regional Scenario Summary | Costs Per Chain | Emissions | Charts

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	

Total specific costs of a single chain

Plant / Process	No. of Plants in Chain	Unused Capacity [% of last unit]	Investment [EUR]	Costs / Year [EUR]
Transport System / Distribution-GI 0	0	0	0	176534
Mechanical Work / NG / GT-EU 1	95	95	0	0
Mechanical Work / NG / GT-EU 1	98	98	0	0
NG / Extraction+Processing / CO 0	0	0	0	5076479
Transport / NG / Distribution / HF 0	0	0	0	158837
Transport / NG / Pipeline NG->EU 1	99	99	0	0
Transport / NG / Distribution-loca 0	0	0	0	79418
CGH2 / Filling Station / in 1.5 MP 76	94	94	35948000	4363833
GH2 / NG / Steam Reforming / H 48	15	15	39623184	4746644
Electricity / Power-Plant-Mix-EU-1 0	0	0	0	1054337
Transport System / Distribution-F 0	0	0	0	102802
Transport System / Distribution-GI 0	0	0	0	510437
Metal / Steel / Provision / Mix GE 1	93	93	0	0
Metal / Aluminum / Provision / GE 1	98	98	0	0
Metal / Aluminum / Provision / GE 1	100	100	0	0
Concrete / Provision / GER / GE 1	98	98	0	0
Cement / Provision / GER / GEM 1	100	100	0	0
Plastics / HDPE / Provision / GE 1	100	100	0	0
Metal / Copper / Provision / Sec 1	100	100	0	0
Metal / Nickel / Provision / GABI 1	100	100	0	0
Metal / Zinc / Provision / Primary 1	100	100	0	0
Metal / Copper / Provision / Prim 1	100	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



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Compile Results

close

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

Regional Scenario Summary | Costs Per Chain | Emissions | Charts

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

Copy to clipboard

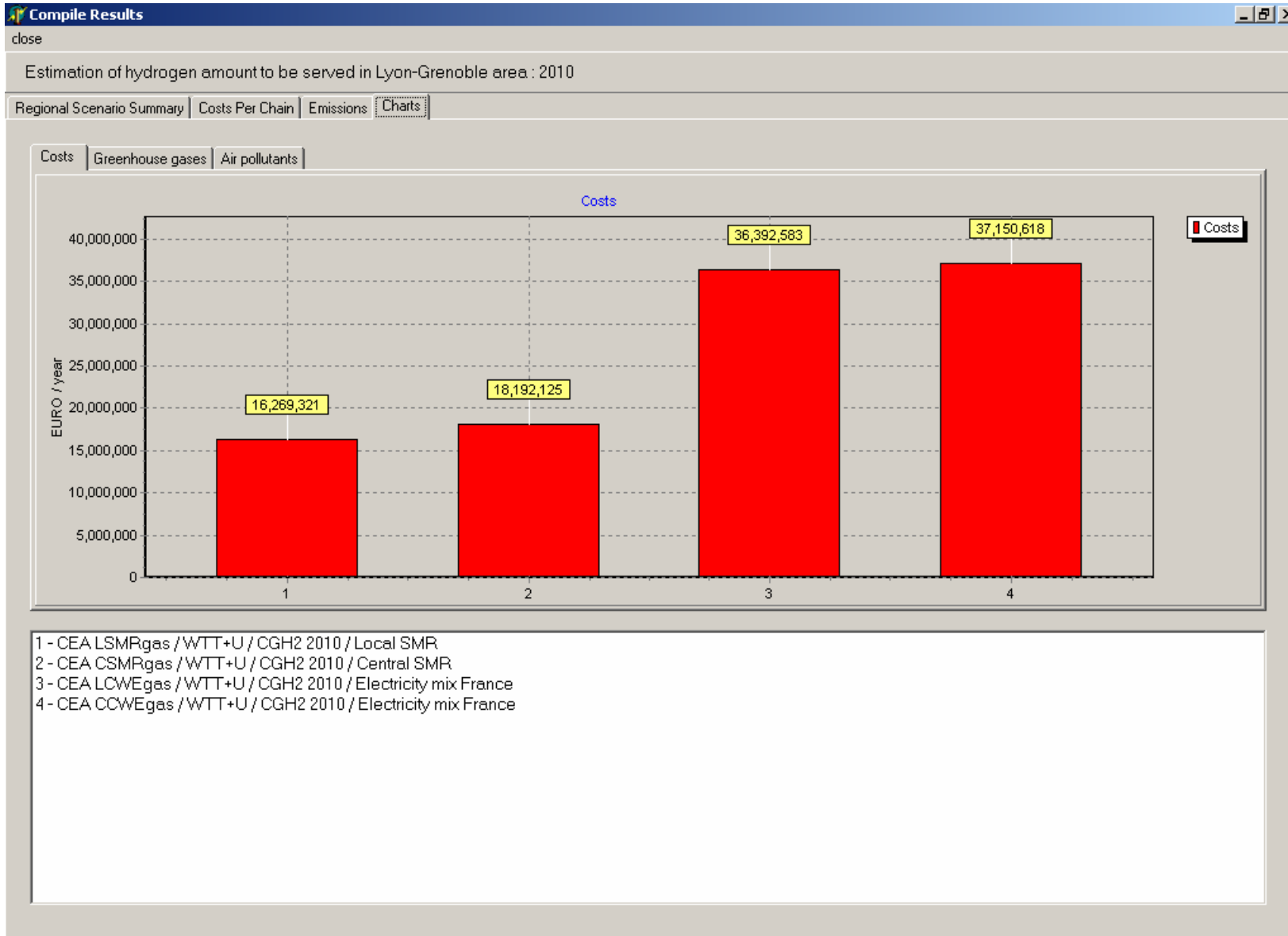
Total costs of the selected regional demand scenario (mix of pathways)

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

Results: costs of regional demand scenario



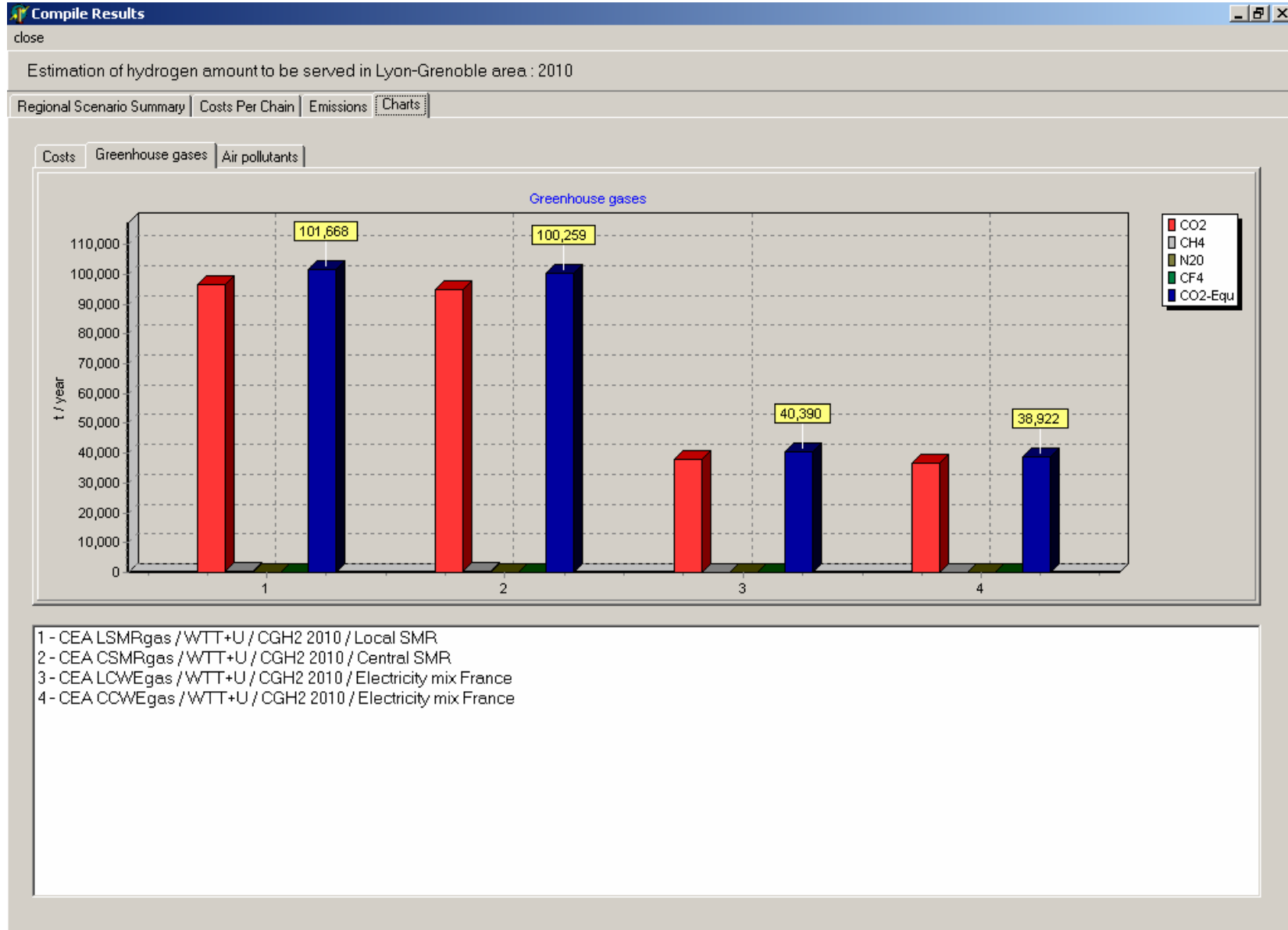
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Results: GHG emissions of a regional demand scenario



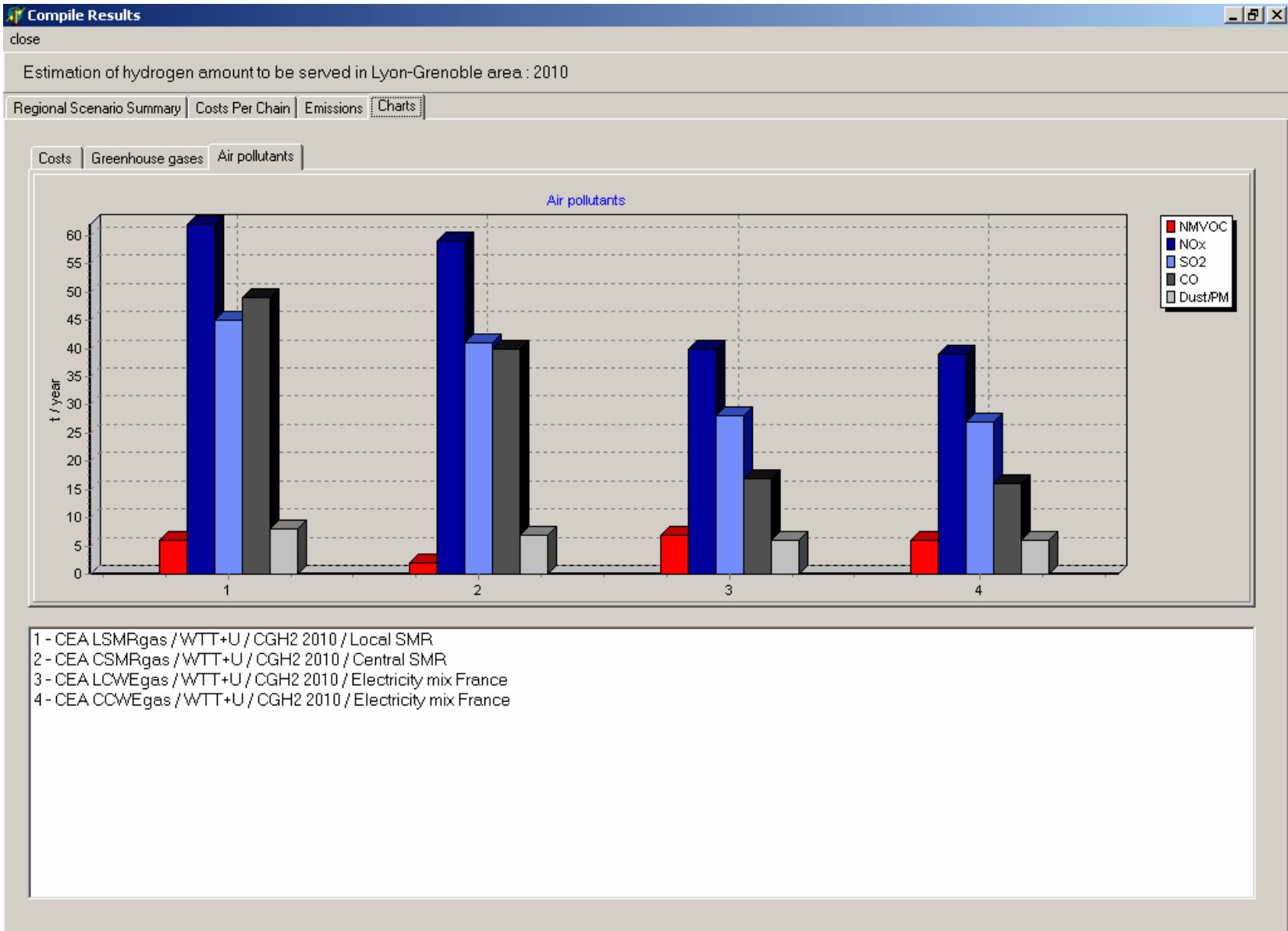
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Results: Air pollutant emissions of a regional demand scenario



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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.



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



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- ..)