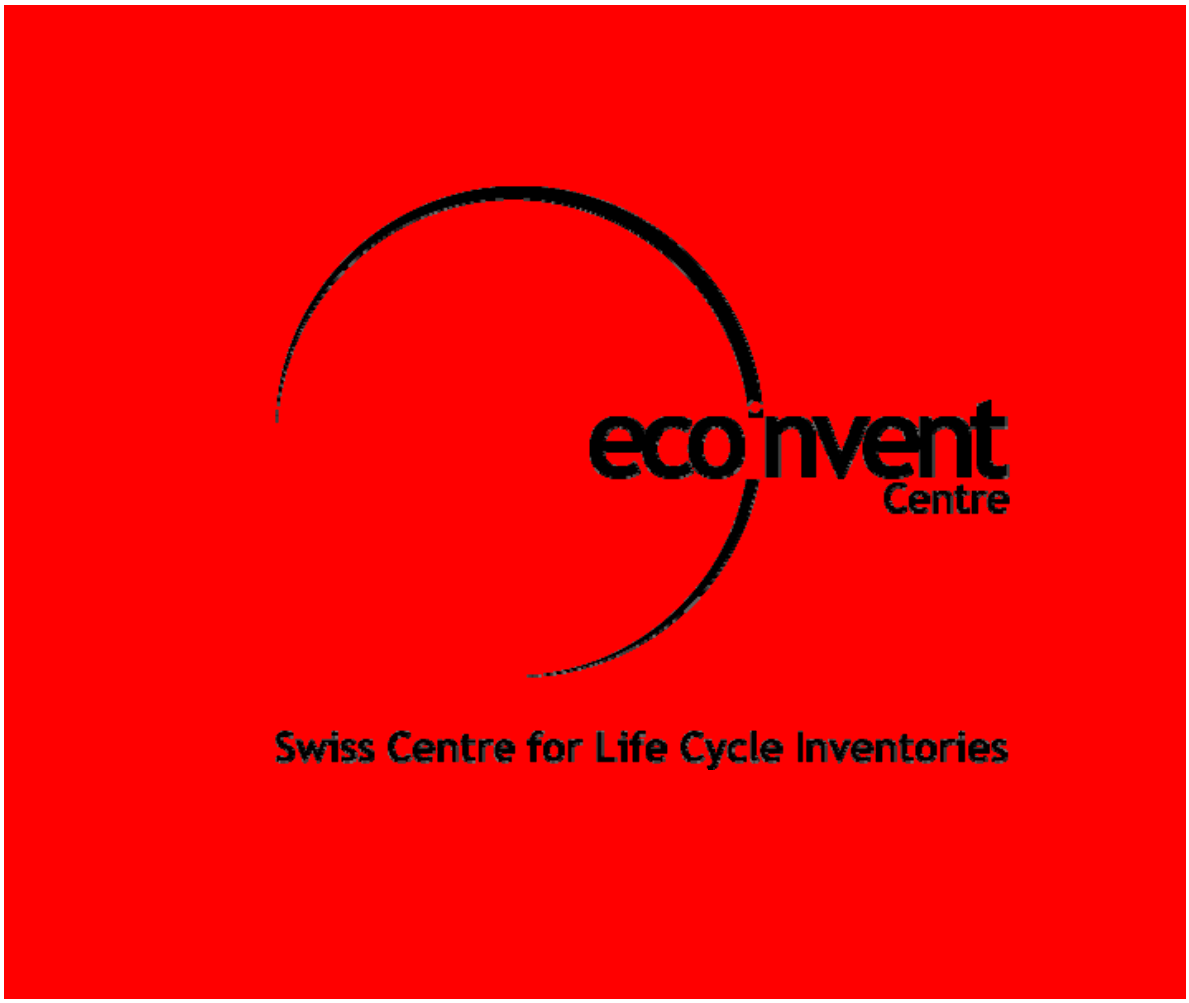

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2nd International ecoinvent Meeting
Lausanne, March 14, 2008

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ecoinvent data v2.0
Energy Supply

Christian Bauer, Paul Scherrer Institut (http://gabe.web.psi.ch/)
Niels Jungbluth, ESU-services Ltd. (www.esu-services.ch)
Rolf Frischknecht, ESU-services Ltd.

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New ecoinvent data v2.0

- **US electricity sector:**
  coal, natural gas & nuclear chains + PV mix
  → electricity mix
- **Chinese electricity sector:**
  coal & nuclear chains + PV mix
  → electricity mix
- **Emerging small scale combined heat and power systems (CHP)**
  (Alex Primas, Basler & Hofmann)
- **Photovoltaics** (Niels Jungbluth)
- **Bioenergy systems** (parallel session)
- **Electricity mixes** (Rolf Frischknecht):
  New: BR & JP, EU-27
  Updated: European countries
  (incl. emissions of coal power plants in PL, CZ, SK, HU)

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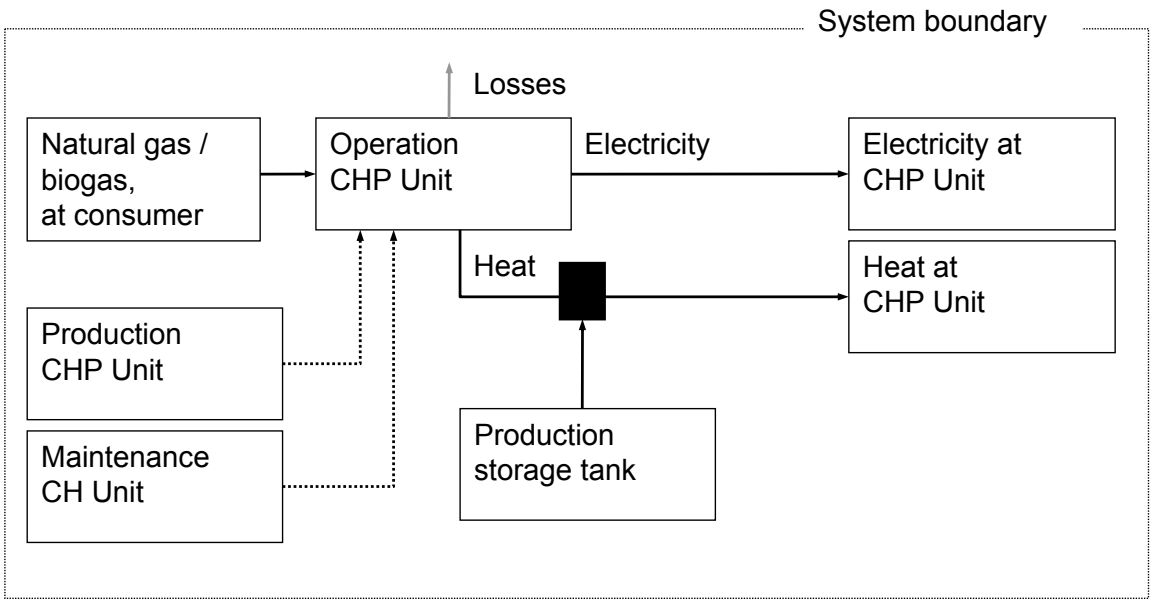
Small CHP: system boundaries

Inventories include micro gas turbines,
fuel cells (PEM and SOFC) and Stirling engines



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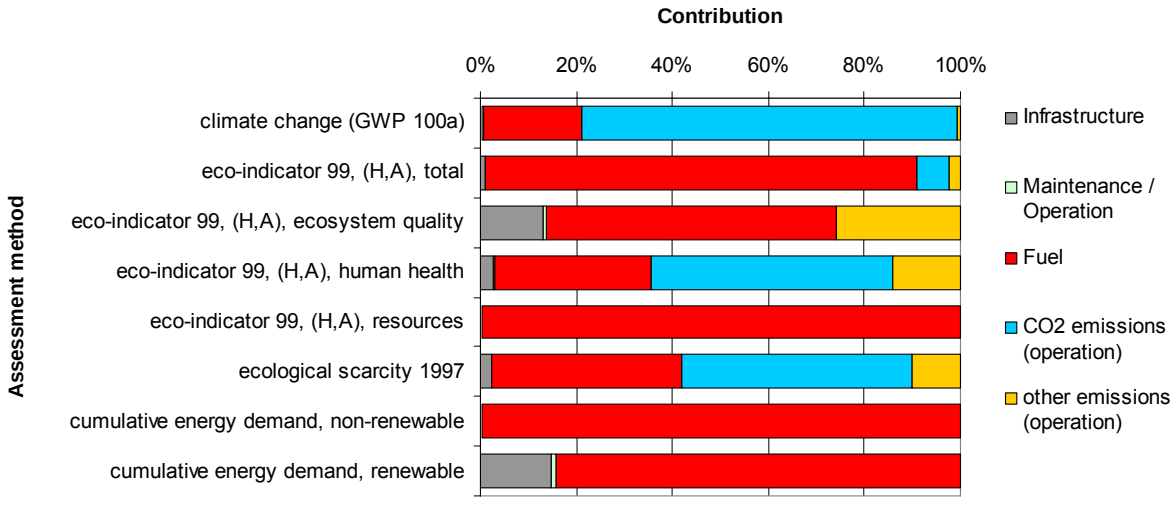
Natural gas, burned in micro gas turbine 100kWe



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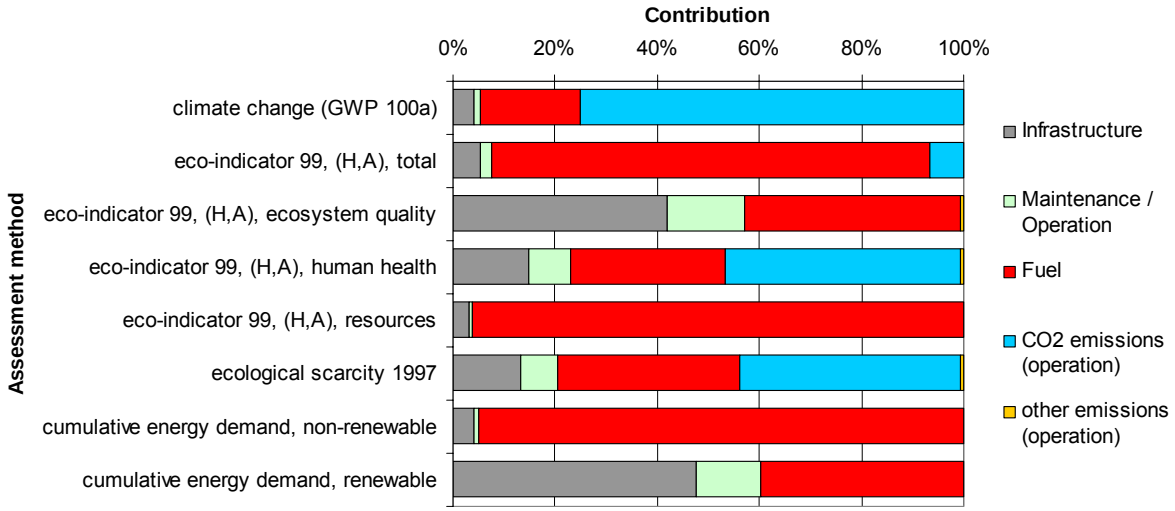
- Natural Gas fuel and CO_2-Emissions from operation are the main impact.

Natural gas, burned in PEM fuel cell 2kWe, future



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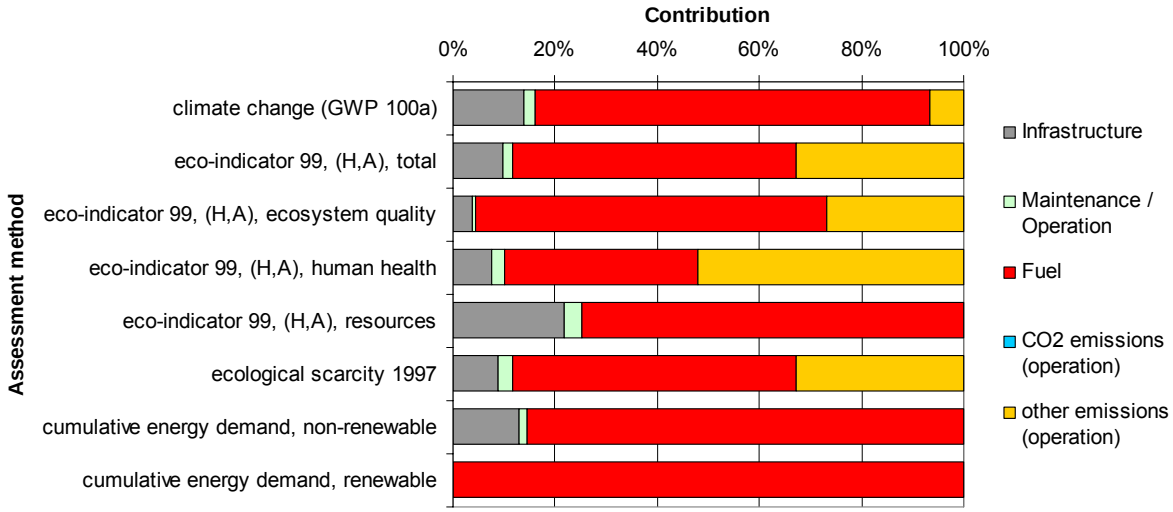
- Infrastructure of fuel cell of importance for impact on ecosystem quality.

Wood pellets, burned in stirling cogen unit 3kWe, future



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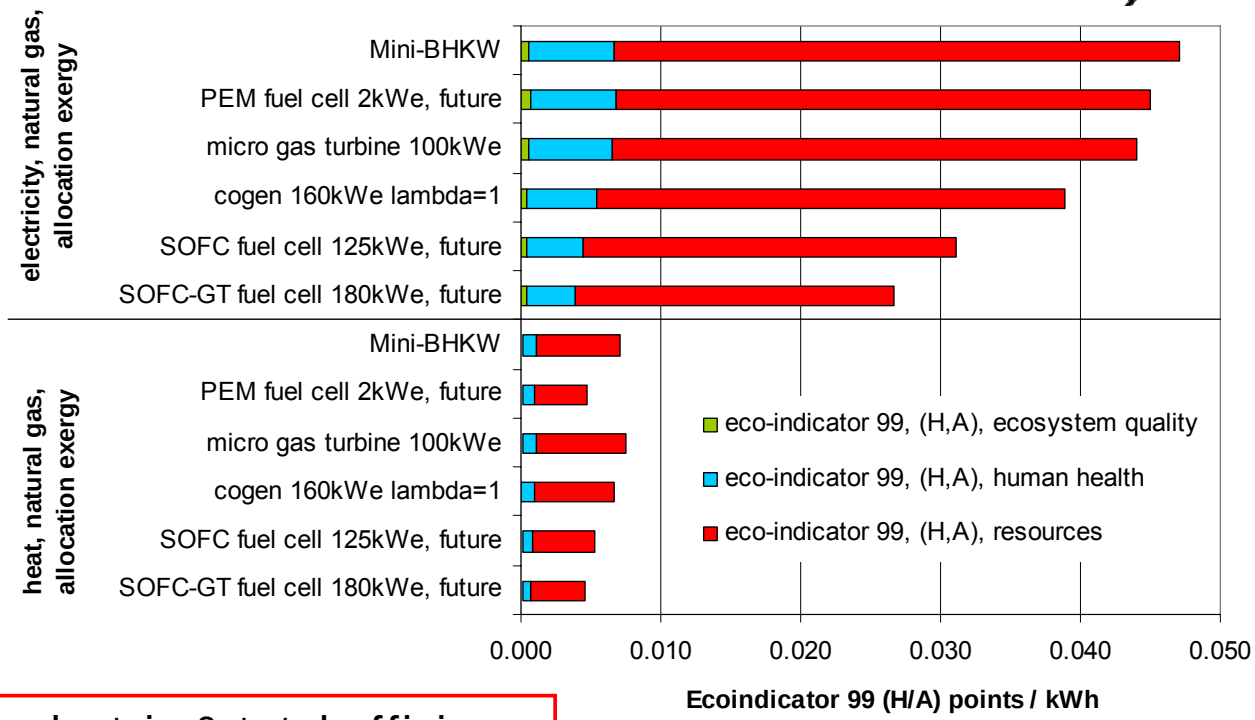
- NOx and Particulate emissions from operation are of importance for total impact.

Small CHP: technical characteristics

Fuel	CHP-System	el. power	el. efficiency	th. efficiency
Natural gas, biogas	Cogen 160kWe lambda=1	160 kW_{el}	η_{el} = 32%	η_{th} = 55%
Natural gas, biogas	Micro gas turbine	100 kW_{el}	η_{el} = 29%	η_{th} = 46%
Natural gas, biogas	SOFC-GT fuel cell	180 kW_{el}	η_{el} = 58%	η_{th} = 22%
Natural gas, biogas	SOFC fuel cell	125 kW_{el}	η_{el} = 47%	η_{th} = 33%
Natural gas	Mini-BHKW	5 kW_{el}	η_{el} = 25%	η_{th} = 65%
Natural gas, biogas	PEM fuel cell	2 kW_{el}	η_{el} = 32%	η_{th} = 55%
Wood pellets	Stirling motor	3 kW_{el}	η_{el} = 23%	η_{th} = 67%

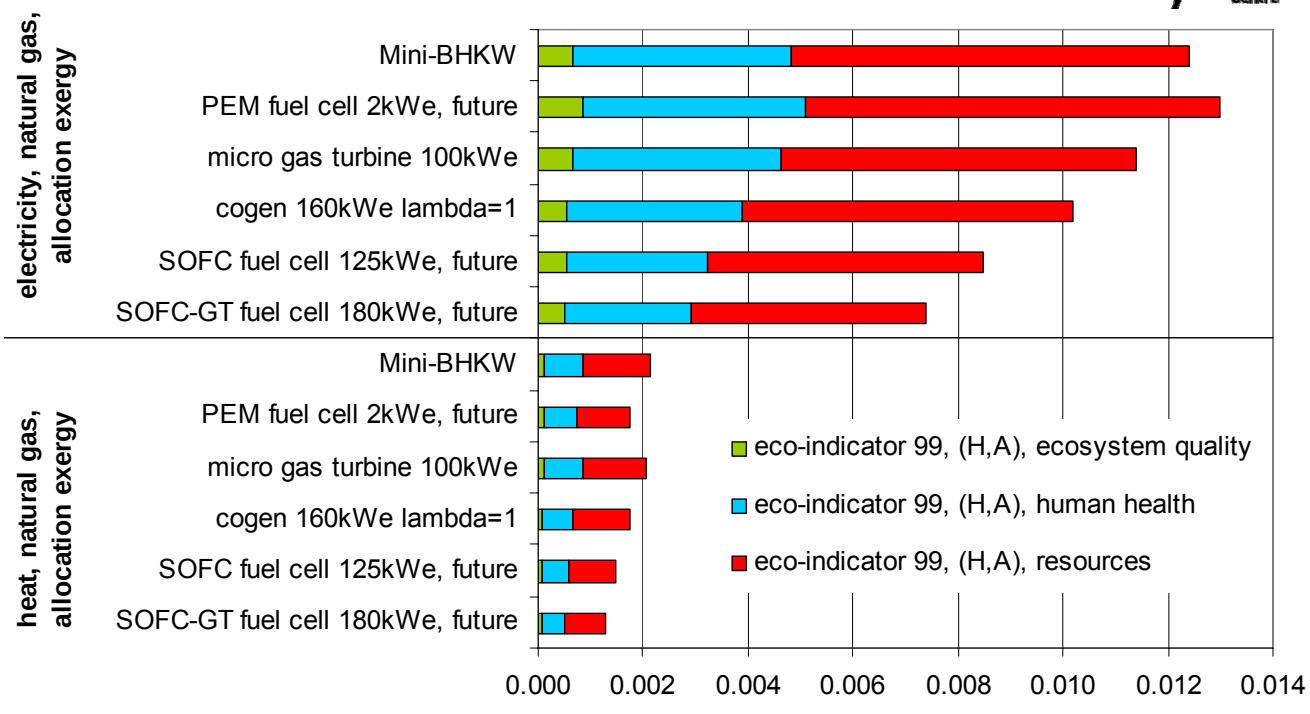
electricity / heat from natural gas



High electric & total efficiency leads to a low impact

Presentation: Christian Bauer

electricity / heat from biogas



Use of Biogas → reduction of fossil resource demand & GHG emissions

Presentation: Christian Bauer

US electricity sector

- US specific modelling for 3 energy chains:
  - hard coal
  - natural gas
  - nuclear
- Main data sources used:
  - US National Renewable Energy Laboratory LCI database
  - Emissions & Generation Resource Integrated Database
  - Nuclear Regulatory Commission, US DOE
  - ecoinvent background data

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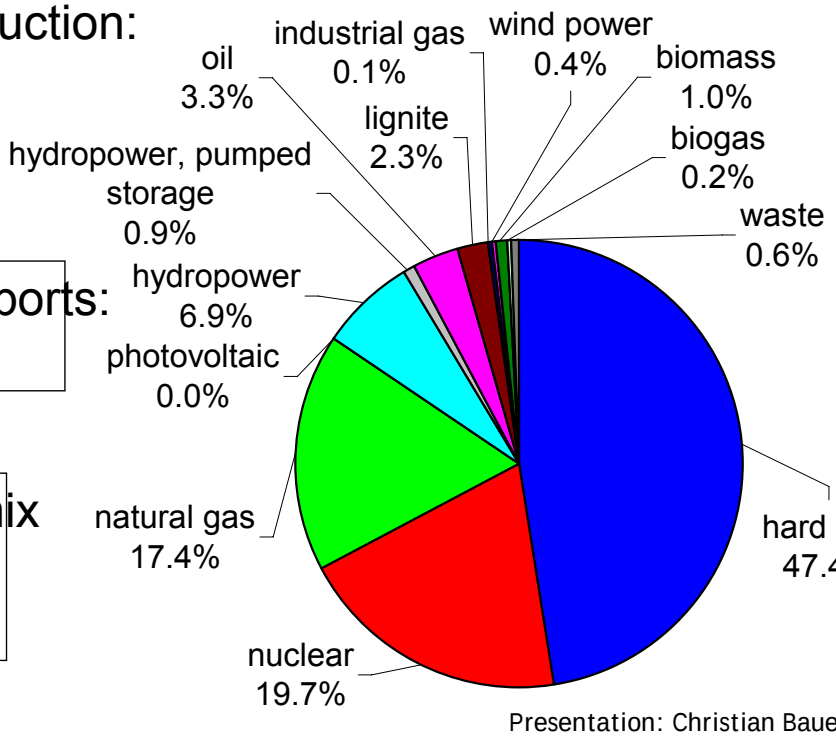
US electricity mix (2004)

Total US production:
4006 TWh/a



Electricity imports:
34 TWh/a

↓

Production mix
≈
Supply mix

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Modeling of US electricity mix (2004)

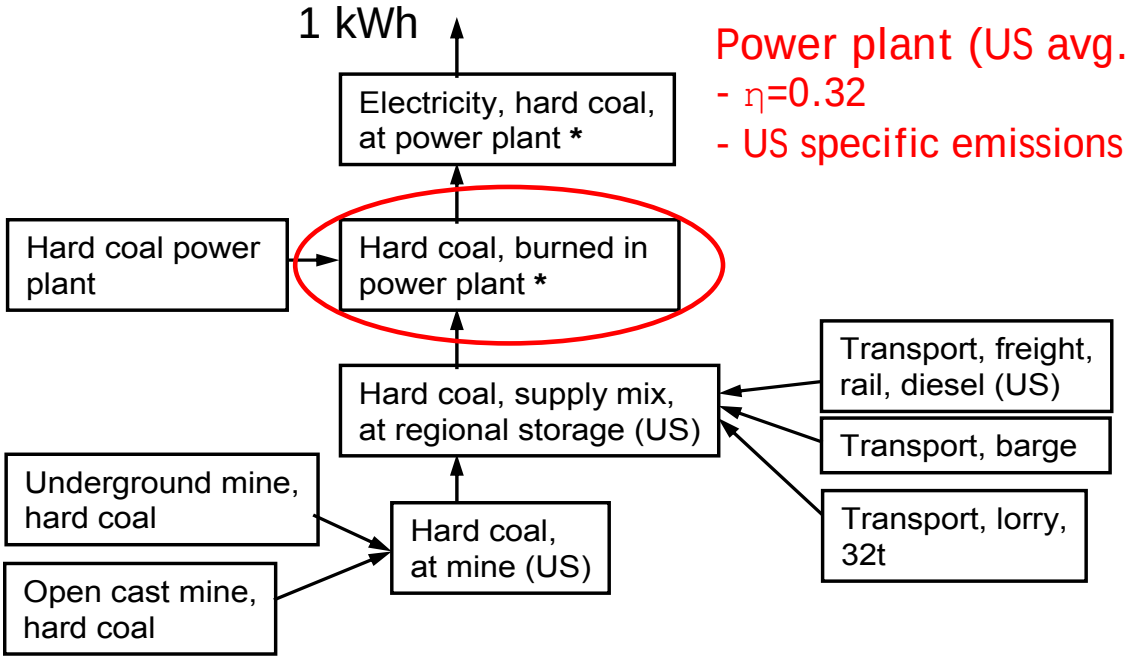
Name	Location	Unit	*electricity, production mix US*	*electricity, supply mix US (incl. imports)*
Location			***US***	***US***
Unit			***kWh***	***kWh***
electricity, hard coal, at power plant	**US**	kWh	**47.41%**	**47.05%**
electricity, nuclear, at power plant	**US**	kWh	**19.68%**	**19.64%**
electricity, natural gas, at power plant	**US**	kWh	**17.42%**	**17.32%**
electricity, hydropower, at pumped storage power plant	**US**	kWh	**0.88%**	**0.87%**
electricity, production mix photovoltaic, at plant	**US**	kWh	**0.01%**	**0.01%**
electricity, hydropower, at power plant	SE	kWh	6.86%	7.28%
electricity, oil, at power plant	UCTE	kWh	3.31%	3.32%
electricity, lignite, at power plant	UCTE	kWh	2.26%	2.34%
electricity, at cogen 6400kWth, wood, allocation exergy	CH	kWh	0.96%	0.96%
electricity, at wind power plant	RER	kWh	0.35%	0.35%
electricity, at cogen with biogas engine, allocation exergy	CH	kWh	0.16%	0.16%
electricity, industrial gas, at power plant	UCTE	kWh	0.10%	0.10%

JS specific modeling for ~ 85% of electricity production

European LCA data used for ~ 15% of electricity production

→ small impact on cumulative LCA results

Model of the US hard coal chain



Power plant (US avg.):
- η=0.32
- US specific emissions

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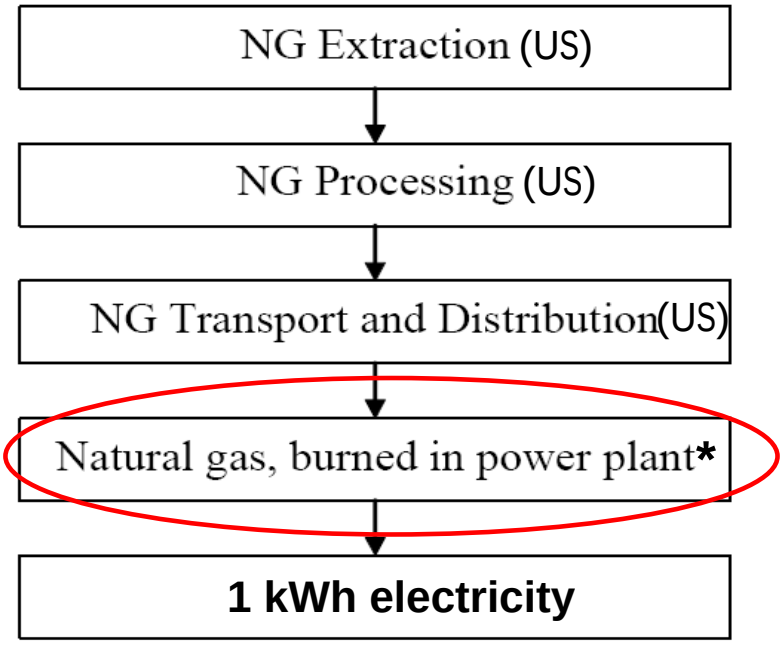
* specifically modeled for eight US councils following North American Electric Reliability Corporation (NERC)

Model of the US natural gas chain



Power plant (US avg.):
- η=0.34
- US specific emissions

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* specifically modeled for eight US councils following North American Electric Reliability Corporation (NERC)

Presentation: Christian Bauer

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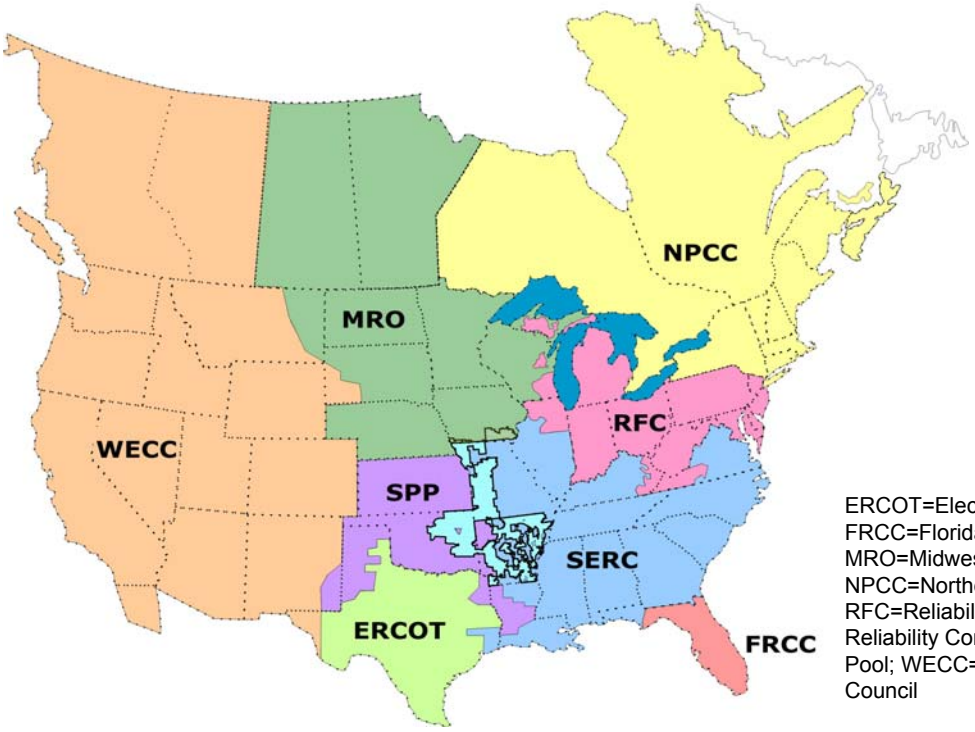
Regions considered for modeling of US coal and gas chains



ERCOT=Electric Reliability Council of Texas; FRCC=Florida Reliability Coordinating Council; MRO=Midwest Reliability Organization; NPCC=Northeast Power Coordinating Council; RFC=Reliability First Corporation; SERC=SERC Reliability Corporation; SPP=Southwest Power Pool; WECC=Western Electricity Coordinating Council

Presentation: Christian Bauer

Key characteristics of US hard coal electricity prouction

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		US total	ERCOT	FRCC	MRO	NPCC	RFC	SERC	SPP	WECC
installed net capacity	GW_{el}	346.5	8.9	10.5	22.6	8.1	130.9	112.5	22.1	31.4
fuel input	MJ	2.04E+13	6.06E+11	5.81E+11	1.63E+12	4.49E+11	6.90E+12	6.46E+12	1.49E+12	2.37E+12
total net generation	kWh	1.81E+12	5.19E+10	6.06E+10	1.18E+11	4.03E+10	6.38E+11	5.86E+11	1.10E+11	2.05E+11
average net efficiency	%	31.8%	30.8%	37.5%	26.0%	32.3%	33.2%	32.7%	26.6%	31.1%
NO_x	kg/kWh	1.85E-03	7.44E-04	2.03E-03	2.71E-03	1.33E-03	1.84E-03	1.64E-03	2.30E-03	2.10E-03
SO_2	kg/kWh	5.17E-03	2.73E-03	2.90E-03	3.99E-03	5.71E-03	6.81E-03	5.48E-03	3.78E-03	1.70E-03
CO_2	kg/kWh	1.09E+00	1.13E+00	9.24E-01	1.34E+00	1.06E+00	1.05E+00	1.07E+00	1.31E+00	1.12E+00
Hg	kg/kWh	2.49E-08	2.86E-08	9.55E-09	2.49E-08	1.74E-08	3.16E-08	2.28E-08	2.06E-08	1.70E-08

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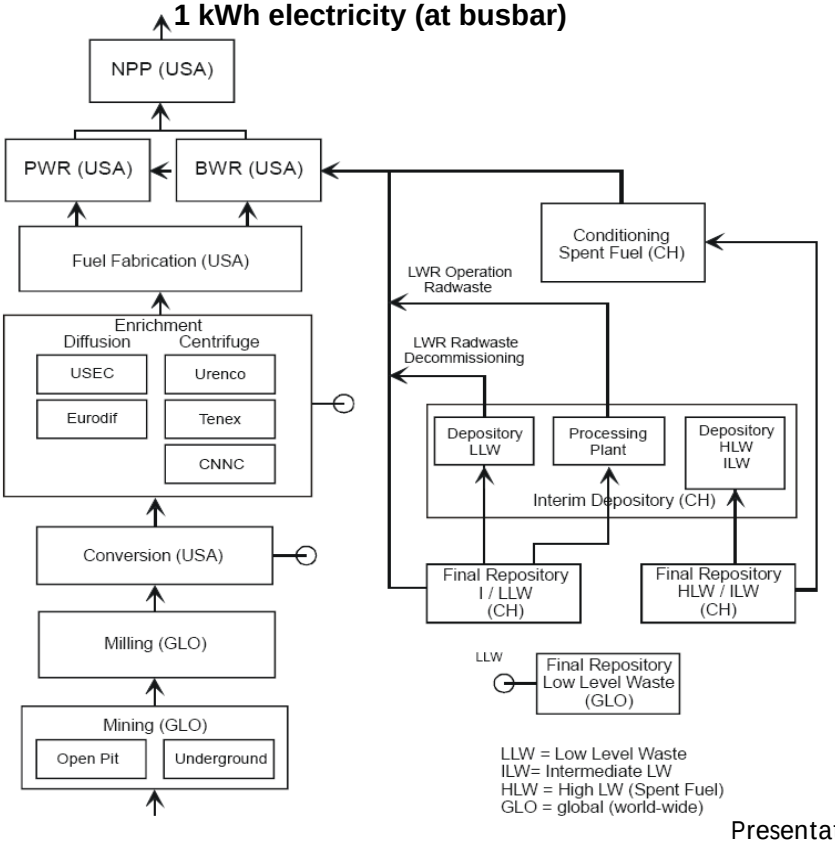
Model of the US nuclear chain



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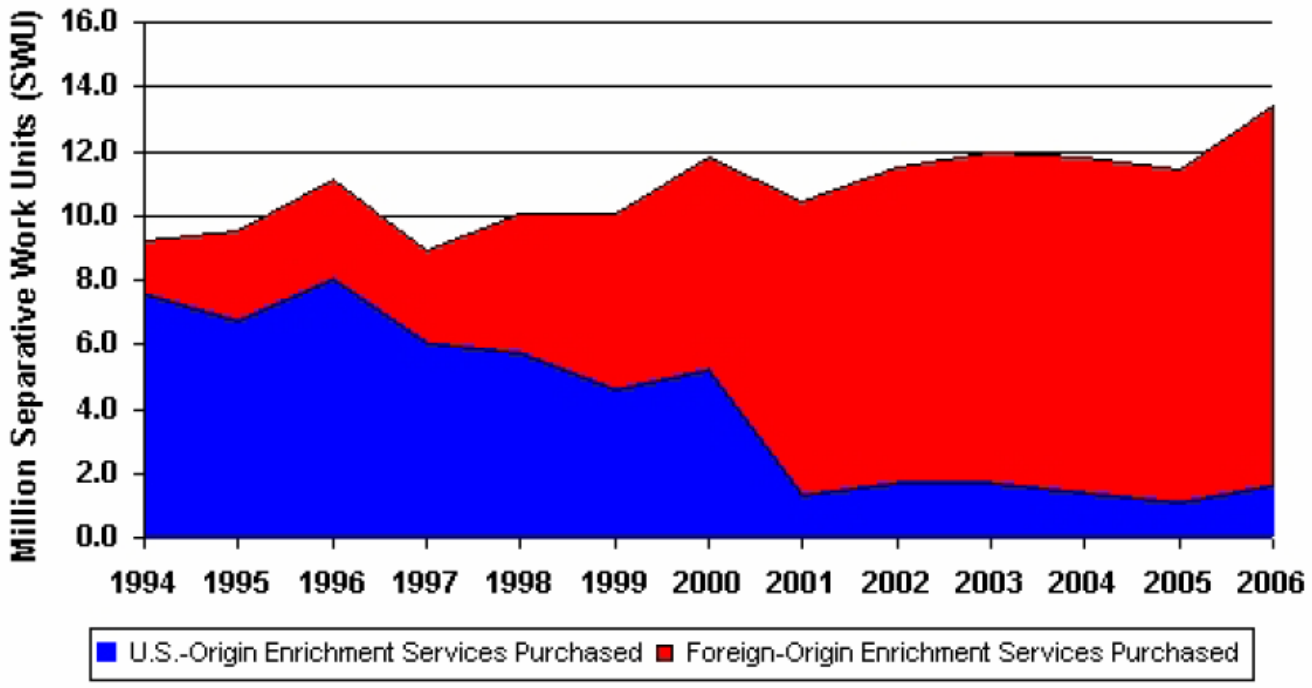
Origin of uranium for US reactors

	2003	2004	2005	2006	average	shares
Australia	9326	11660	9957	17052	11999	19%
Brazil	0	0	0	822	206	0%
Canada	17050	16468	22881	13325	17431	28%
Kazakhstan	4232	4211	1639	1628	2928	5%
Namibia	1034	2780	2963	3009	2447	4%
Russia	7689	10329	12959	15116	11523	18%
South Africa	1438	2091	573	725	1207	2%
Uzbekistan	3725	2303	2505	2020	2638	4%
Other (not specified)	1858	1918	1265	2035	1769	3%
Total Foreign	**46352**	**51760**	**54742**	**55732**	52147	**82%**
United States	10200	12342	11007	10807	11089	**18%**
Total Purchases	**56552**	**64102**	**65749**	**66539**	63236	100%

Origin of U enrichment services

Deliveries in Thousand Separative Work Units (SWU)	**2003**	**2004**	**2005**	**2006**	**average**
Country of Enrichment Service (SWU-origin)					
China	W	W	W	W	
France	2685	2325	1831	2154	
Germany	660	851	583	818	
Netherlands	542	402	581	960	
Russia	4224	4563	5059	4724	
United Kingdom	1586	1379	1379	2001	
Europe[a]	W	W	W	W	
Other[b]	0	0	W	W	
Foreign Total	**10328**	**10411**	**10343**	**11808**	
United States	1665	1374	1052	1630	
Total	**11993**	**11785**	**11394**	**13437**	
Share Foreign to Total	86%	88%	91%	88%	88%

Origin of U enrichment services



Shares of enrichment technologies for US reactors

Technology	Supplier	Fraction
Centrifuge	CNNC	0.074
	Tenex	0.382
	Urenco	0.242
Diffusion	Eurodif	0.185
	USEC	0.118

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Characteristics of US reactors

Parameter		BWR	PWR
Units in operation		35	69
Installed capacity	MW_e	33201	68789
Net electricity generation of nuclear origin in 2006	kWh	2.64E+11	5.23E+11
Share to total electricity of nuclear origin in 2006	%	33.5	66.5
Average load factor 2004-2006	%	91.6	90.9
Average lifetime load factor to end of September 2006	%	72.8	77.8
Average lifetime load factor assumed in ecoinvent	*%*	*80*	*85*
Lifetime assumed in ecoinvent	*a*	*40*	*40*
Lifetime net electricity generated assumed in ecoinvent	*kWh*	2.80E+11	2.98E+11

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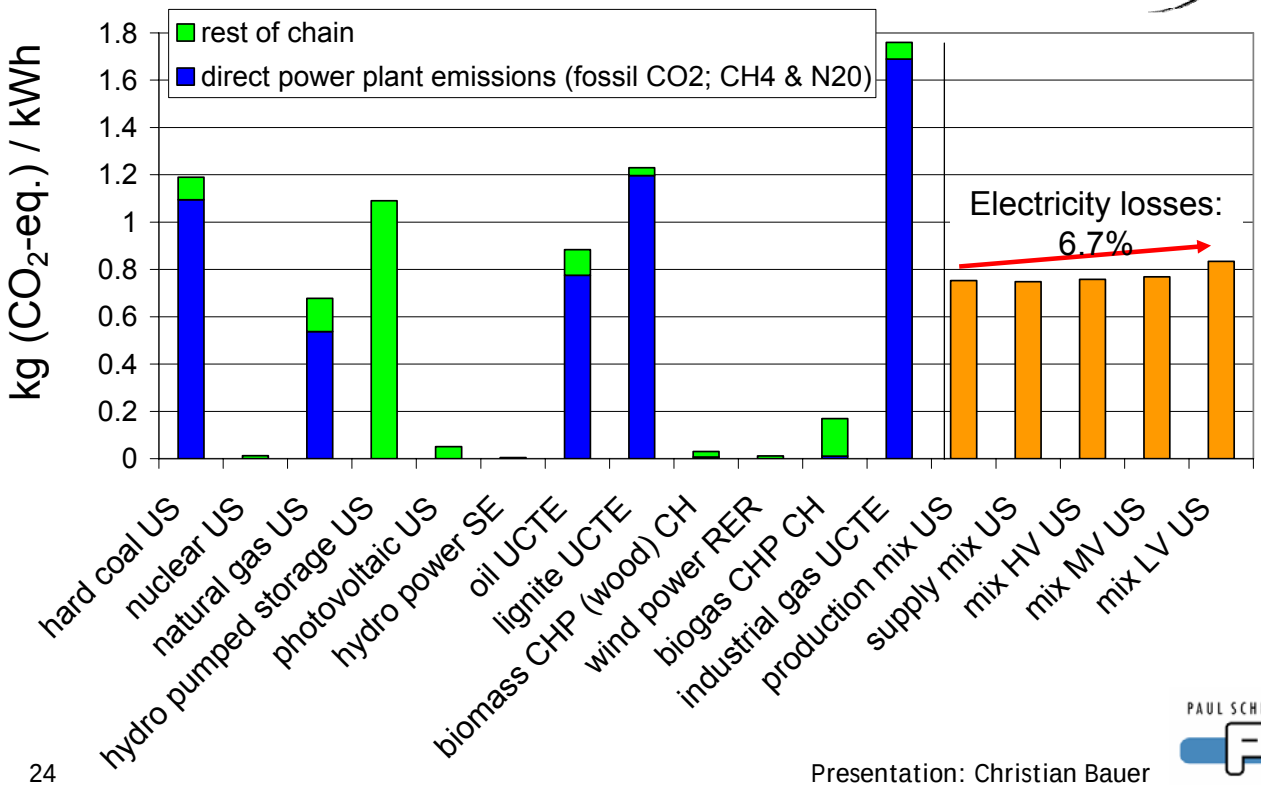
GHG emissions, US electricity mix



Chinese electricity sector

- China specific modelling for 2 energy chains:
  - hard coal
  - nuclear
- Main data sources used:
  - China Energy Technology Program (CETP):
    reflects situation at end of the 1990's
  - ecoinvent background data

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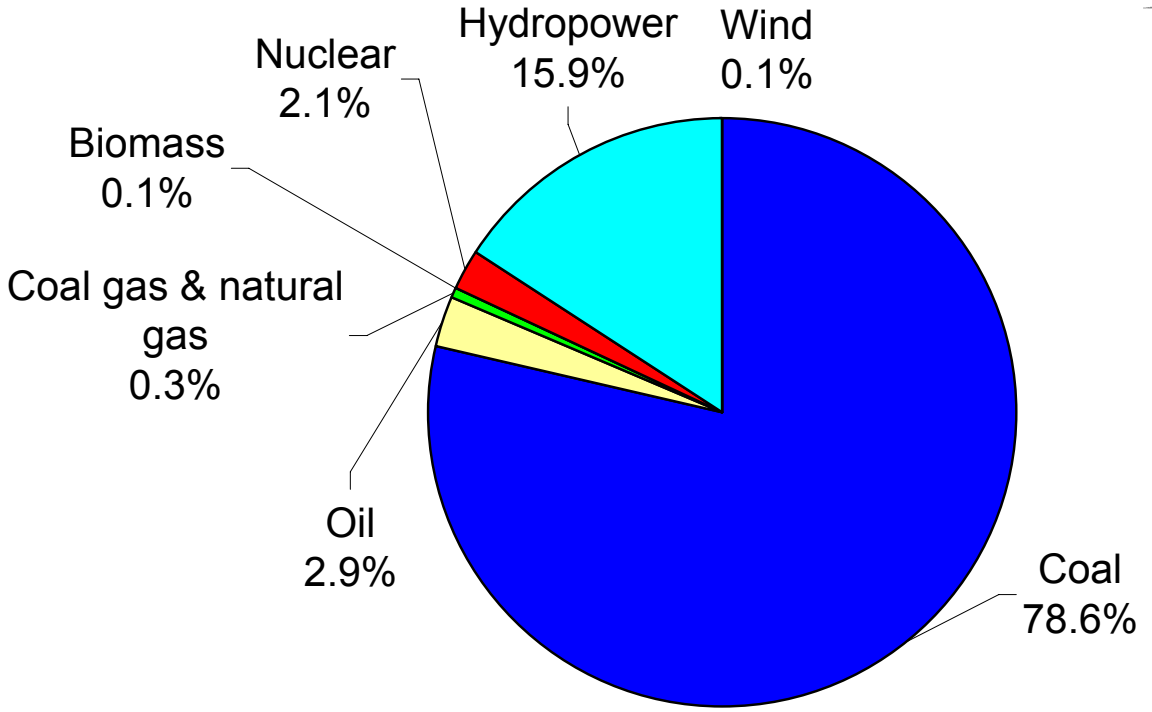
Chinese electricity mix (2005)



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Modelling of CN electricity mix

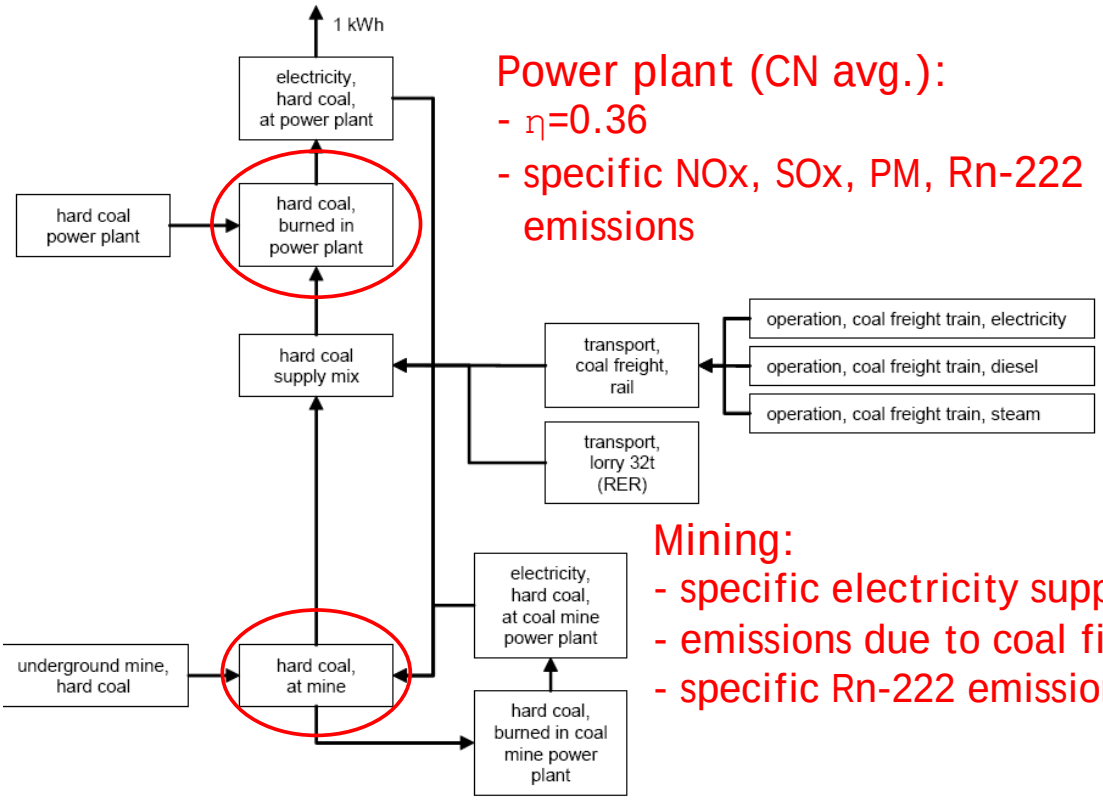
Name Location InfrastructureProcess Unit	Locati	Infrastru eProce	Unit	*electricity mix* *CN* *0* *kWh*
electricity, hard coal, at power plant	CN	0	kWh	0.7863
electricity, nuclear, at power plant	CN	0	kWh	0.0213
electricity, hydropower, at power plant	FI	0	kWh	0.1589
electricity, oil, at power plant	CZ	0	kWh	0.0287
electricity, natural gas, at power plant	CENTREL	0	kWh	0.0032
electricity, at cogen ORC 1400kWth, wood, allocation exergy	CH	0	kWh	0.0010
electricity, at wind power plant 600kW	CH	0	kWh	0.0006

specific modeling for ~ 81% of electricity production

European LCA data used for ~ 19% of electricity production

→ small impact on cumulative LCA results

Model of the Chinese coal chain



Power plant (CN avg.):
- η=0.36
- specific NOx, SOx, PM, Rn-222 emissions

Mining:
- specific electricity supply, η=0.13
- emissions due to coal fires
- specific Rn-222 emissions

Nuclear chain in China

- Mostly based on the Swiss nuclear LCA model
- Centrifuge enrichment only (diffusion for military), based on Russian technology (CN electricity)
- No reprocessing
- PWR only

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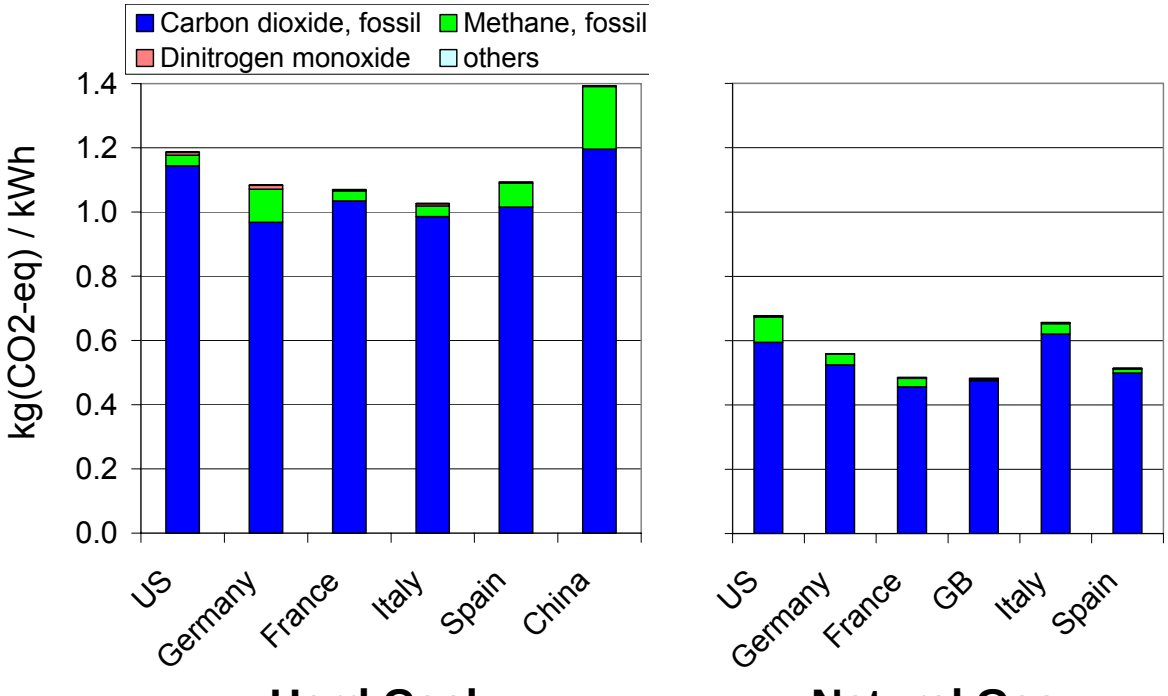
GHG emissions, US (CN) hard coal & natural gas in comparison



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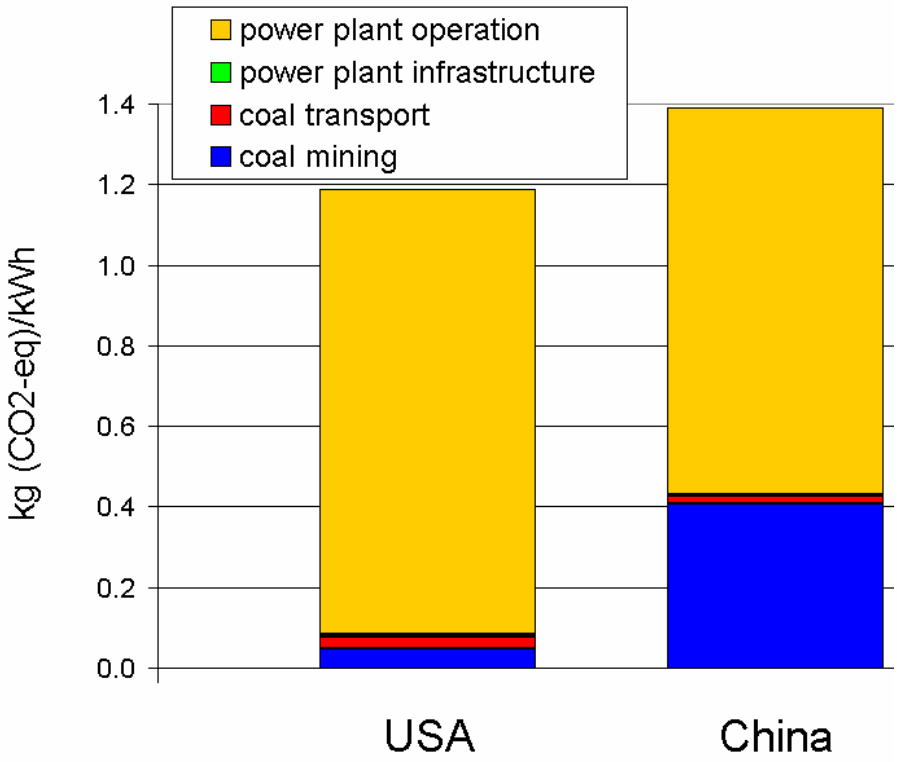
Electricity, hard coal, US & China



45% CH_4
38% coal fires
14% electricity cons.

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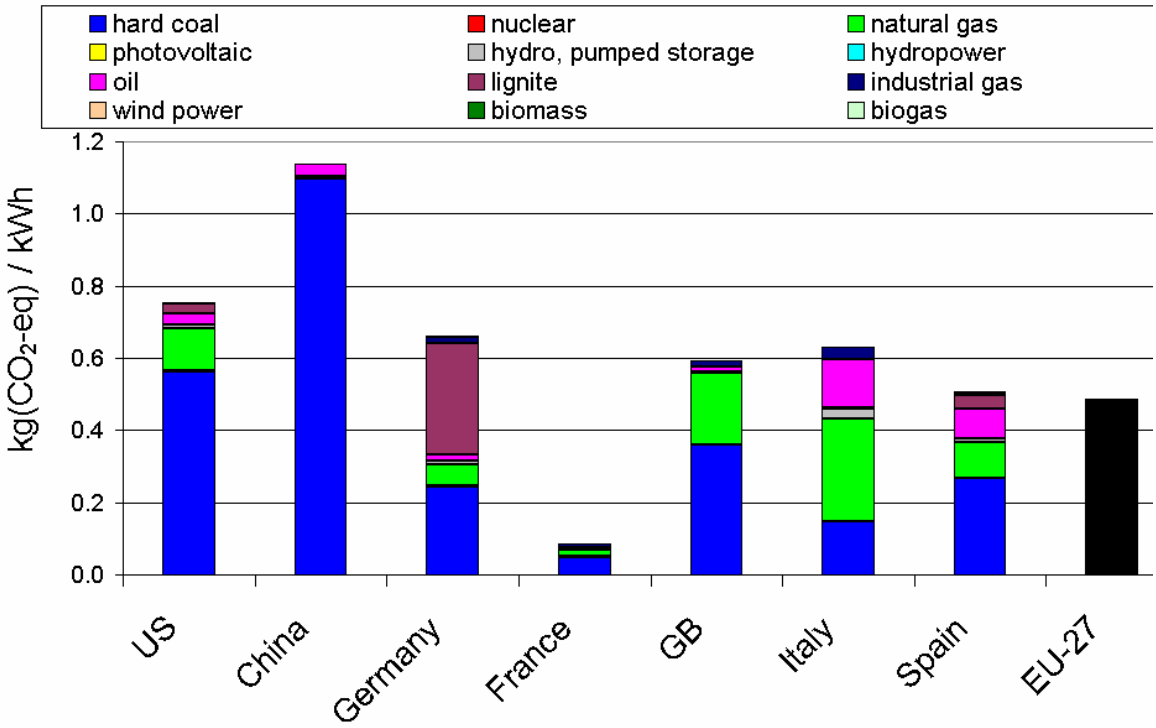
GHG emissions: US, CN vs. European electricity production mixes



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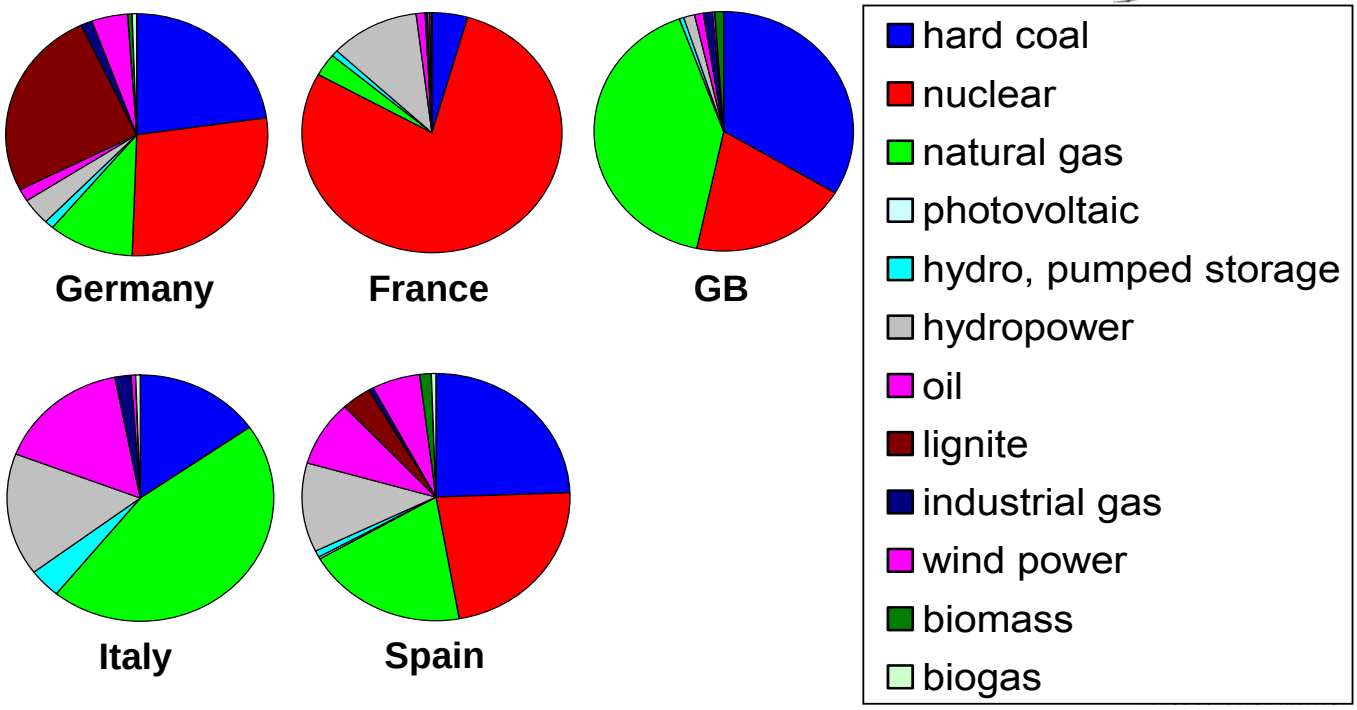
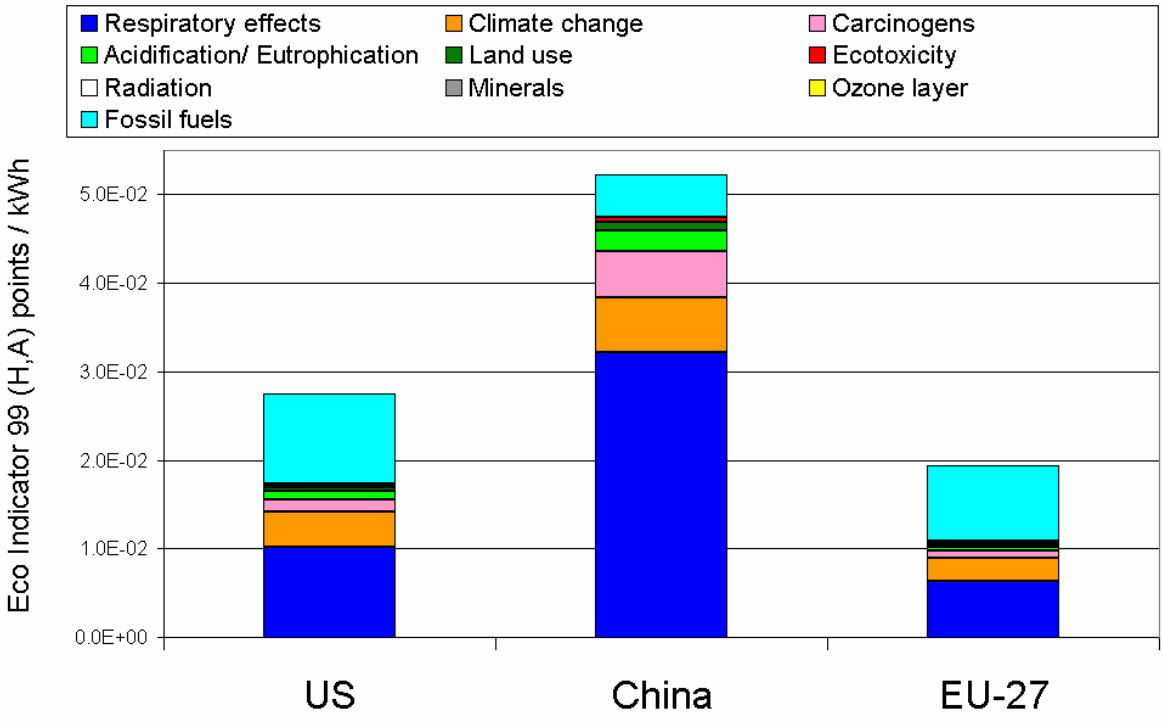
Presentation: Christian Bauer

Composition of European electricity mixes (2004)



Eco-Indicator 99 (H,A): US, CN vs. EU-27 electricity mix



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Conclusions

- Current modelling of US & CN electricity production covers the most important technologies (as contributors to cumulative environmental impacts)

  → allows better LCA modelling in these countries
- Performance of avg. fossil US & CN power plants is relatively poor, compared to European averages

  → high GHG emissions of electricity mix
- Due to currently high installation rate of coal power plants in CN, modelling will have to be reworked in a few years.

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