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College on Evaluation of Energy Technologies and Policies for Implementation of Agenda-21

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Application of MESSAGE to Lithuanian Study

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Application of MESSAGE to Lithuanian Study

Energy Supply Options. A Detailed Multi-Sector Integrated Energy Demand Supply and Environmental Analysis.

A.Galinis

Lithuanian Energy Institute

Plan of presentation

Overview of current situation

General methodological approach

Object of the analysis

Scenarios analyzed

Overview of candidates

Fuel prices

Load representation

Reserve capacity

Environmental constrains

Some results of the study

Task of the study:

Evaluation of consequences in Lithuanian energy sector related to earlier forced closure of nuclear power plant.
(Capacity replacement, investment requirement, changes in operation cost and fuel balance, electricity and heat prices, environmental impact)

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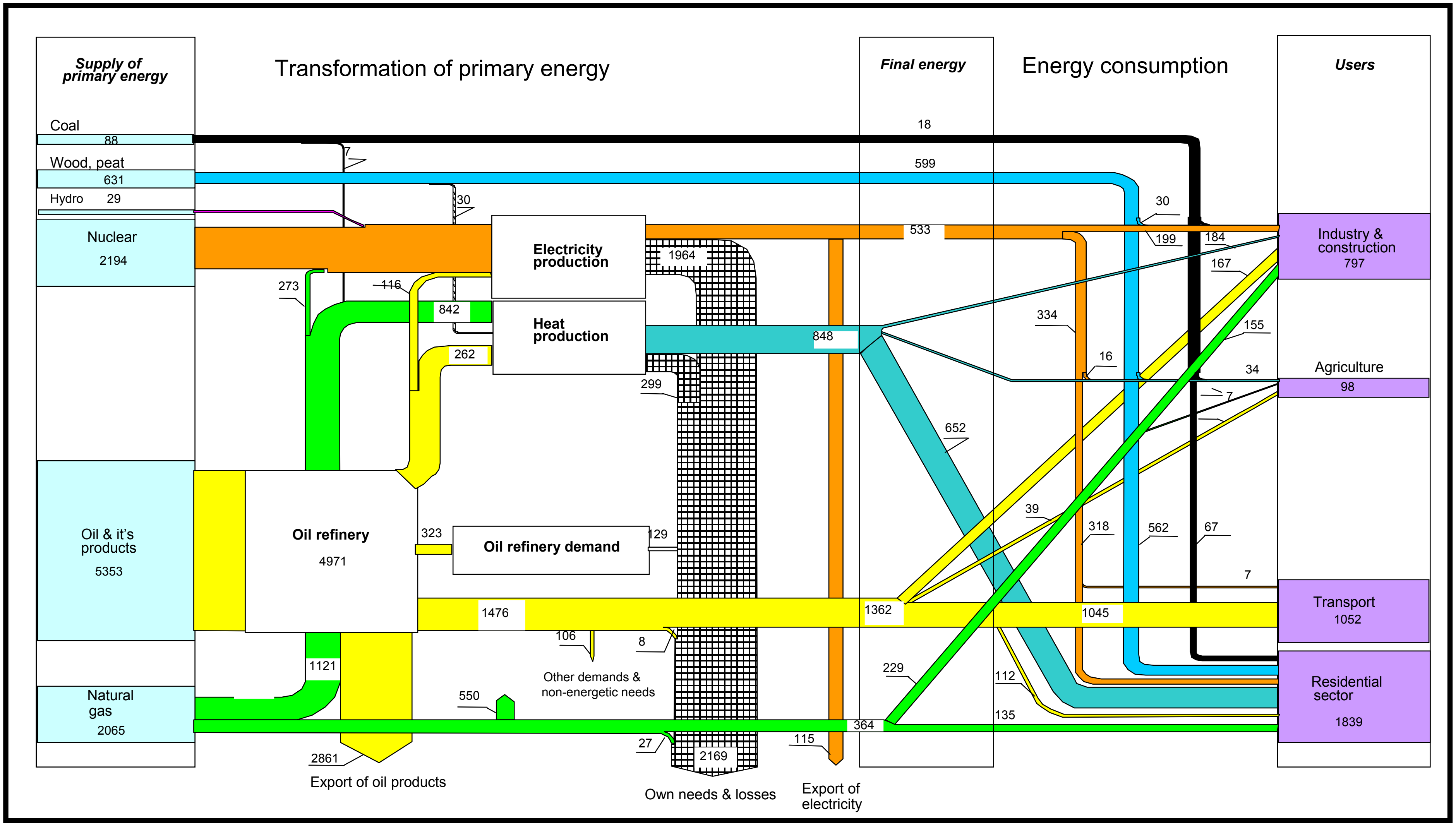
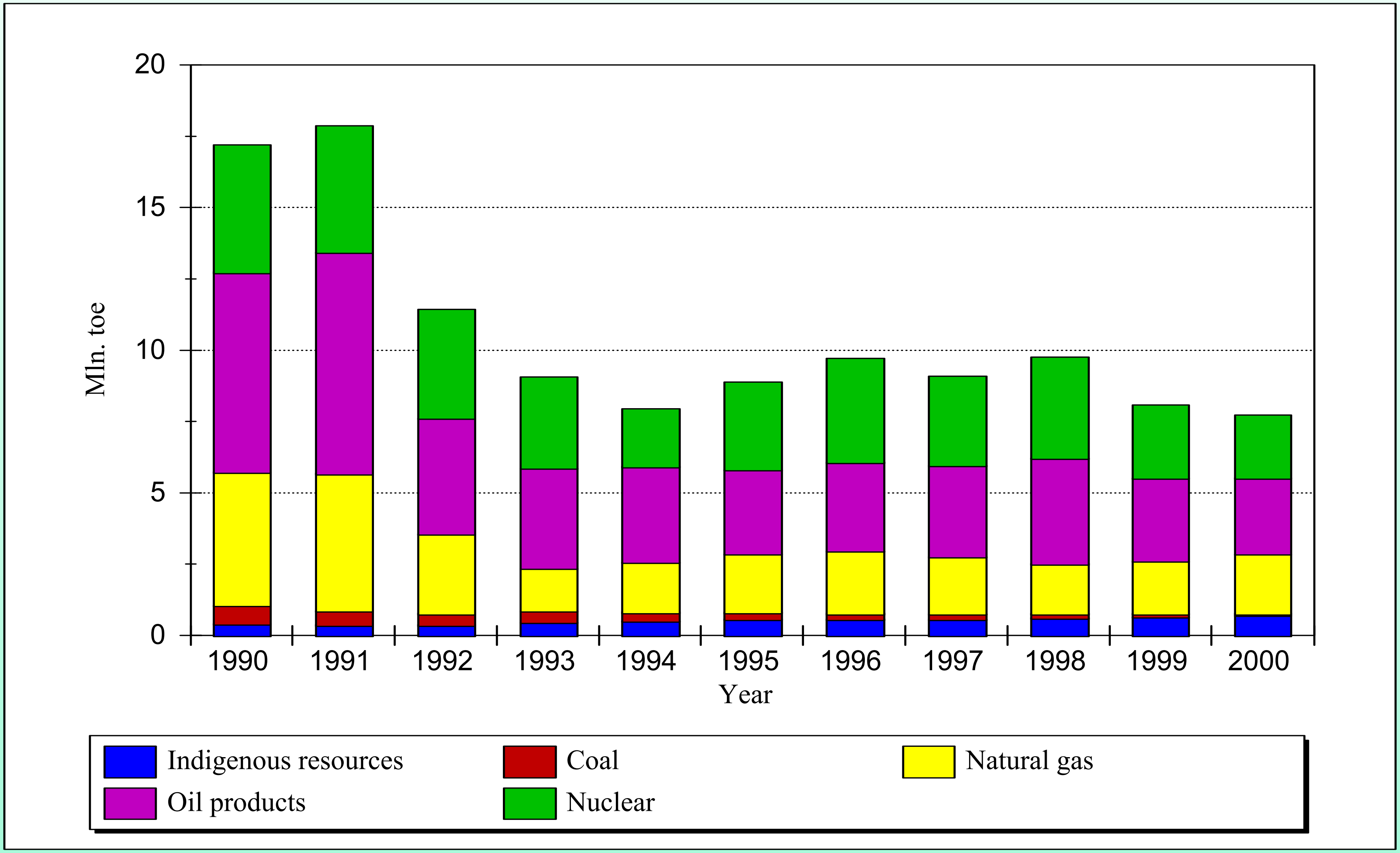
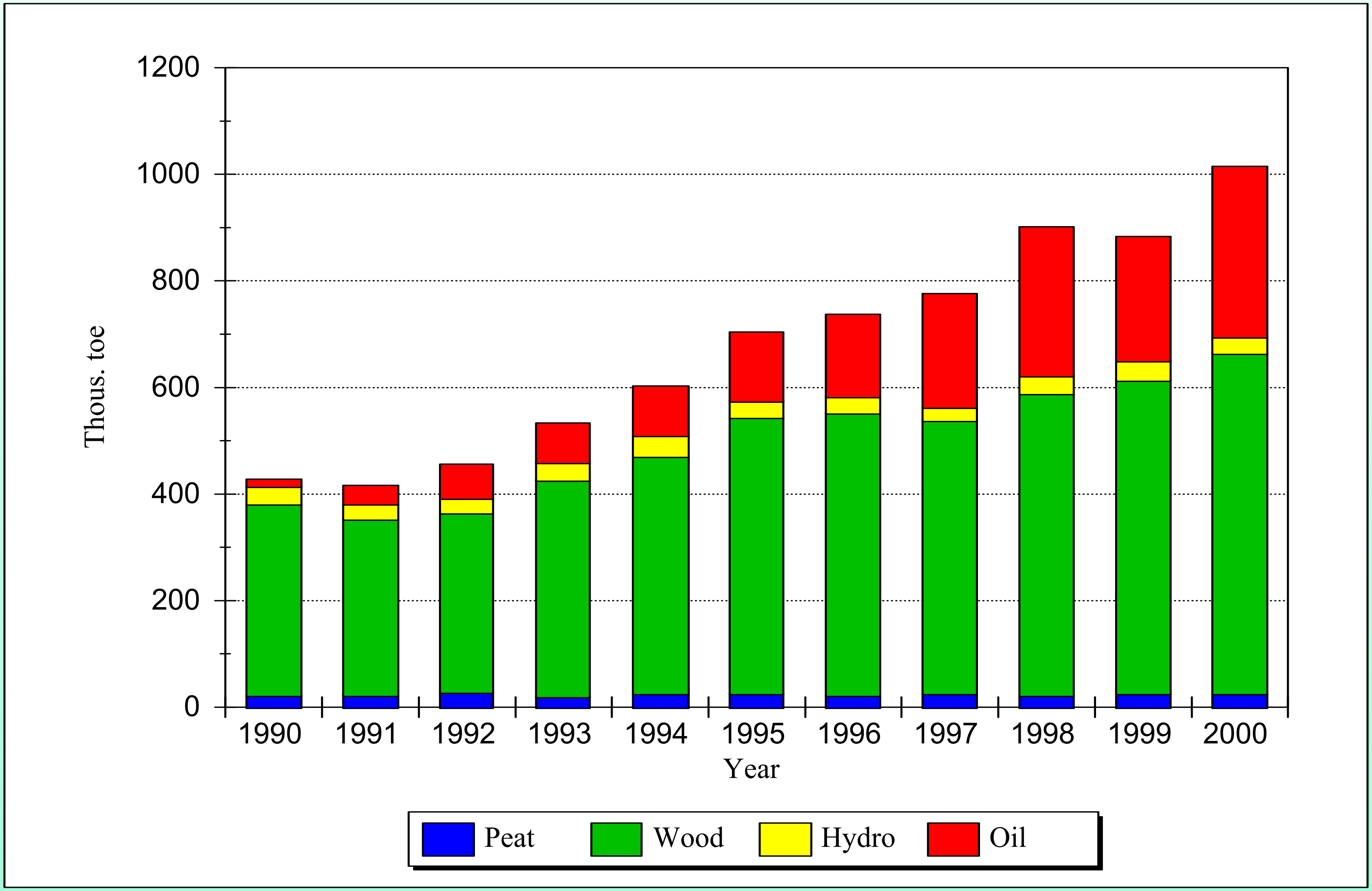
Diagram of main fuel and energy flows in 2000 m., thous. t o.e.



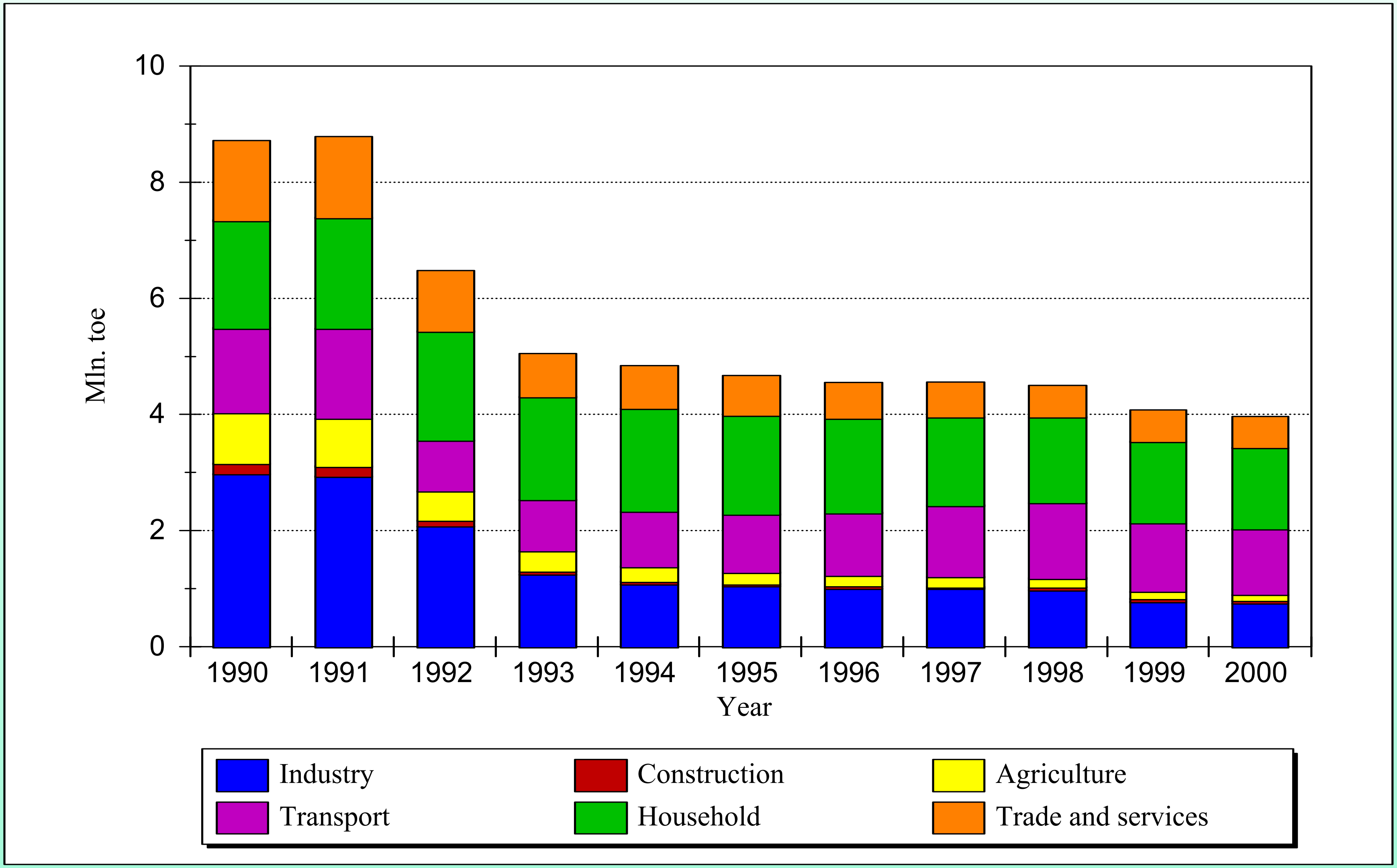
PRIMARY ENERGY CONSUMPTION IN LITHUANIA



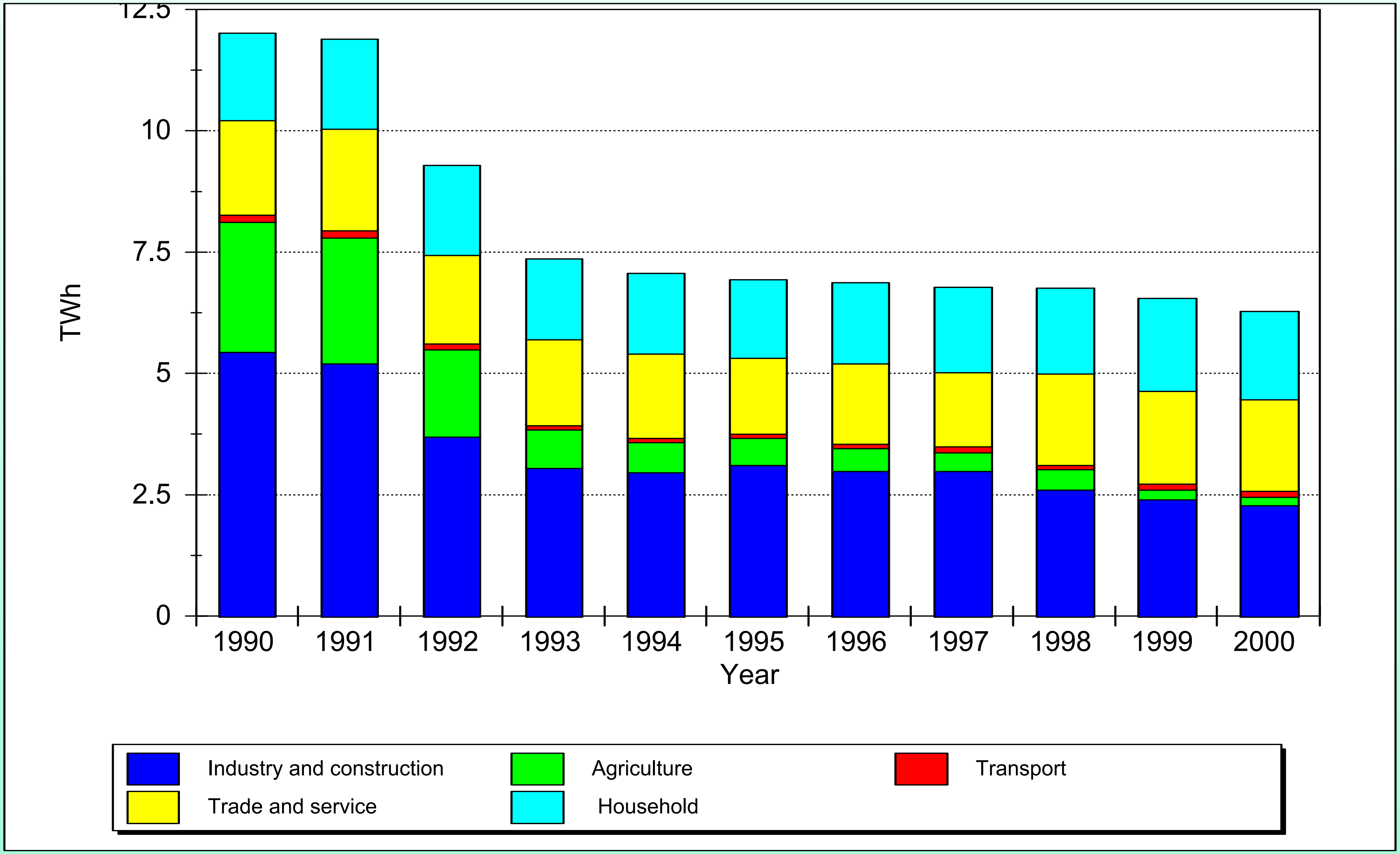
CONSUMPTION OF INDIGENOUS RESOURCES



FINAL ENERGY CONSUMPTION IN LITHUANIA



FINAL ELECTRICITY CONSUMPTION IN LITHUANIA



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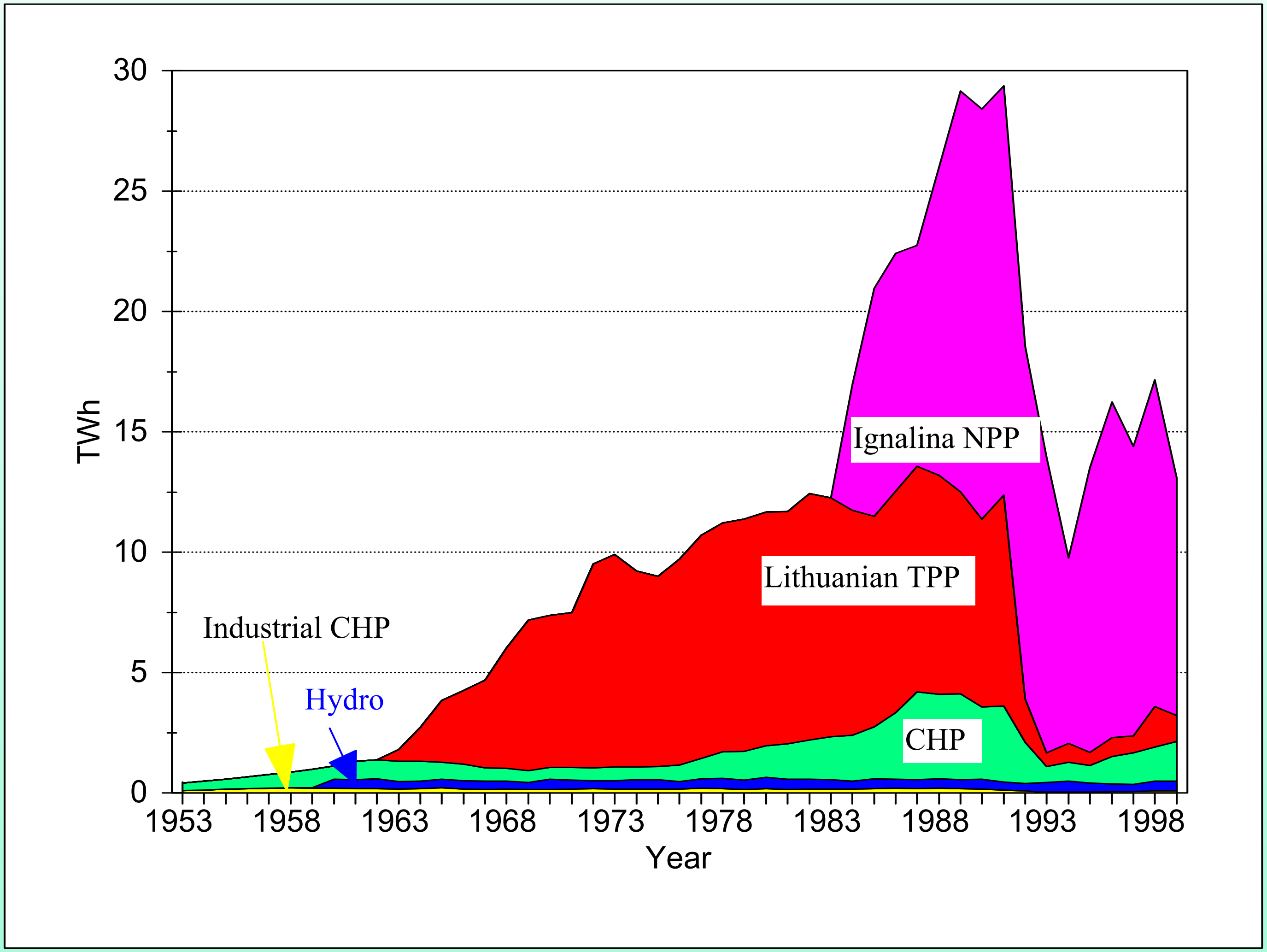
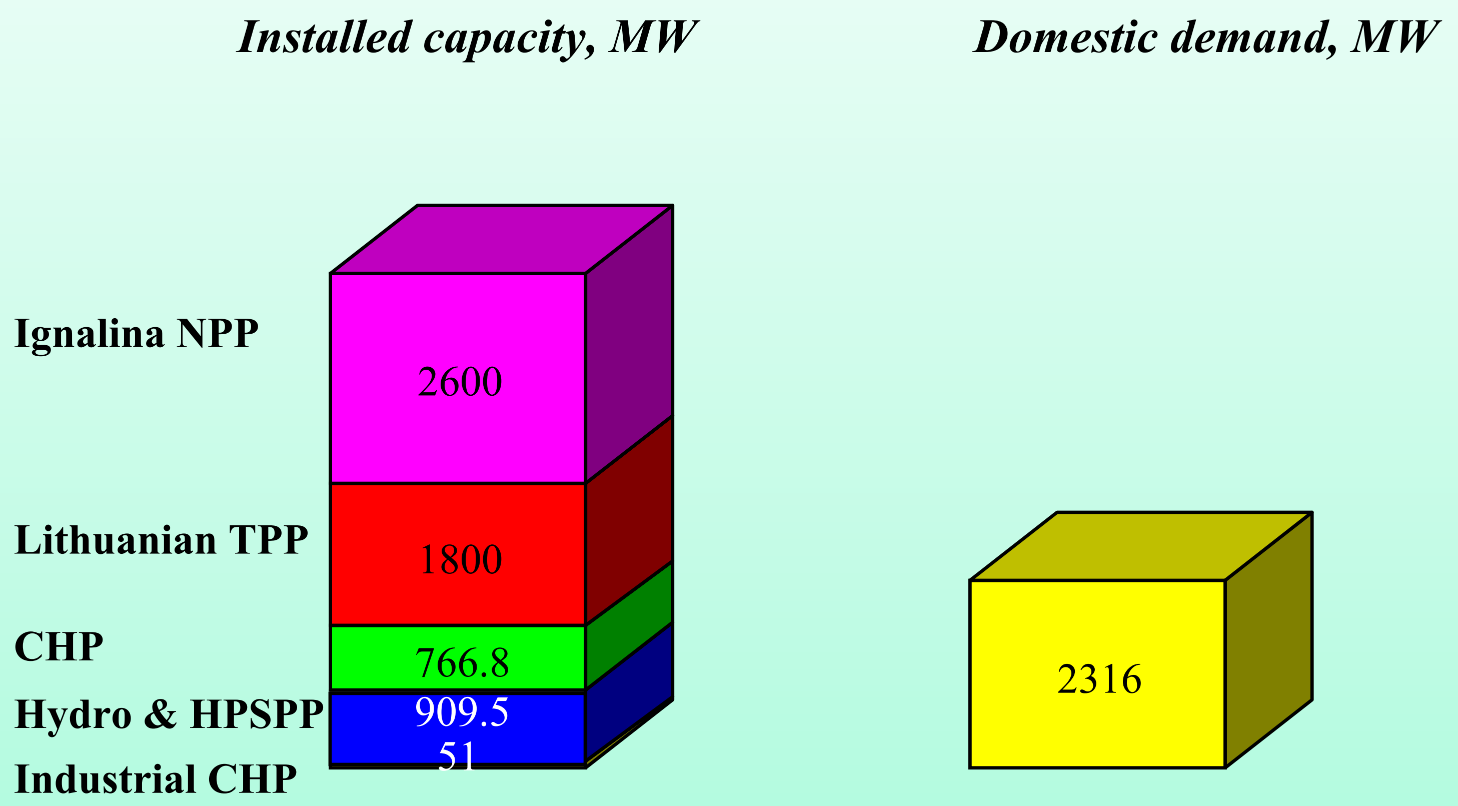
Electricity production in Lithuania



Lithuanian power system in 1999



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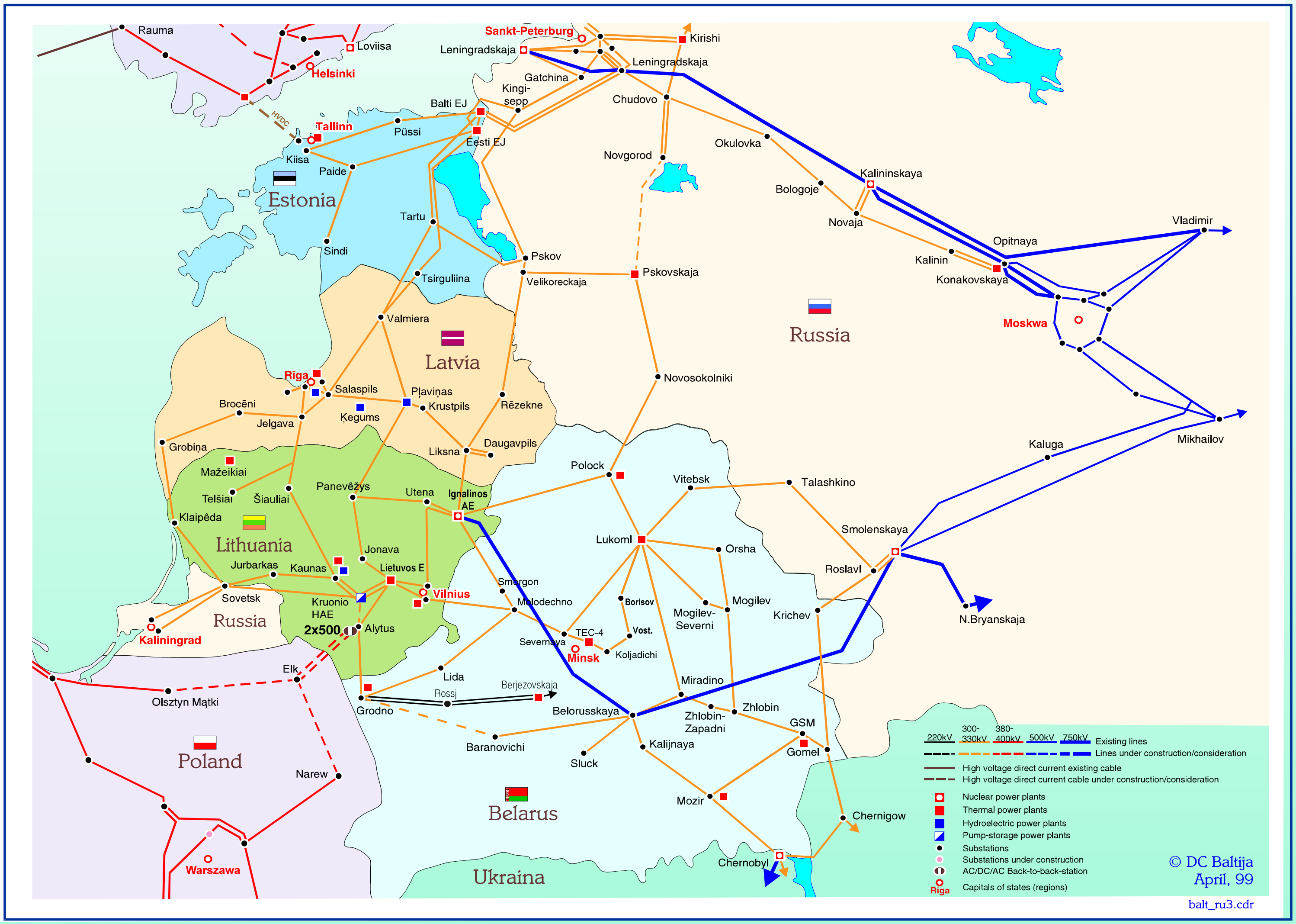
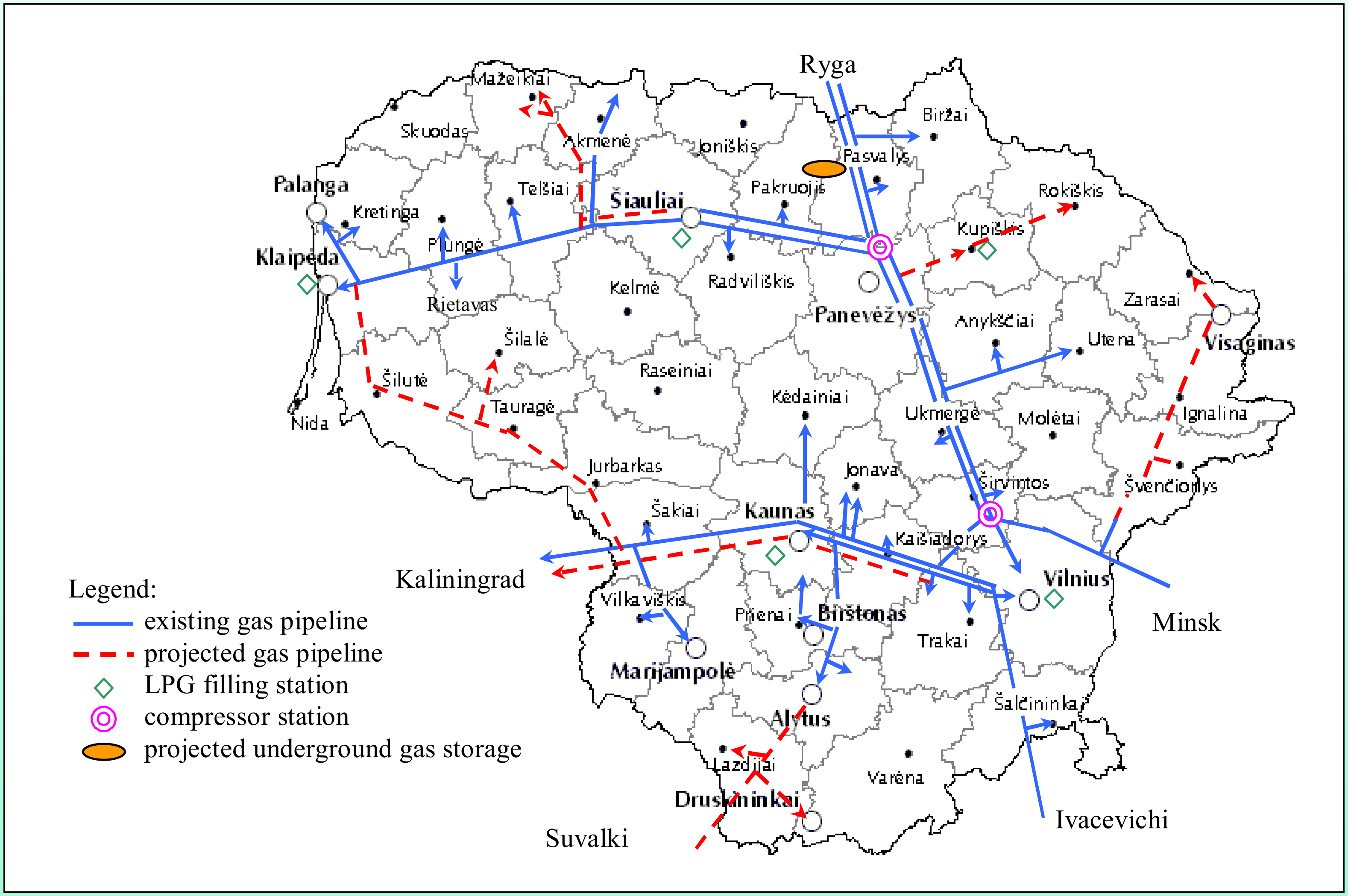
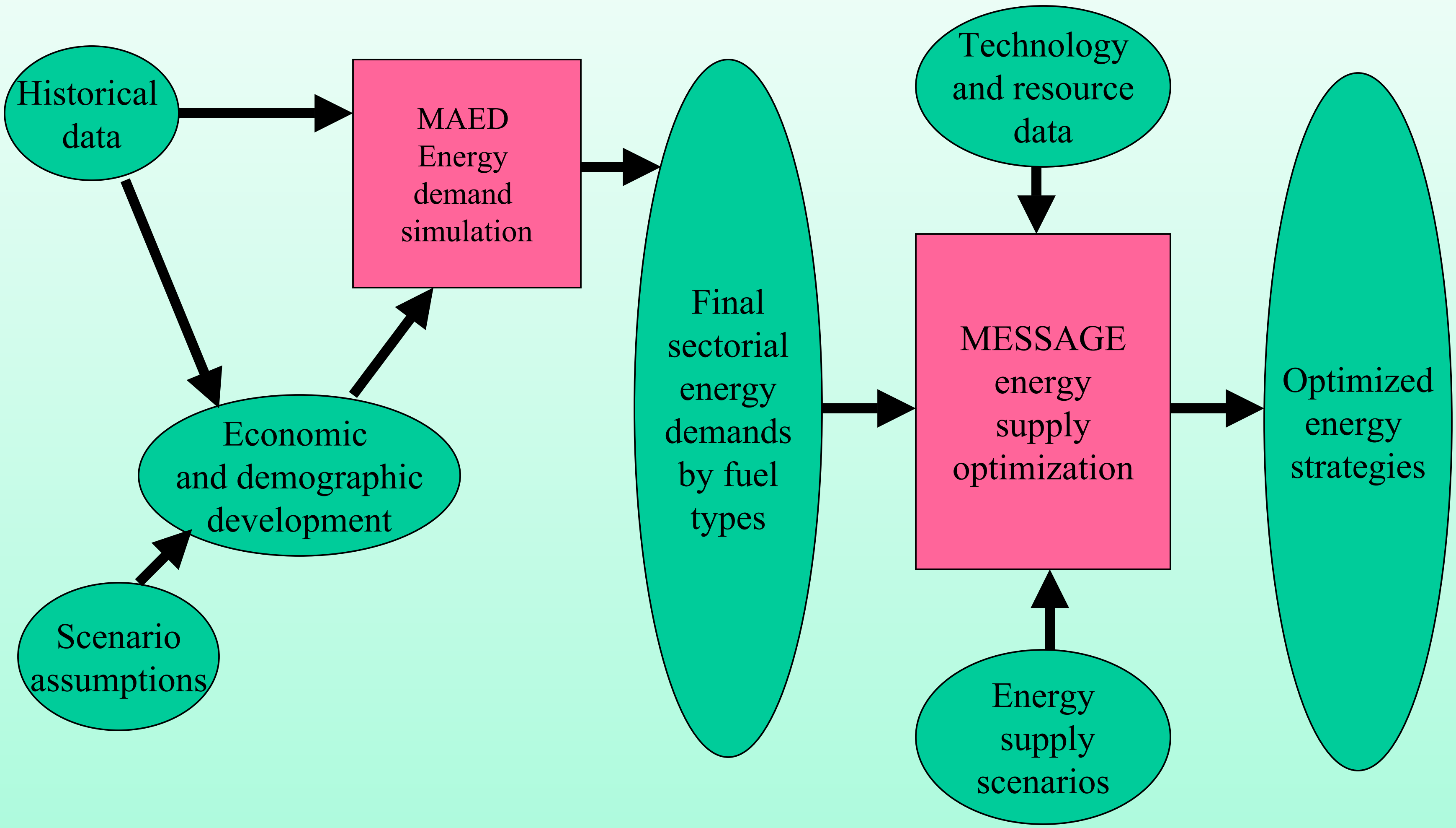
Network of power system



Lithuanian Gas System Network



General methodological approach



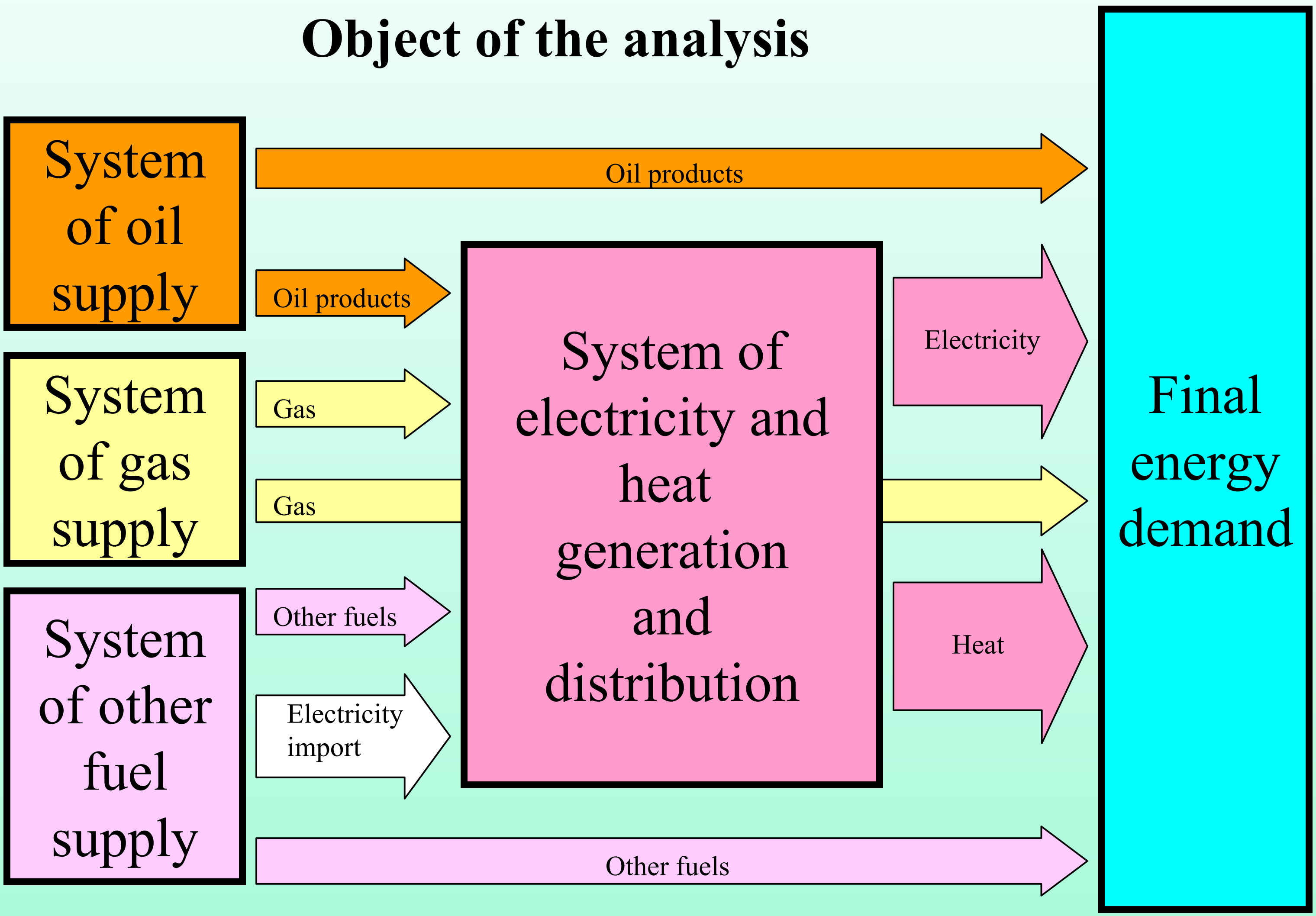
Object of the analysis

Power system development in context of:

Power and district heating system,

Whole energy system.

Object of the analysis



Object of the analysis

System of oil supply:

Import of crude oil and oil products,

Extraction of crude oil,

Refining of crude oil,

Desulphurisation of oil products,

Distribution of oil products,

Export of oil products.

Object of the analysis

System of gas supply:

Import of natural gas,

Transport and distribution of natural gas,

Extension of gas network,

Export of natural gas.

Object of the analysis

System of other fuel supply:

Import and distribution of coal, coke, lignite,

Import and distribution of orimulsion,

Import of nuclear fuel,

Preparation and distribution of:
wood, wood waste, peat, straw, biogas.

Object of the analysis

System of electricity and heat generation and distribution :

Utilization of existing capacities,

Modernization of existing capacities,

Decommissioning of obsolete capacities,

Construction of new capacities,

Implementation of emission reduction technologies,

Electricity transmission and distribution,

Heat distribution.

Object of the analysis

Final energy demand :

Time depending total electricity demand per country,

Time depending heat demand in Vilnius, Kaunas, Klaipeda, Mazeikiai, Elektrenai, other cities,

Time depending demand of natural gas in branches of national economy: industry, service, transport, agriculture, household,

Annual demand of other energy forms in branches of national economy: industry, service, transport, agriculture, household.

Power system. Scenarios analyzed

The first unit of the Ignalina NPP in all cases was assumed to be closed at the end of 2004.

Case 1 Ignalina unit-2 is closed at the end of 2009;

Case 2 Ignalina unit-2 is closed at the end of 2017;

Case 3 Ignalina unit-2 is closed at the end of 2009, new NPP is built in 2010;

Case 4 Ignalina unit-2 is closed at the end of 2009, limitation of gas share in fuel consumption structure;

Case 5 Ignalina unit-2 is closed at the end of 2009, rechaneling of unit2 at 2010;

Case 6 Ignalina unit-2 is closed at the end of 2009, high energy demand;

Whole energy system. Scenarios analyzed

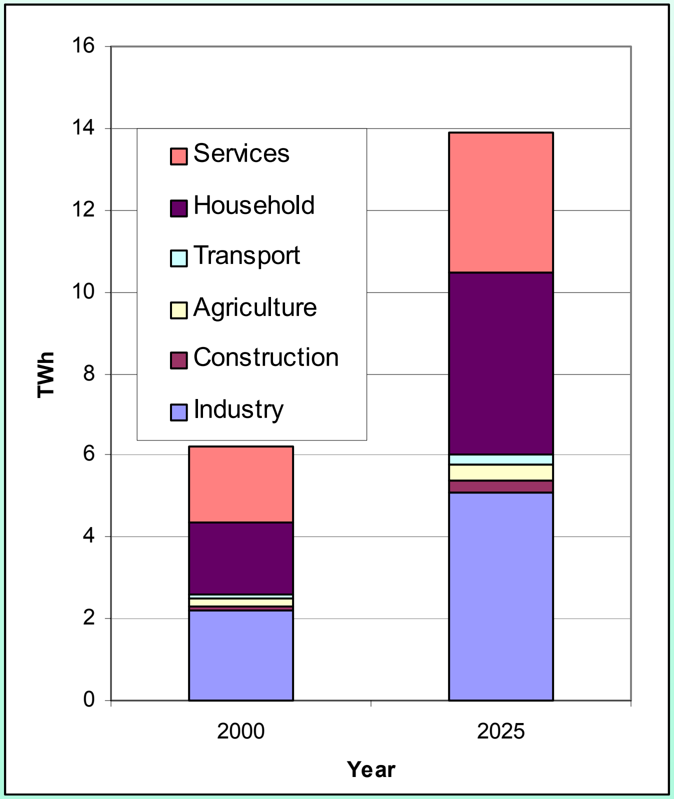
Scenario	WHAT would be the future energy supply sector in Lithuania, and WHAT would be its associated economic and environmental implications IF the first unit of Ignalina NPP to be closed in 2004 and the Unit 2 to be closed in 2009 and in addition the following conditions apply?
1	No special constrains on other existing and future technologies
2	Construction of new CCGT units at the site of Lithuanian TPP is not allowed.
3	A new NPP with capacity of 600 MW to be brought on line in 2010.
4	A new NPP with capacity of 600 MW to be brought on line in 2015
5	A new NPP with capacity of 600 MW to be brought on line in 2015. Electricity import during 2010-2015 is not possible.
6	A new NPP with capacity of 600 MW to be brought on line in 2015 and modernization of the Lithuanian TPP will start thereafter

Whole energy system. Scenarios analyzed. *Sensitivity analysis.*

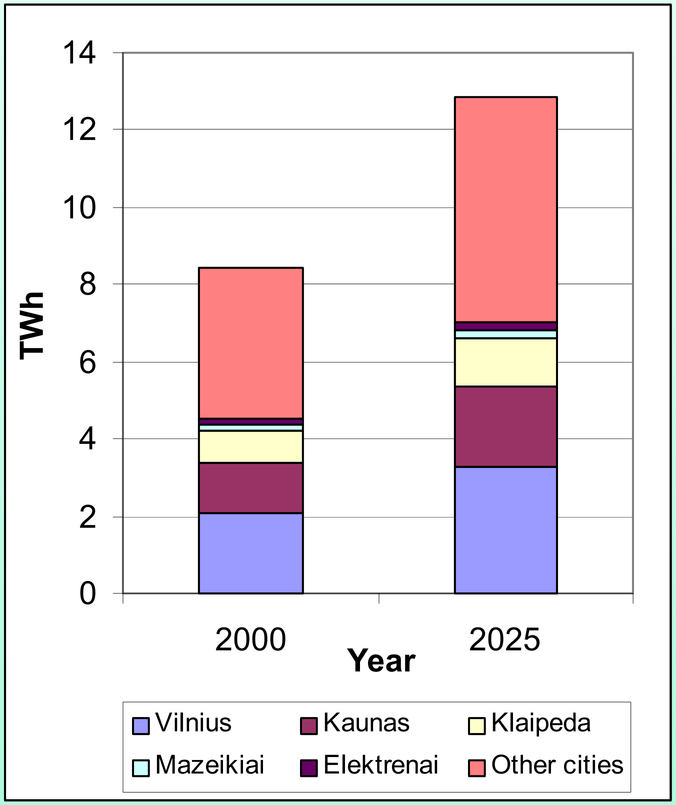
Sensitivity analysis with respect to	WHAT would the optimal supply sector in Lithuania change IF the following conditions apply
Operation time of Unit 2 of Ignalina NPP	Scenario 1 + Unit 2 of Ignalina to be in operation till 2017
Capital investment of new NPP	Scenario 3 + Investment of 1000 US$/kW versus 1500 US$/kW
Discount rate	Scenario 3 + Investment of 1000 US$/kW versus 1500 US$/kW, with discount rate of 6 % and 10 % Scenario 1 + discount rate of 6 % versus 10 %
Unit size of new NPP	Scenario 3 + unit capacity of 1000 MW versus 600 MW
Fuel prices	Scenario 1 + higher fuel prices

Final demand

Electricity (Basic scenario)

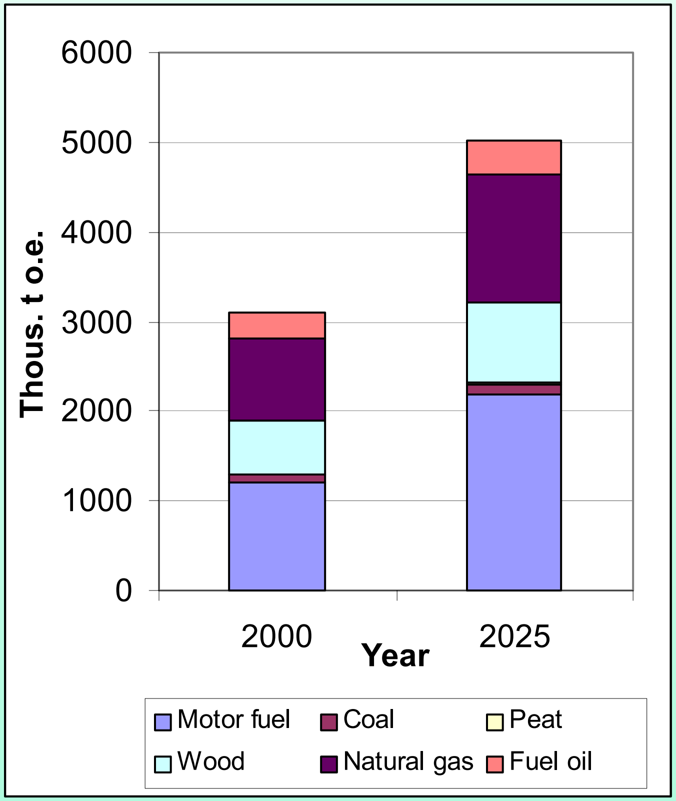


District heat (Basic scenario)

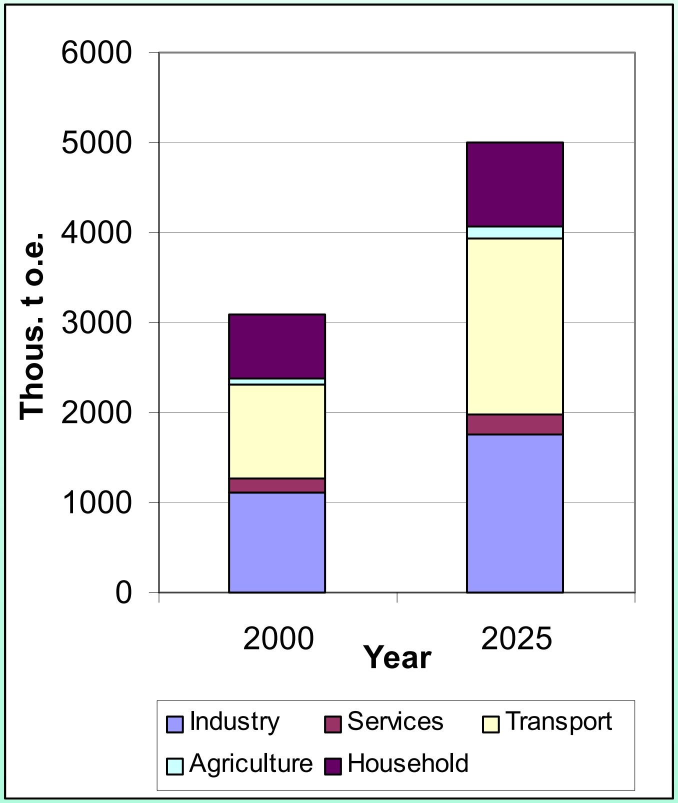


Final demand

By fuel type (Basic scenario)

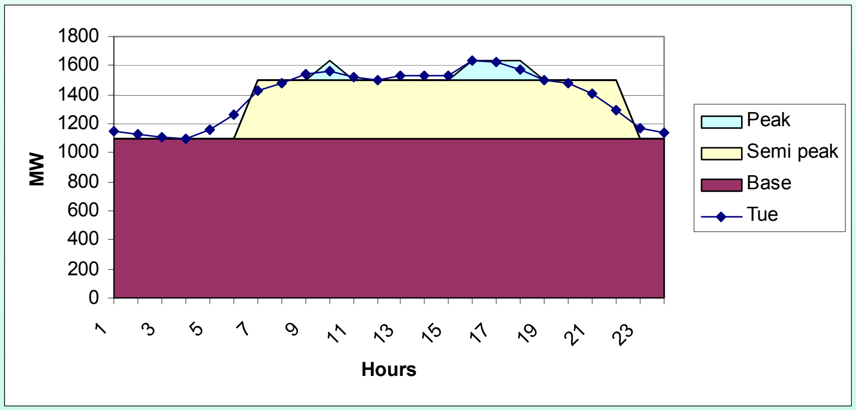


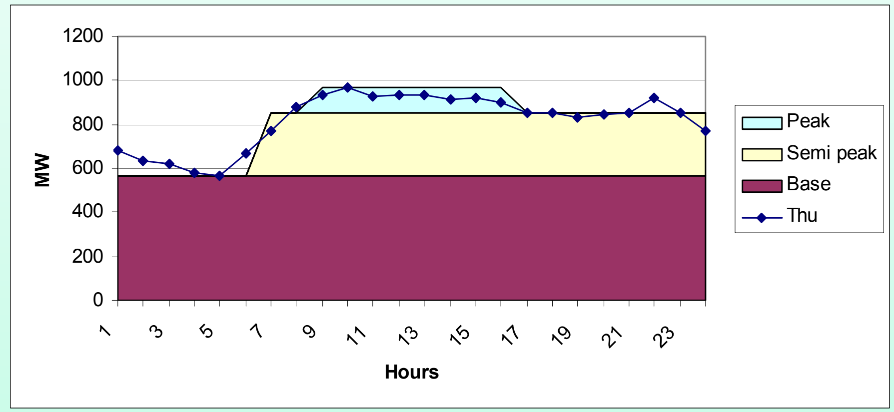
In branches of national economy (Basic scenario)



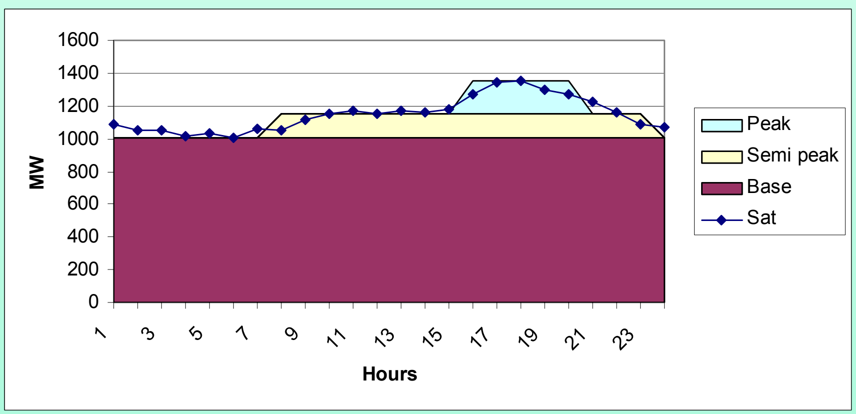
Final demand

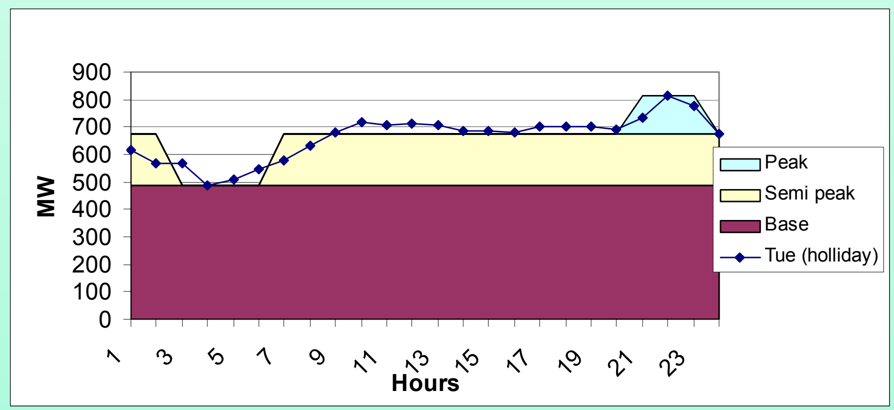
Winter | Working day | Summer





Weekend, holiday



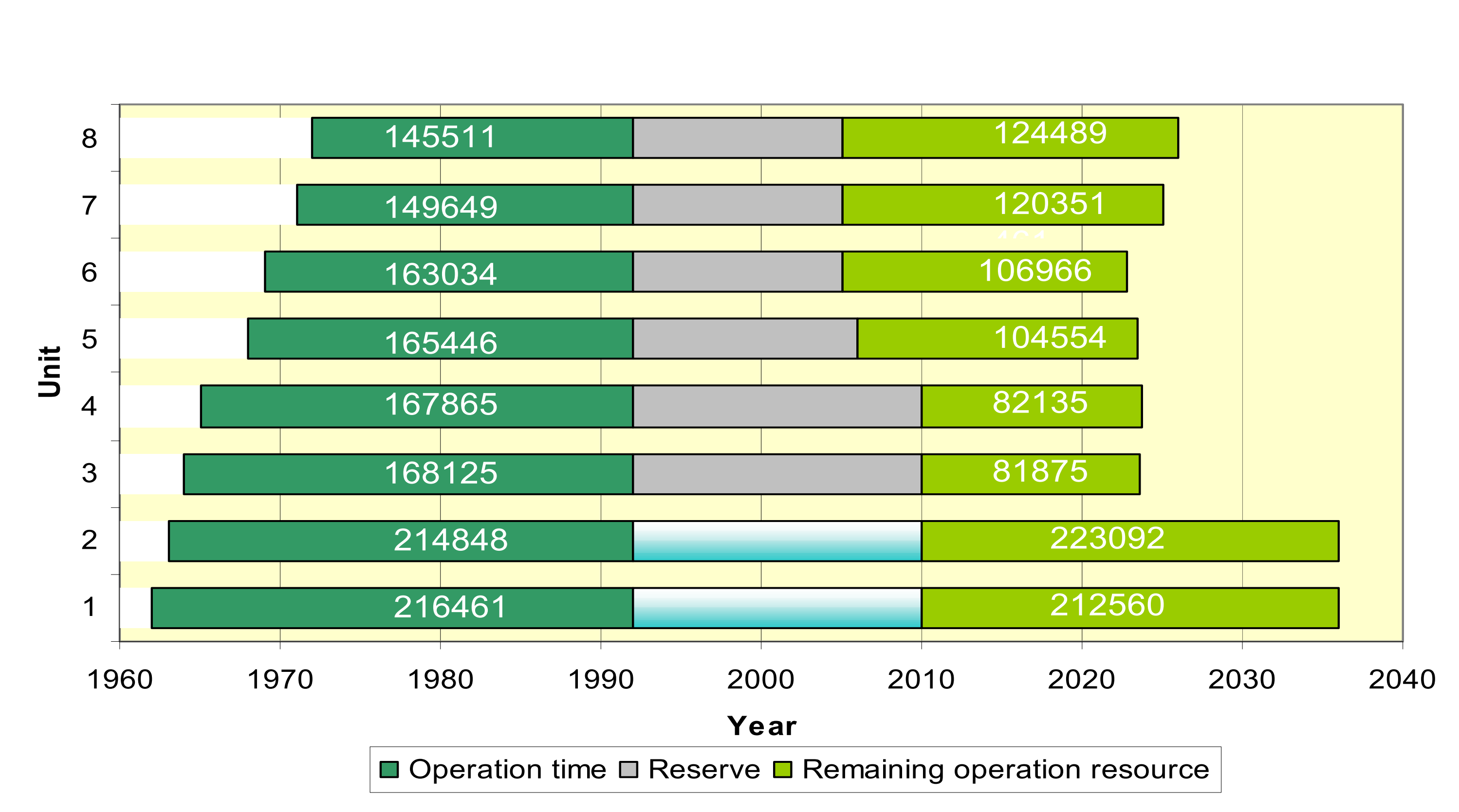


Final demand

Period		Energy fraction in season	Day	Energy fraction in days	Energy fraction in load regions						
					1	2	3	4	5	6	7
Electricity	End of winter	0.3622	WD	0.7195	0.198	0.135	0.049	0.225	0.147	0.18	0.066
			SSH	0.2805	0.257	0.335	0.246	0.126	0.037		
	Summer	0.4413	WD	0.736	0.172	0.087	0.395	0.346			
			SSH	0.264	0.085	0.122	0.596	0.154	0.043		
	Begining of winter	0.1965	WD	0.7393	0.154	0.179	0.051	0.268	0.152	0.134	0.062
			SSH	0.2607	0.215	0.358	0.308	0.119			
Heat	End of winter	0.4592	WD	0.7195	0.25	0.125	0.042	0.208	0.125	0.167	0.083
			SSH	0.3085	0.292	0.333	0.208	0.125	0.042		
	Summer	0.2195	WD	0.7096	0.25	0.083	0.333	0.333			
			SSH	0.2904	0.083	0.167	0.583	0.125	0.042		
	Begining of winter	0.3213	WD	0.7132	0.208	0.167	0.042	0.25	0.125	0.125	0.083
			SSH	0.2868	0.25	0.375	0.25	0.125			

Overview of candidates: *Lithuanian TPP*

Operational History and Remaining Lifetime of Different Units at Lithuanian TPP



Overview of candidates: *Lithuanian TPP*

Investments into Environmental Protection Measures and Equipment Modifications

No	Measures	Reference	Investment, million LTL (million EUR)	Civil work, contingency million LTL
1	Installation of Low NOx burners on boilers No. 8A, 8B, 7A, 7B, 5A, 5B, 1, 2	[41]	56	0,5
2	Erection of flue gas desulphurisation plant on boilers No. 8A, 8B, 7A, 7B, 6A, 6B, 5A, 5B, 1, 2	[41]	455	7,0
3	Erection of Electrostatic Precipitator on boilers No. 8A, 8B, 7A, 7B, 6A, 6B, 5A, 5B, 1	[42]	95	4,5
4	Construction of SCR deNOx equipment on boilers No. 8A, 8B, 7A, 7B	Estimation	240	2,0
		SUBTOTAL:	**846,0 (245)**	**14,0 (4.1)**
5	Control System Modernization. Units No. 8, 7, 5, 1, 2	[43]	91,7	1,0
6	Reconstruction of regenerative air preheater sealing system on boilers No. 8A, 8B, 7A, 7B, 6A, 6B, 5A, 5B (2 preheaters on each boiler part), 1 (1 preheater on each boiler)	[44]	18,9	0,3
7	Implementation of antiexplosive safety devices and blocking system for boilers No. 8A, 8B, 5A, 5B	[45]	4,3	0,2
8	Replace generator, unit No.5	[46]	46,0	0,4
9	Replace feed water pump, unit No.5	[46]	12,0	0,2
10	Preparation for burning of orimulsion at 7 remaining boilers of 300 MW units	Estimation	7.5	
11	Preparation for burning of orimulsion at 3 remaining 150 MW units	Estimation	3.3	
		SUBTOTAL:	***183.7 (53.2)***	***2,1 (0.6)***
		TOTAL	***1029.7 (298.2)***	***16.1 (4.7)***

Overview of candidates: *Vilnius CHP*

Investments into Environmental Protection Measures and Equipment Modifications

Measure	Investments, million LTL
Conversion of the Vilnius CHP 3 to orimulsion firing	3.8
Electrostatic filter and desulpharisation unit	76
Installation of low NO_x burners	8-14
Modification of air preheaters, control and instrumentation system and reconstruction of electrical system to meet UCPT requirements	58
Subtotal	145.8-151.8
Additional gas turbine in front of existing steam boilers	370 US$/kW

Overview of candidates: *Kaunas HPP and Kruonis HPSPP*

Investments into Environmental Protection Measures and Equipment Modifications

Refurbishment of Kaunas HPP	14 million Euro
Additional units at Kruonis HPSPP	4*(150-200) million LTL

Overview of candidates: *New CHP*

Location of the Plant with electrical capacity	Estimated investment cost, million LTL
Klaipeda 225 MW	630
Alytus 90 MW	270
Marijampole 50 MW	175
Siauliai 138 MW	385
Panevezys 130 MW	375

Power to heat ratio 0.6

New small modular CHP 500 $/kW, power to heat ratio 0.5
New CHP on renewables 1000 $/kW, power to heat ratio 0.1
Conversion of boiler houses into CHP: by adding GT 400 $/kW
by adding steam turbine 400 $/kW

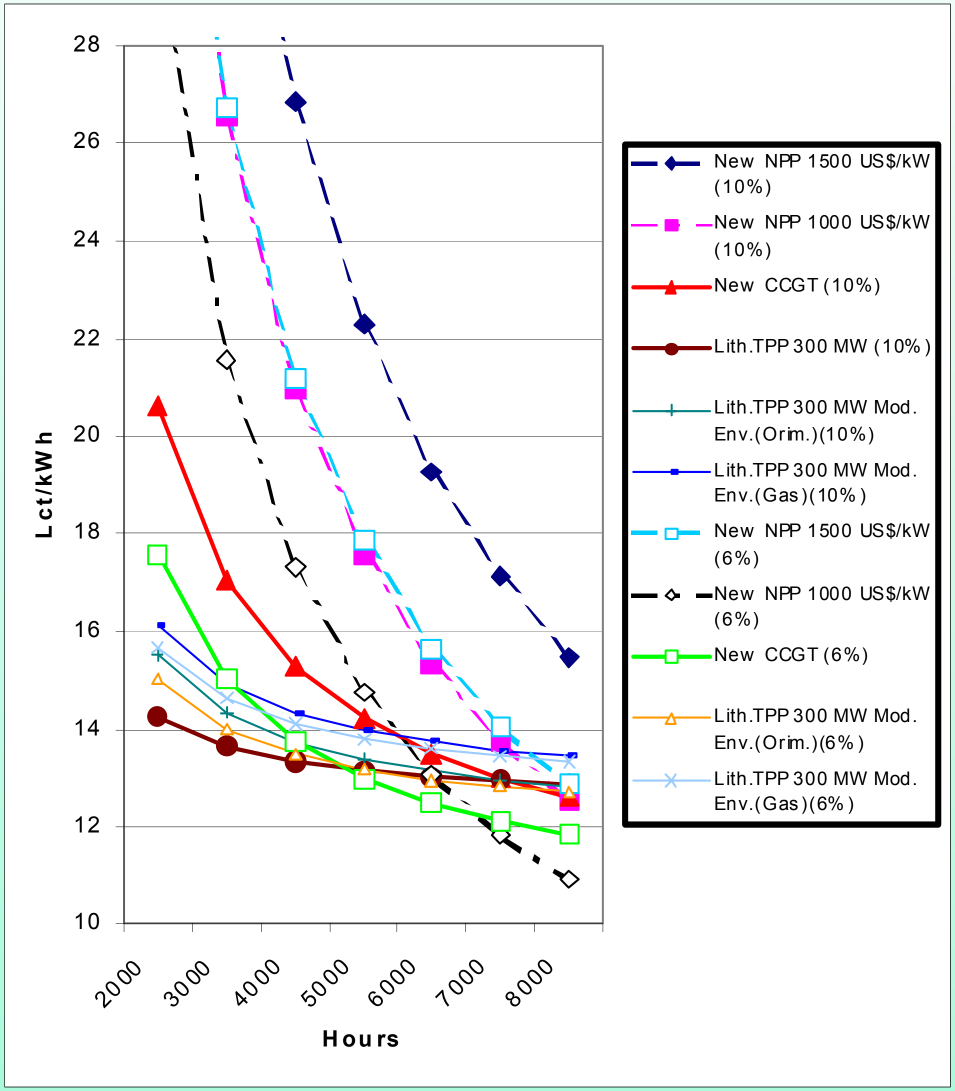
Overview of candidates: *New hydro PP*

Power plant	Capacity	Investments	Operation hours
Alytus HPP	about 72 MW,	LTL 600 million,	4600
Birstonas HPP	about 72 MW,	LTL 600 million,	4200
Karmelava HPP	about 30 MW,	4520 LTL/kW,	6700
Jonava HPP	about 30MW,	6300 LTL/kW,	6500

Overview of candidates: *Other power plants*

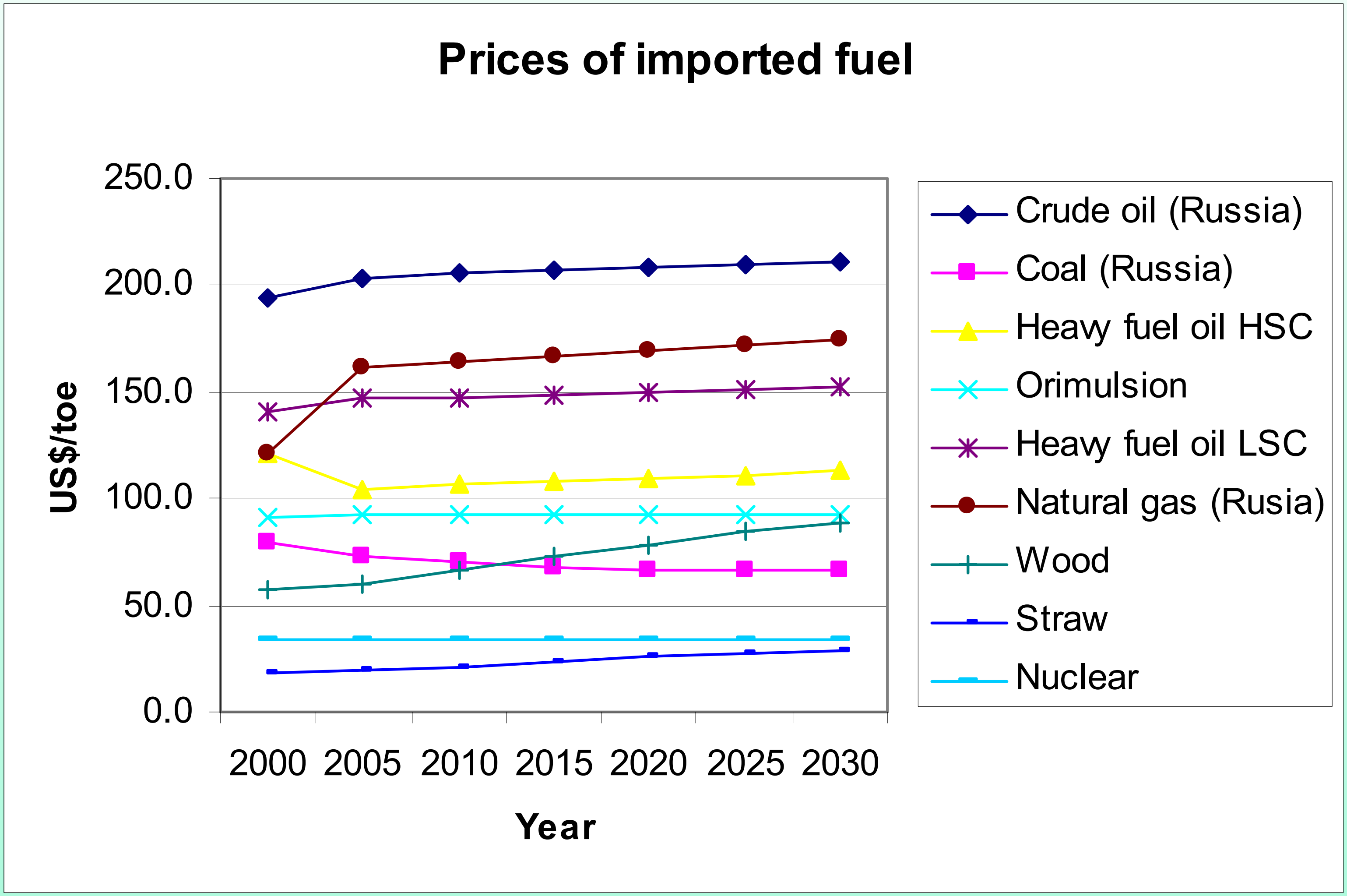
New nuclear power plant		1500 $/kW	600 or 1000 MW
New CCGT at:	Elektrenai site	400 $/kW	600 MW
	Ignalina site	400 $/kW	600 MW
	New site	500 $/kW	Unconstrained
New gas turbine		350 $/kW	Unconstrained
New wind PP		1050 $/kW	180 MW

Overview of candidates



Overview of candidates: *Own electricity consumption*

Power plant	Alternative in MESSAGE model	GWh/GWh		
		After 2000	After 2005	After 2010
Ignalina NPP		0.119	0.1	0.1
Lithuanian TPP	Alternative a	0.1105	0.0715	0.0465
	Alternative b	0.1556	0.1132	0.0856
Vilnius CHP-3	Alternative a	0.0396	0.05	0.05
	Alternative b	0.1165	0.0865	0.0865
Vilnius CHP-2	Alternative a	0.2214	0.1382	0.1382
HOB at Vilnius CHP-2		0.0427	0.0427	0.0427
Kaunas CHP, PT-60	Alternative a	0.0493	0.0493	0.0485
	Alternative b	0.1754	0.1124	0.1116
Kaunas CHP, T-110	Alternative a	0.0493	0.0493	0.0485
	Alternative b	0.1322	0.0908	0.09
Petrasiunai CHP	Alternative a	0.425	0.2372	0.2364
HOB at Petrasiunai CHP		0.0384	0.0384	0.0384
Mazeikiai CHP	Alternative a	0.1074	0.0671	0.0671
	Alternative b	0.2468	0.102	0.102
Industrial CHP	Alternative a	0.2294	0.2294	0.2294
Klaipeda CHP	Alternative a	0.1739	0.1739	0.1739
HOB at Klaipeda CHP		0.0205	0.0205	0.0205
Other HOB		0.0418	0.0418	0.0418


Prices of imported fuel
250.0
200.0
150.0
100.0
50.0
0.0
US$/toe
2000 2005 2010 2015 2020 2025 2030
Year
Crude oil (Russia)
Coal (Russia)
Heavy fuel oil HSC
Orimulsion
Heavy fuel oil LSC
Natural gas (Rusia)
Wood
Straw
Nuclear

Reserve capacity

For each scenario:

10% from installed capacity of each power plant (about 300 MW);
Major part of installed capacity of Kruonis HPSPP;
Support from neighboring countries.

In addition for nuclear scenarios:

2*150 MW units at Lithuanian TPP in the case of 600 MW unit capacity of new NPP;
3*150 MW units at Lithuanian TPP in the case of 1000 MW unit capacity of new NPP.

Environmental constrains

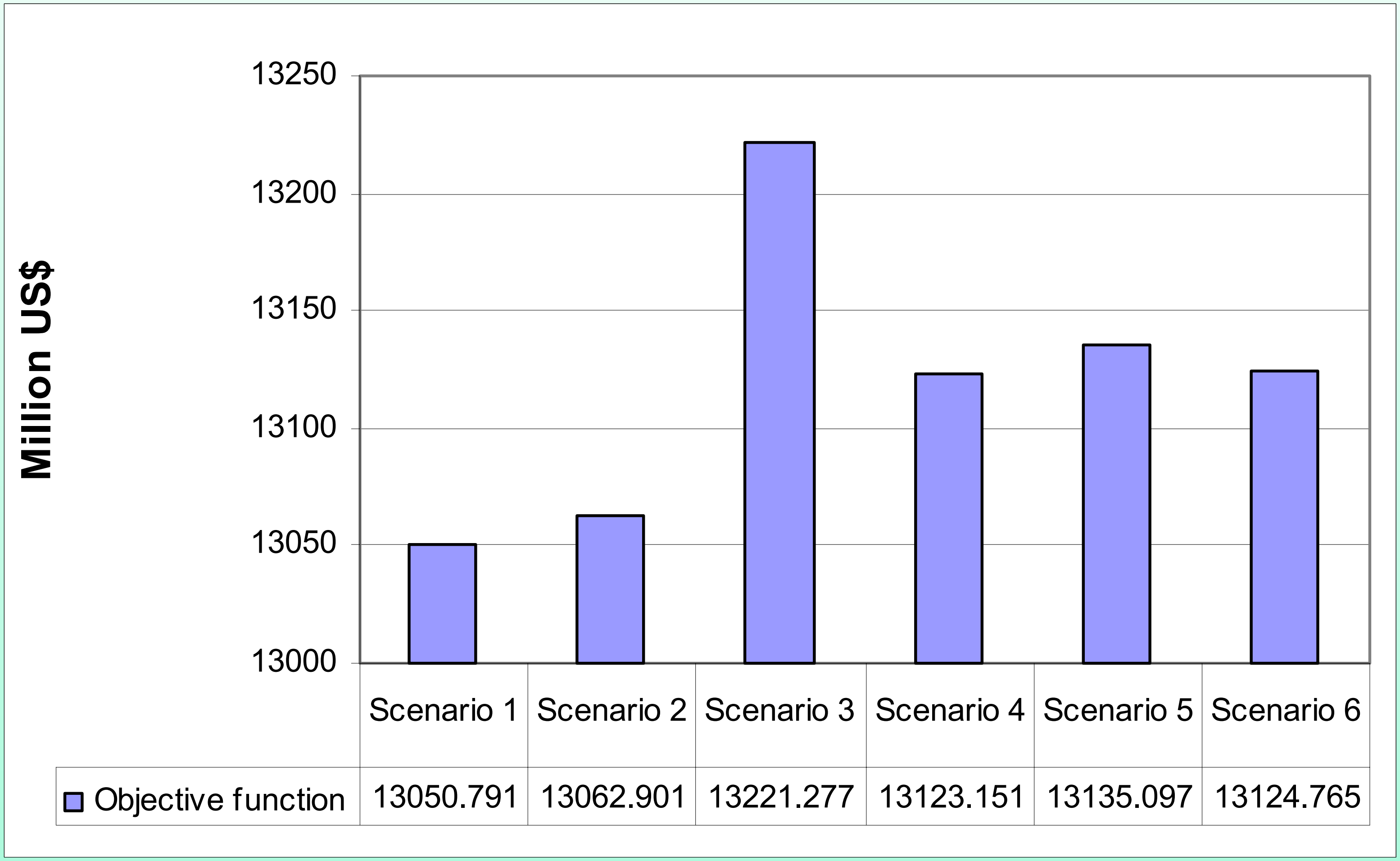
No constrains on CO2 and NOx emissions;

Limitation on SO_2 emissions for power plants:

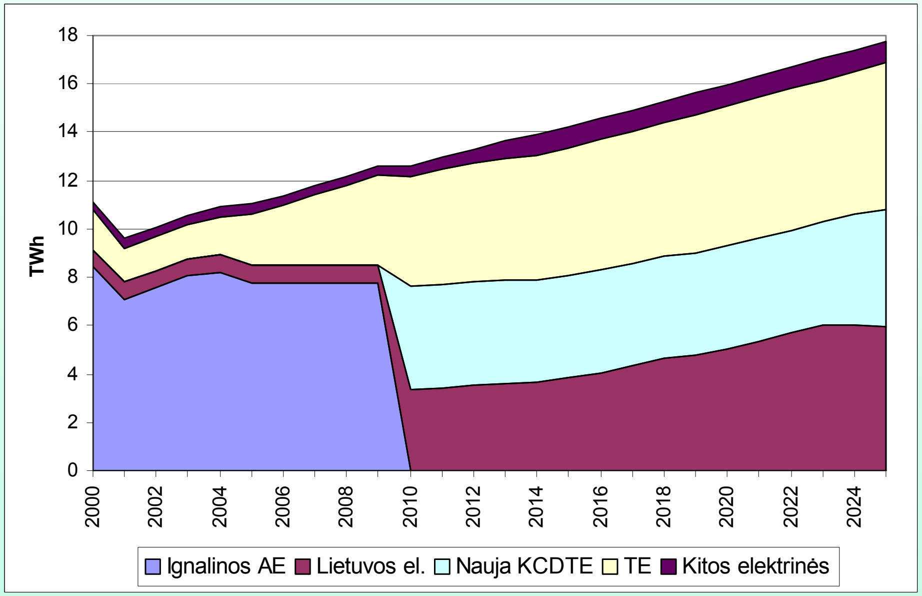
2700 mg/Nm^3 until 2004;
1700 mg/Nm^3 from 2004 until the end of 2007;
400 mg/Nm^3 since 2008.

No SO_2 emission constrains for boiler-houses and refinery.

Objective function

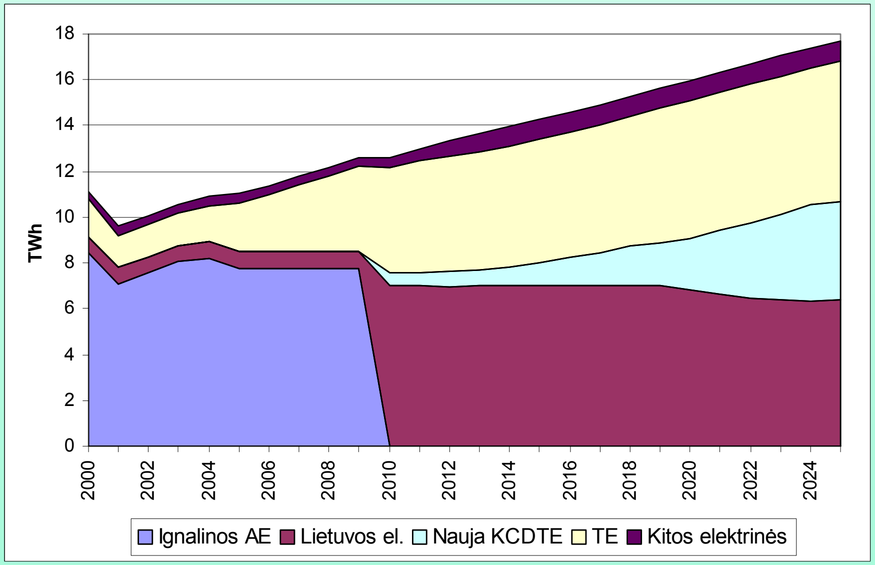


Fossil fuel scenarios: Electricity production



Construction of new CCGT

Modernization of Lithuanian TPP



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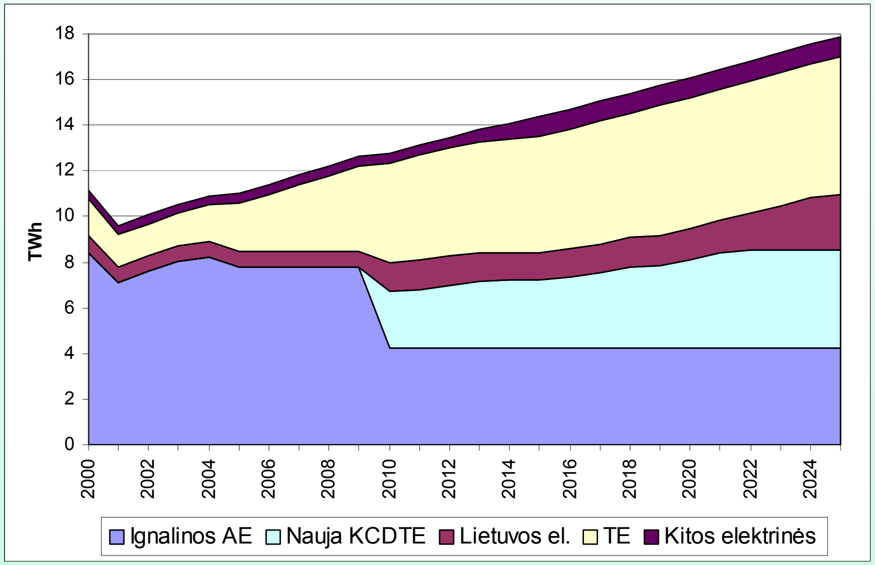
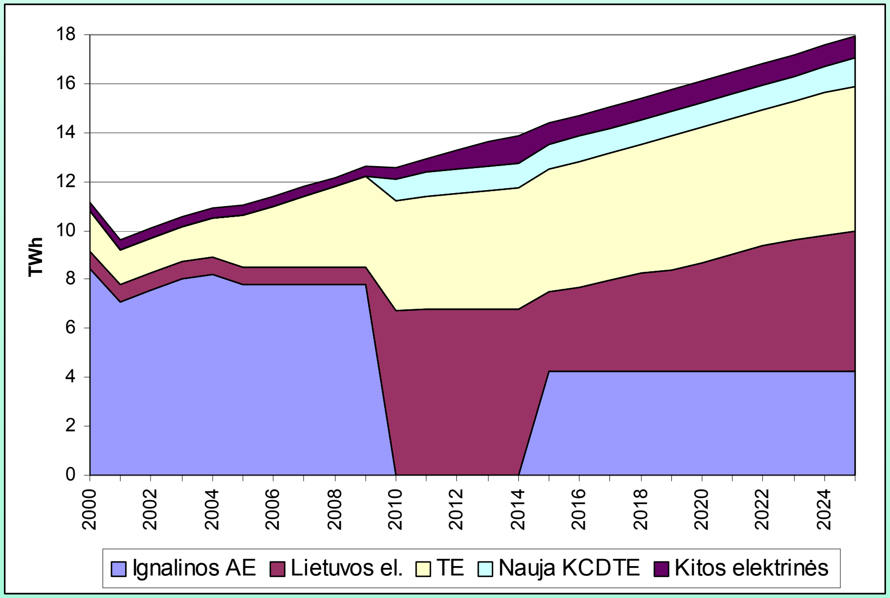
Nuclear scenarios: Electricity production



New NPP after 2010

New NPP after 2015



Preferable power plants:

existing CHP;
new CHP;
new CCGT units at the site of the Lithuanian TPP;
modernized 300 MW units at the Lithuanian TPP;
new CCGT units at the site of the Ignalina NPP;
new CCGT units at new site,
new nuclear units.

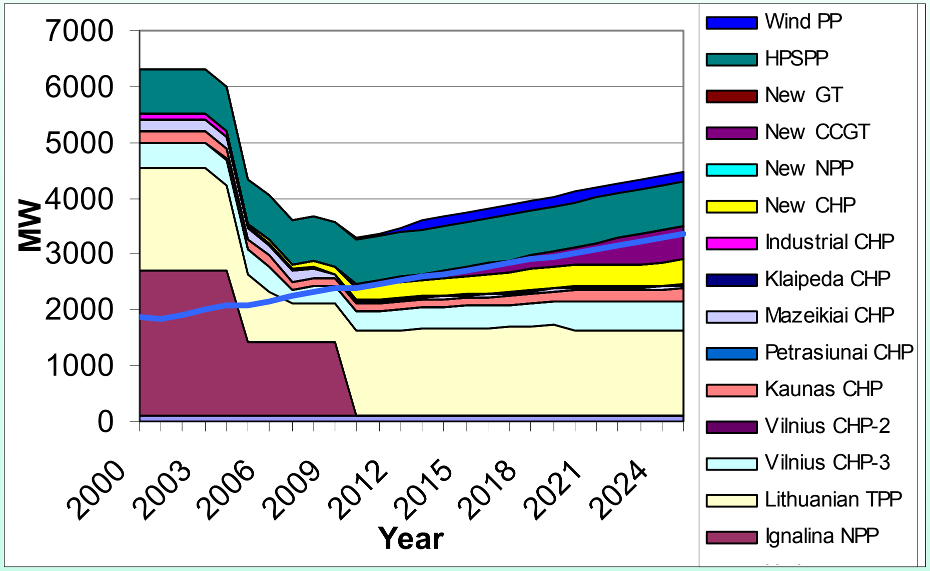
Actual contribution of mentioned candidates will depend on final energy demand in the country and energy policy options related with political preferences of security of energy supply.

Structure of generating capacities in 2025, MW

(basic demand, constant fuel prices, 10% discount factor)

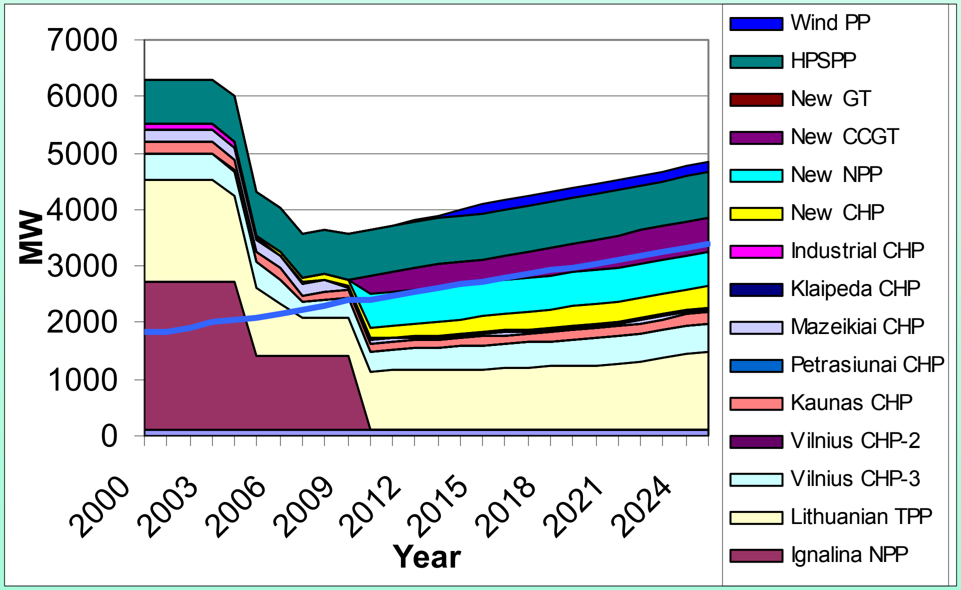
	Fossil fuel scenarios	Nuclear scenario	Postponed nuclear scenarios
Lithuanian TPP	1500	1370	900-1800
Existing CHP	800-820	790	700-790
New CHP	400-450	390	340-370
New CCGT	680-600	600	600-160
New nuclear PP	0	600	600
Hydro & HPSPP	914	914	914
Wind PP	180	180	180
Import	0	0	580-0
Total	*4474-4464*	*4844*	*4814*

Capacity balance



Modernization of Lithuanian TPP

New NPP after 2010



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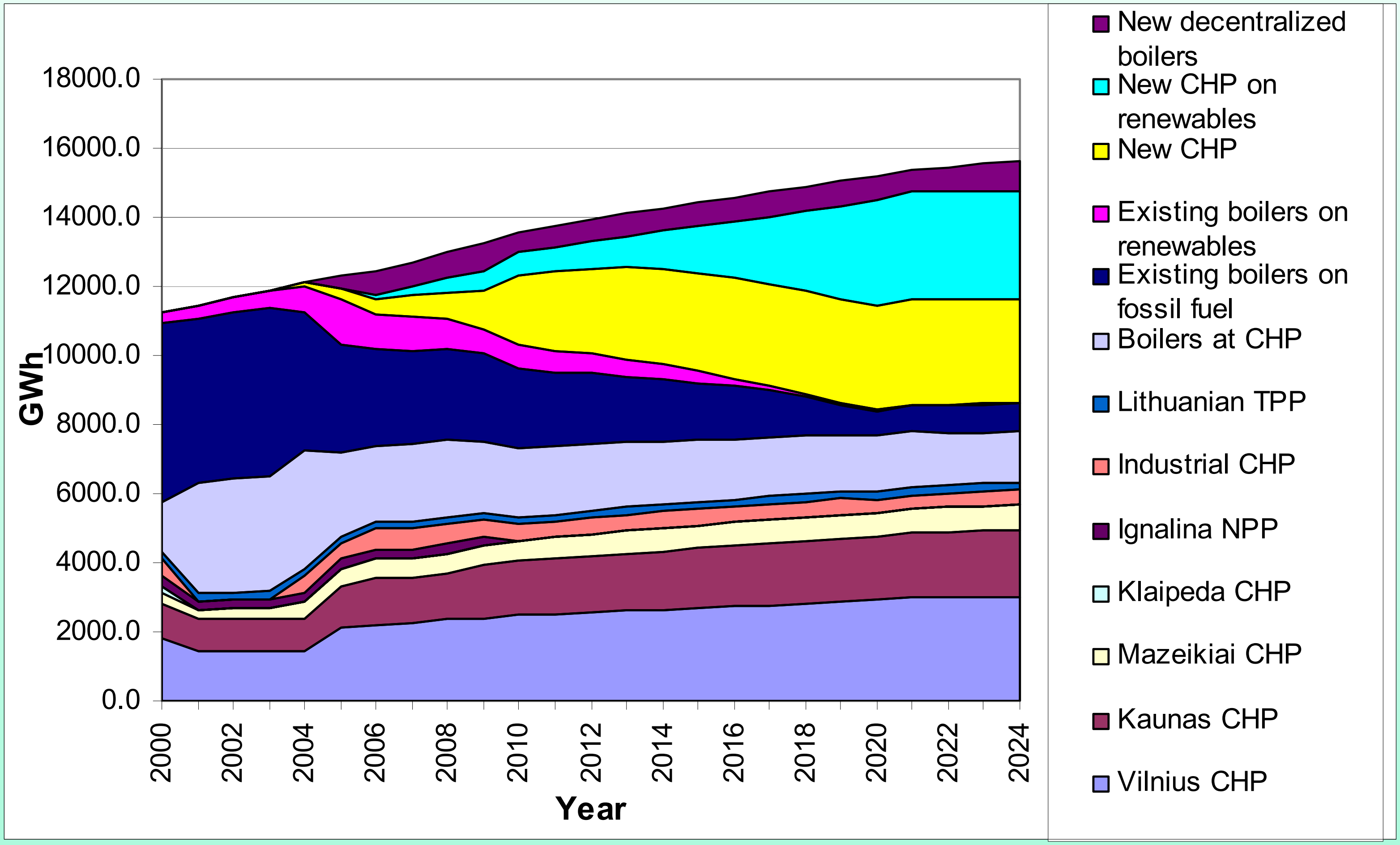
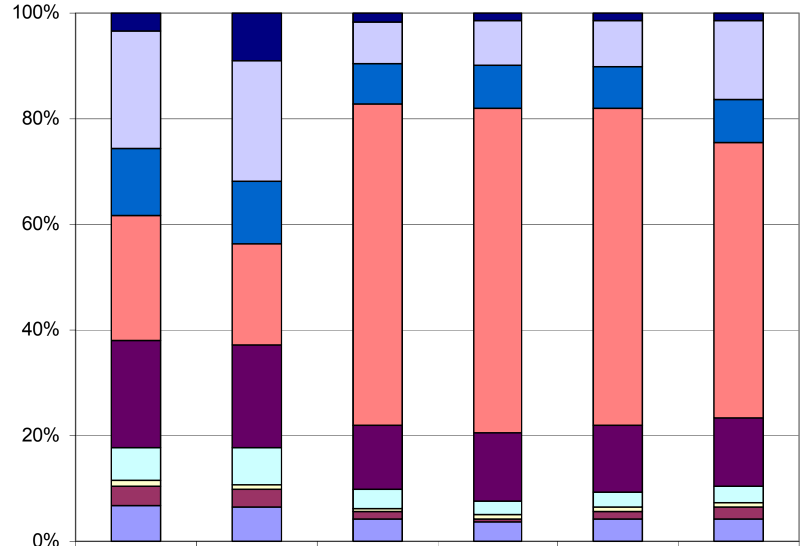
Dynamics of Heat Production for Scenario 1

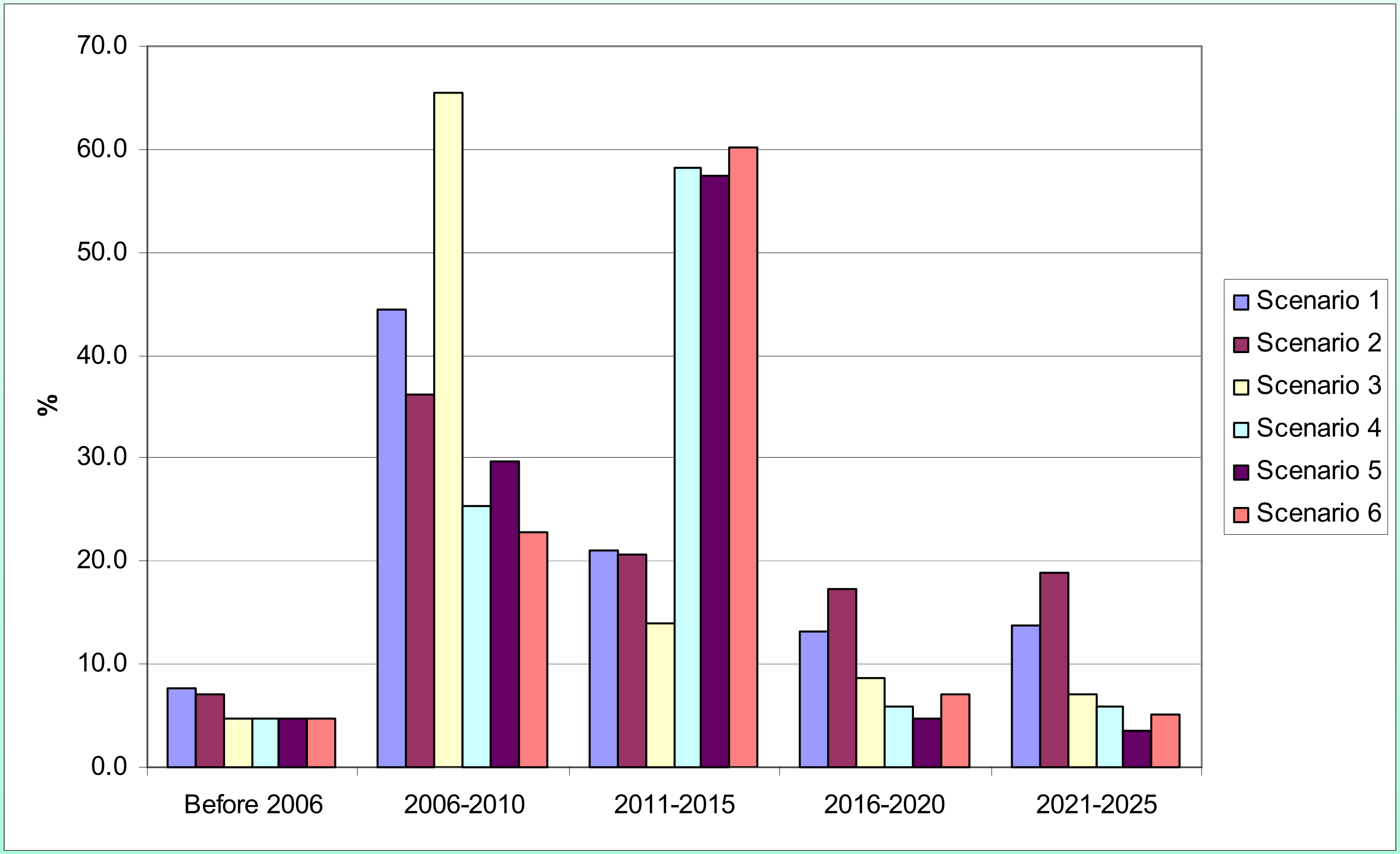


Allocation of total investments in 2000-2025 in analysed scenarios

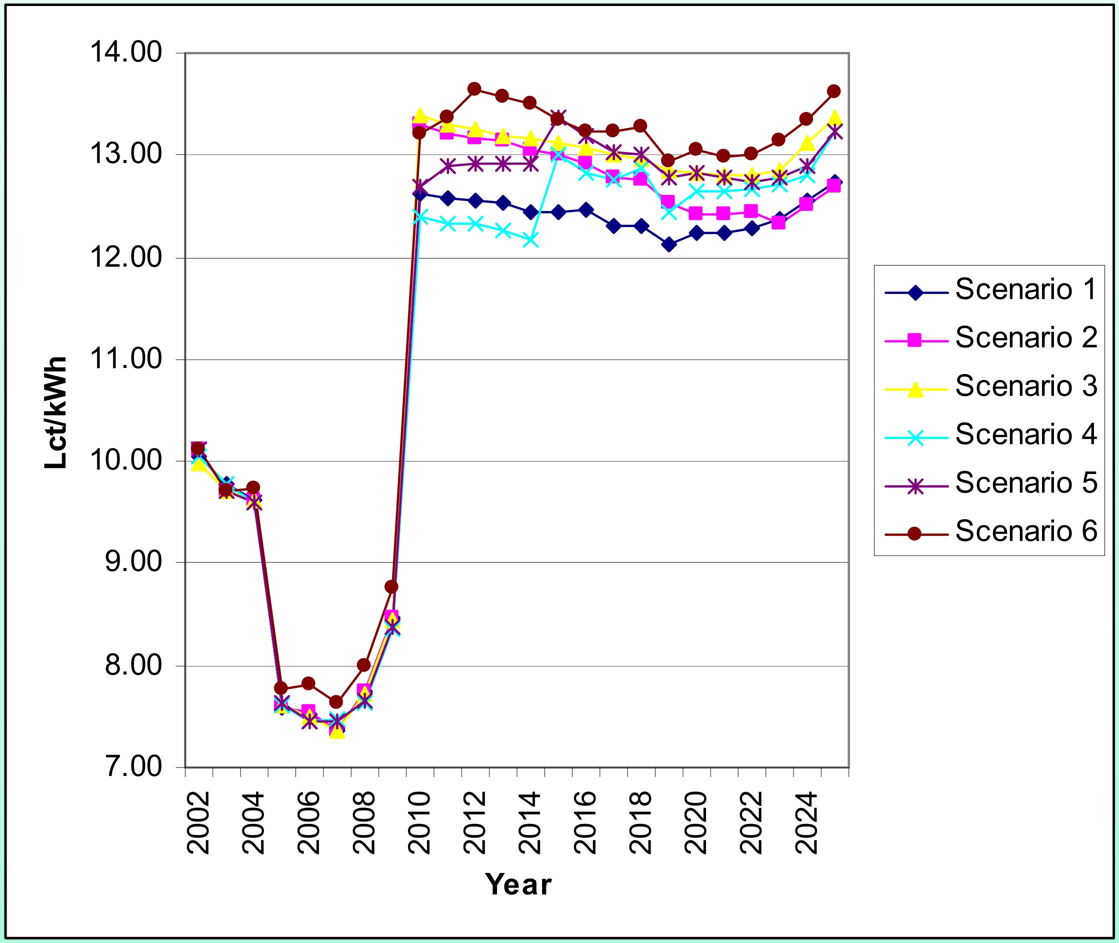


	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
Gas supply system	3.4	9.0	1.6	1.5	1.3	1.5
Environmental measures	22.2	23.0	7.8	8.4	8.7	14.9
Power Plants on renewables	12.7	11.8	7.6	8.1	8.0	8.0
New TPP	23.6	19.2	60.9	61.5	60.0	52.2
New CHP	20.3	19.4	12.1	12.9	12.7	12.9
Heat only boilers	6.2	6.9	3.8	2.7	2.9	3.3
Hydro	1.1	1.0	0.7	0.7	0.7	0.7
Existing TPP	3.7	3.5	1.4	0.5	1.5	2.3
Existing CHP	6.8	6.4	4.1	3.7	4.2	4.2

Distribution of investments in time for analysed scenarios



Average electricity production cost in all analysed scenarios



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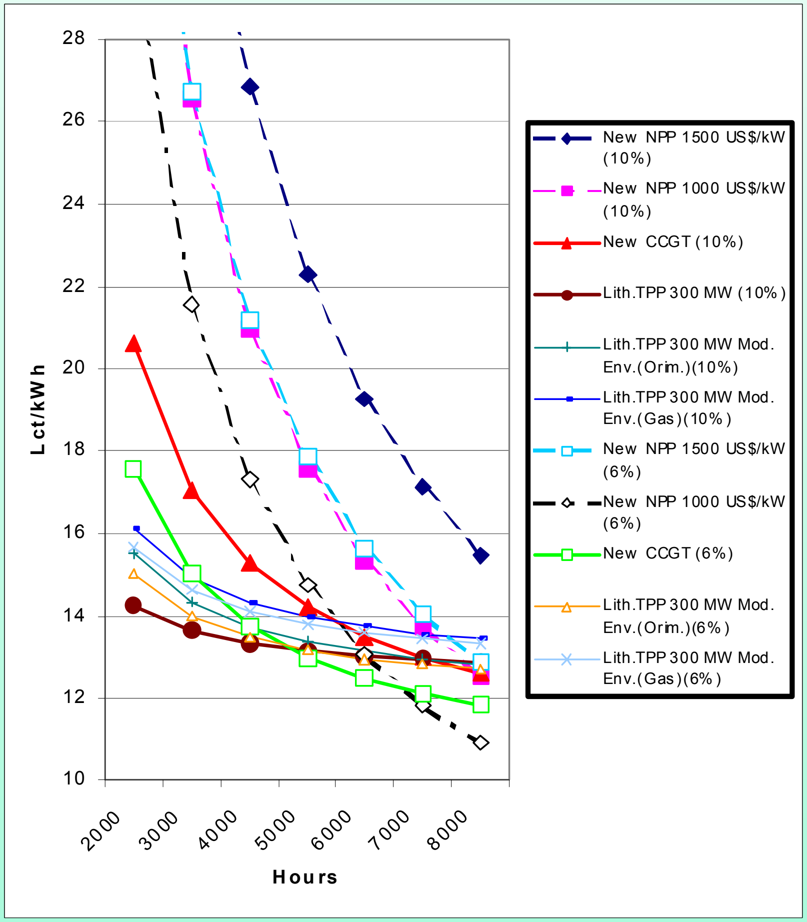
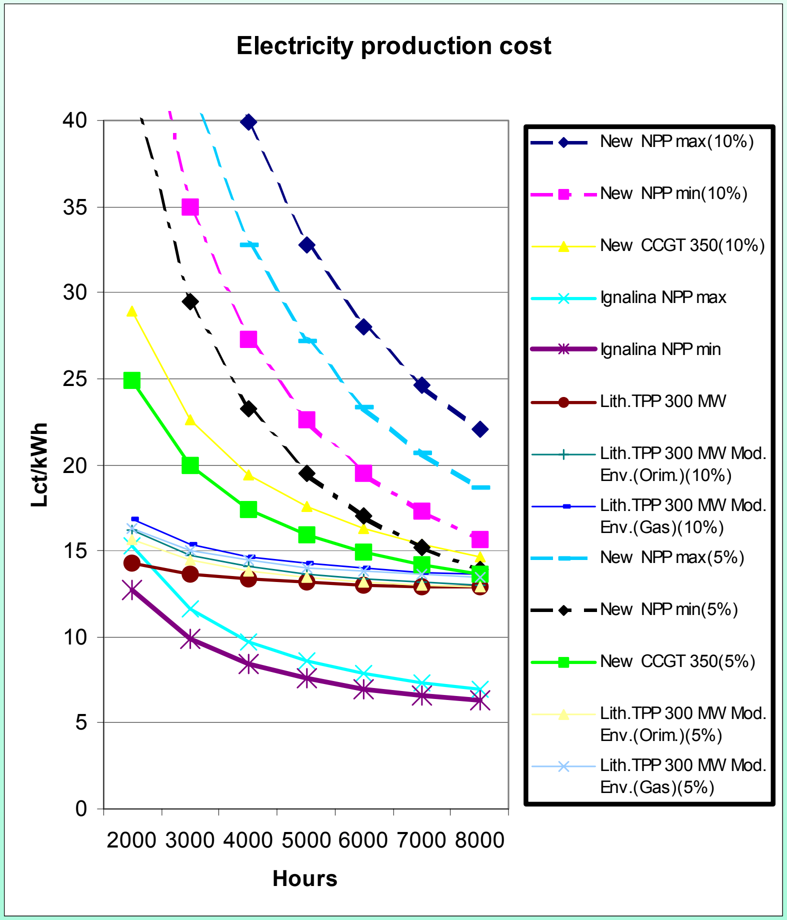
Levelized electricity production cost

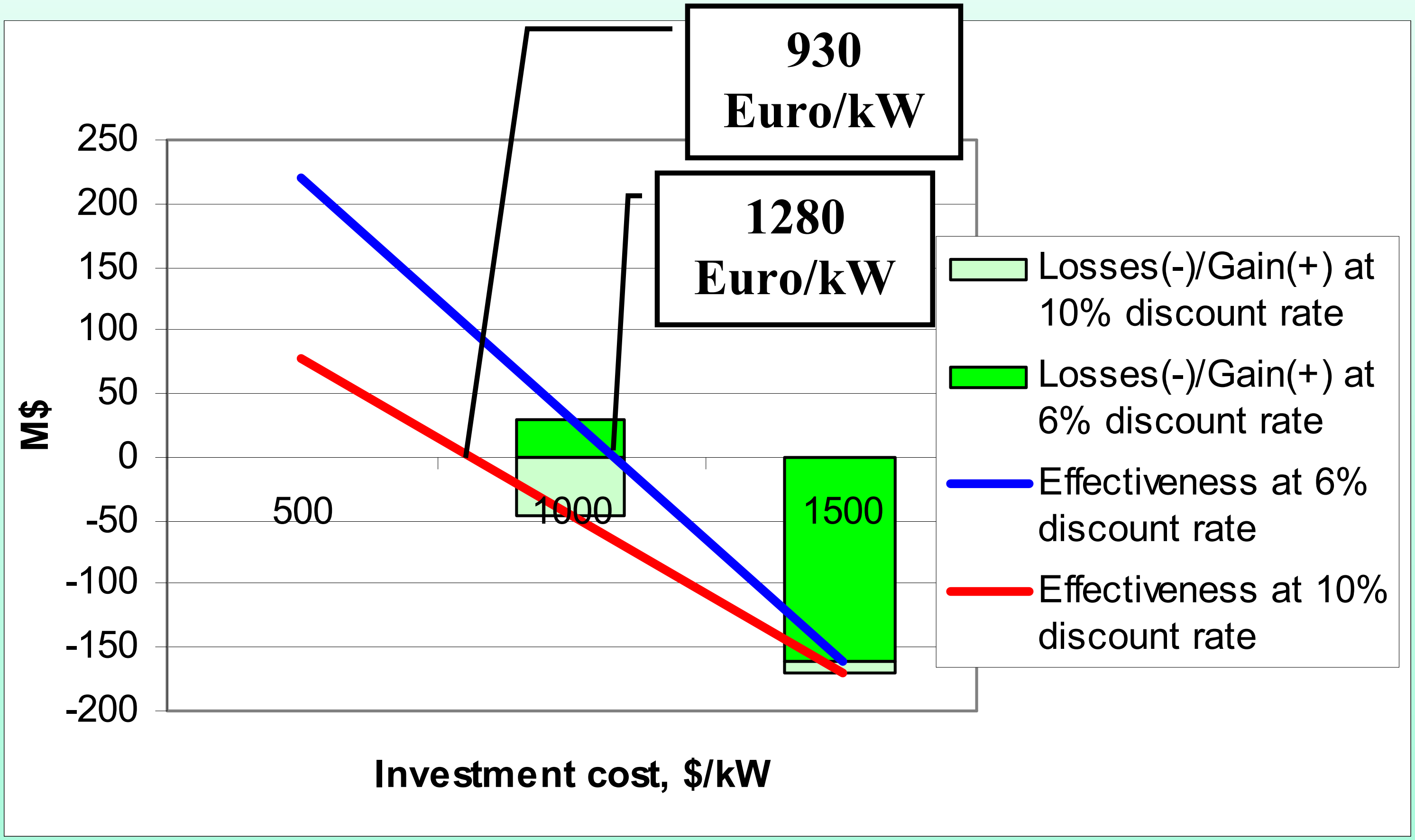
Repayment period - lifetime



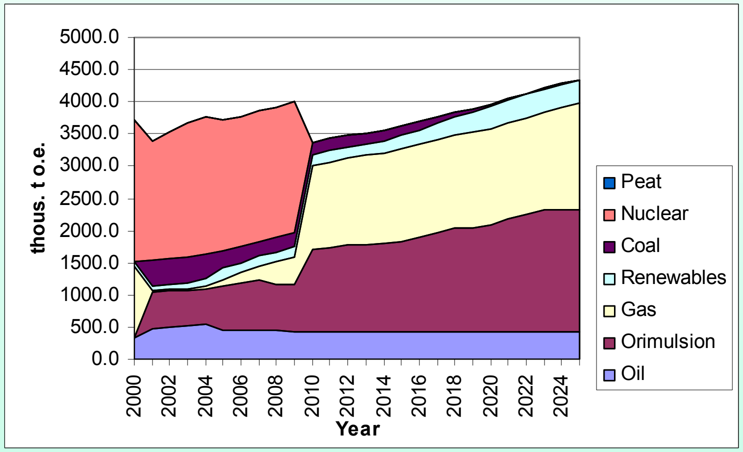
Repayment period 10 years



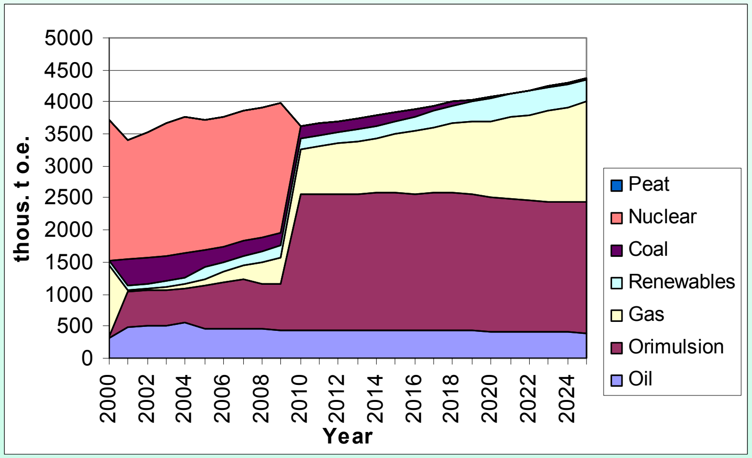
Effectiveness of new nuclear power plant in Lithuanian energy system



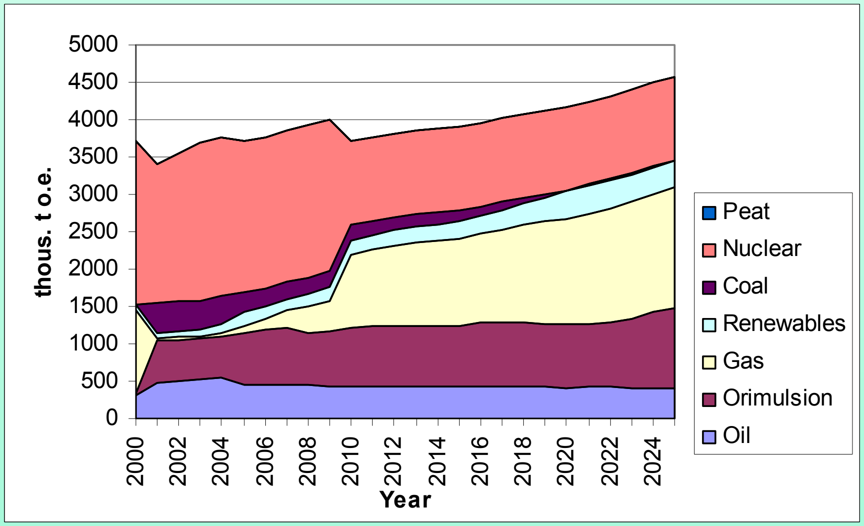
Fuel for electricity and district heat production



Scenario 1



Scenario 2



Scenario 3

Security of energy supply

New CCGT

(-) High dependency on supply of natural gas

New NPP

(+) Higher fuel diversity

(-) Power plants tightly linked to particular fuel type

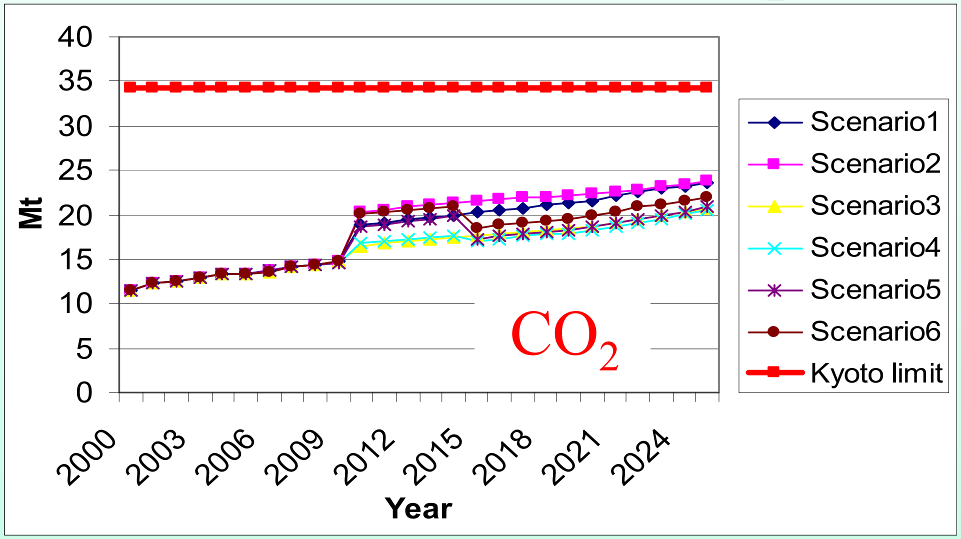
Modernization of Lithuanian TPP

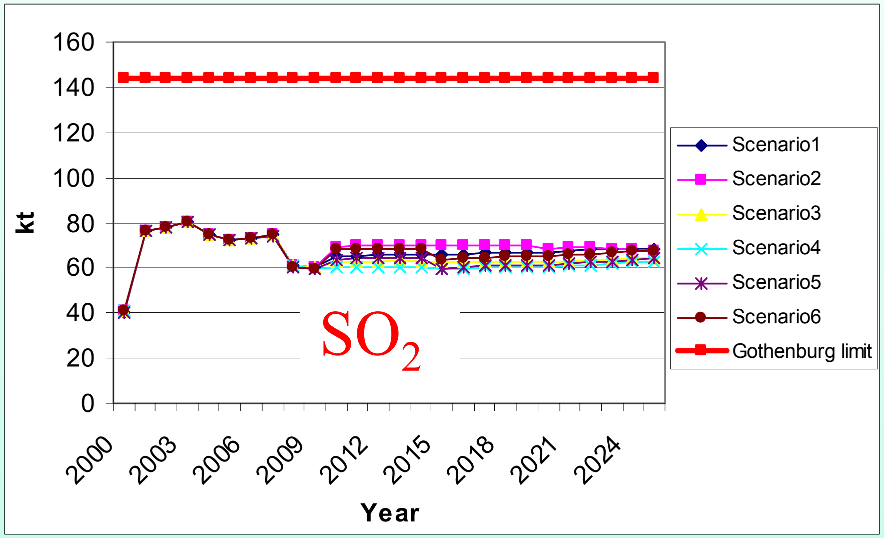
(+) Highest fuel supply diversity

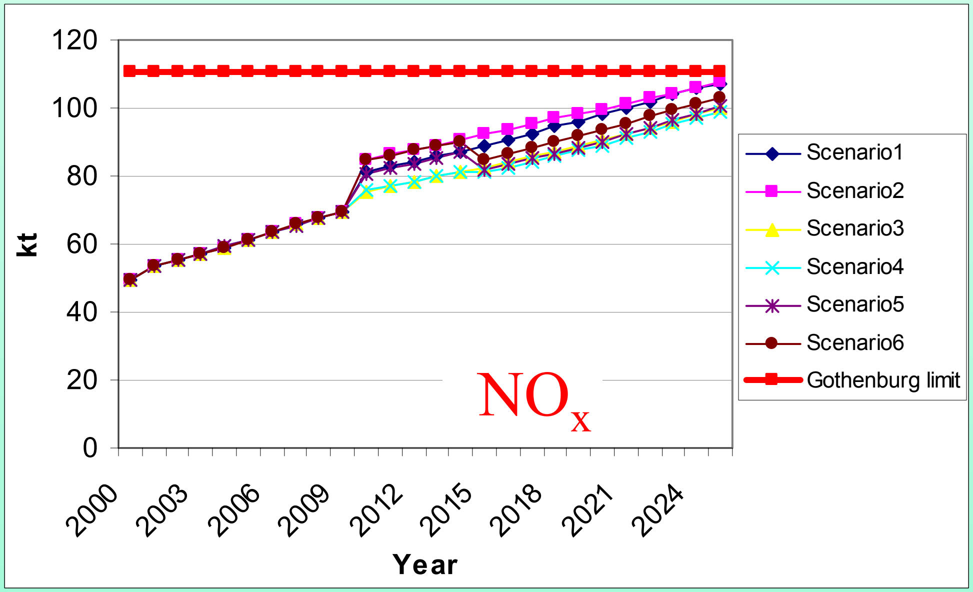
(+) Three fuel types: oil, gas, orimulsion

(+) Better possibility to choose fuel supplier and negotiate price

Emissions into atmosphere related to fuel combustion







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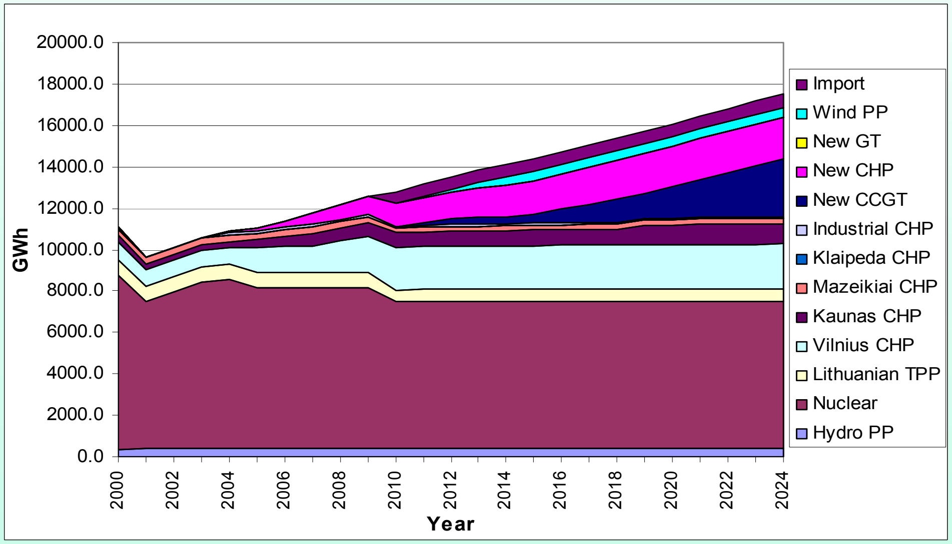
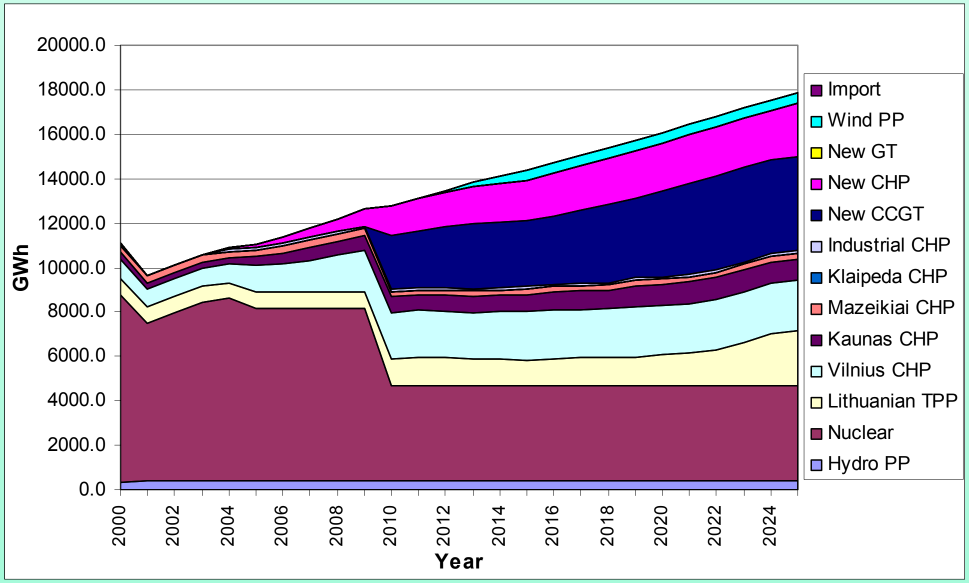
Impact of unit size of nuclear power plant

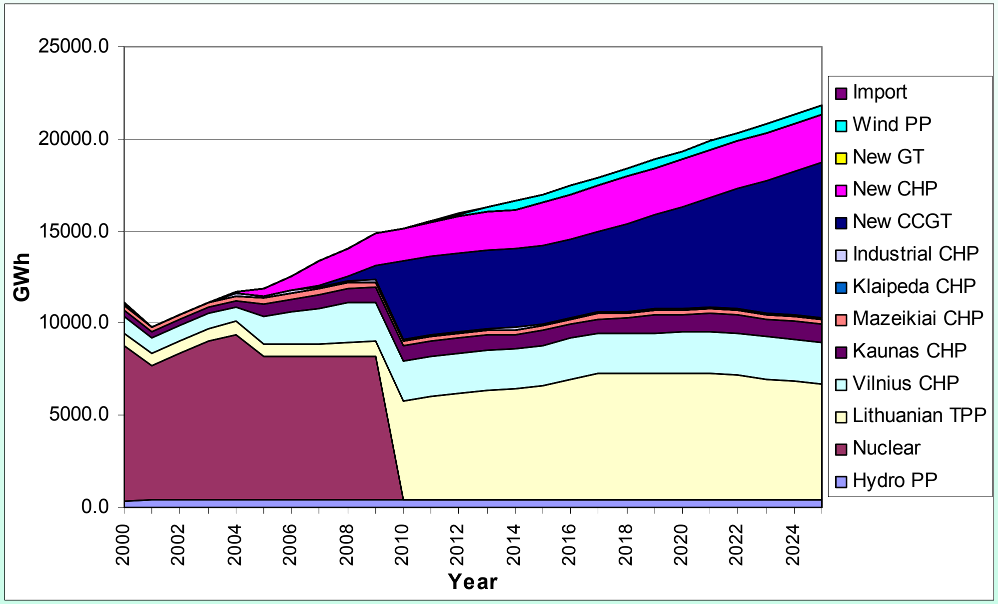


1000 MW

600 MW

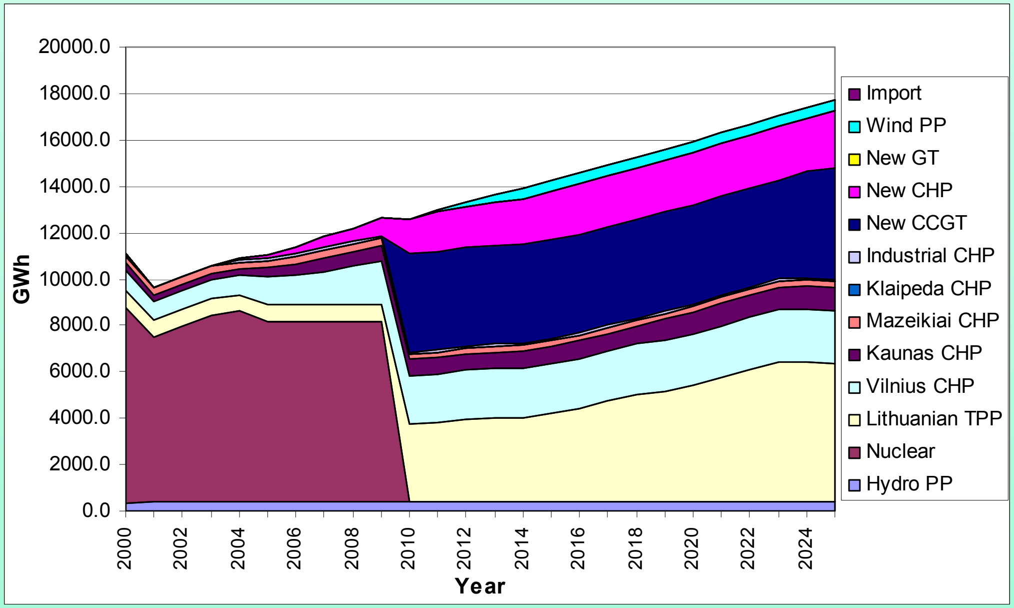


Impact of demand



High demand

Basic demand



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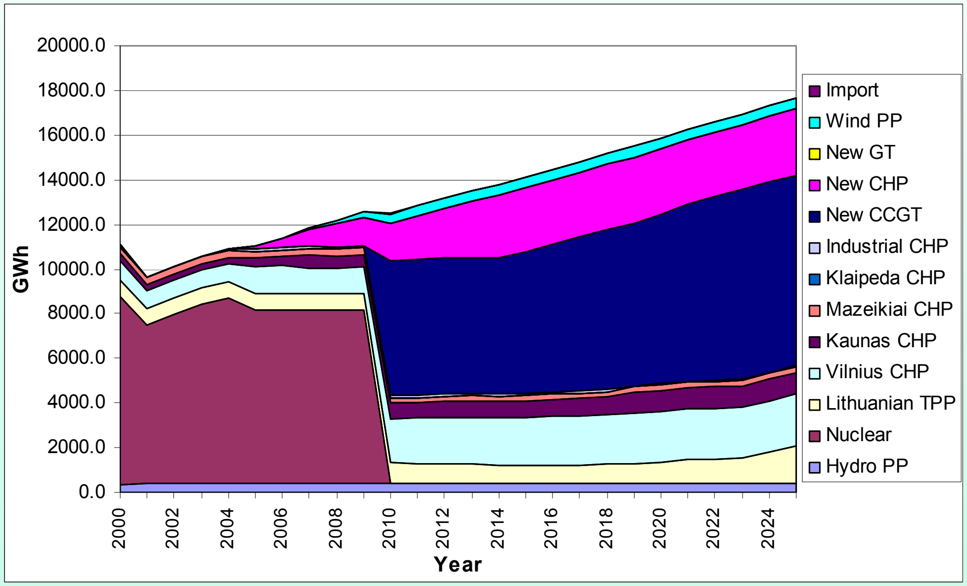
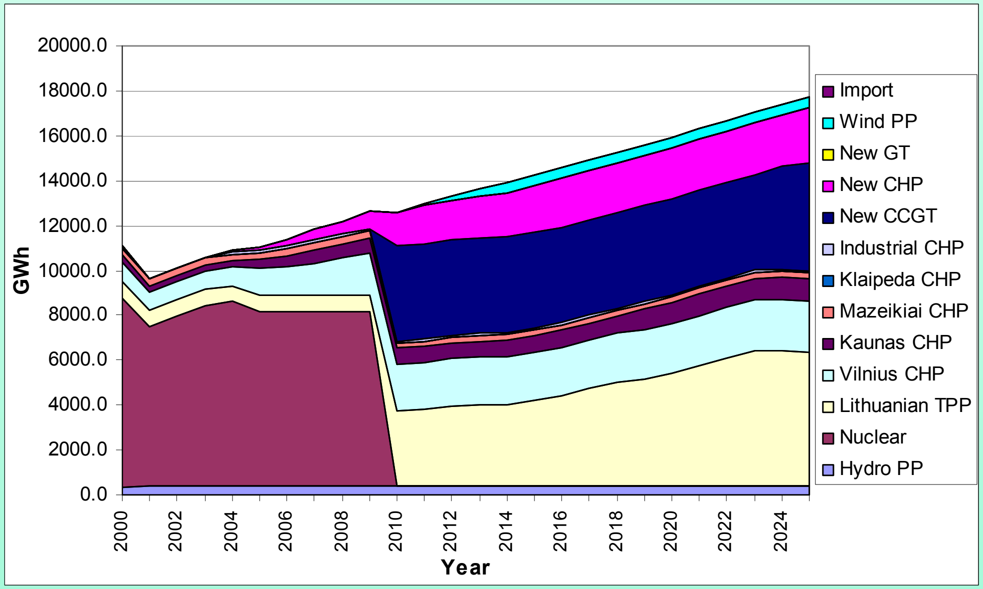
Impact of discounting factor



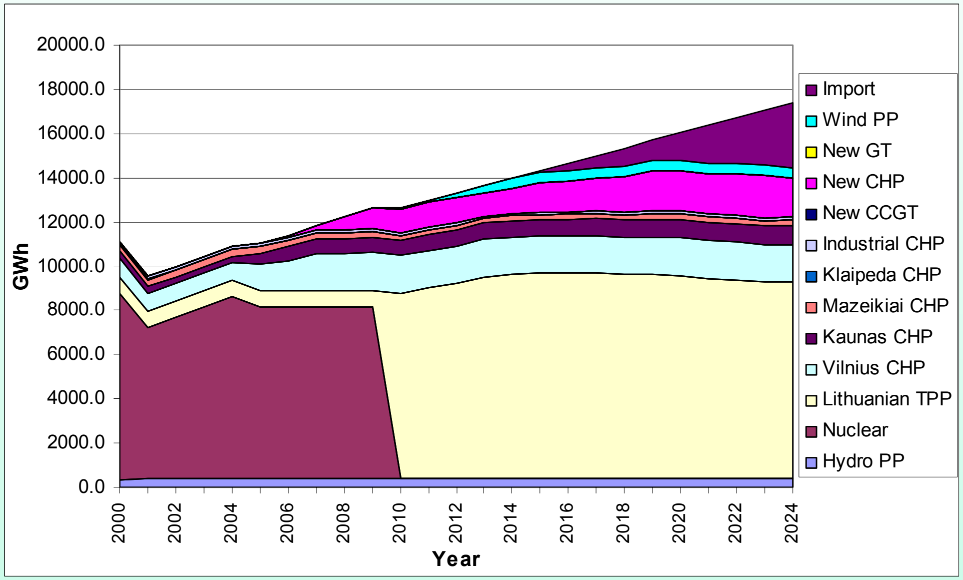
6% discounting factor

10% discounting factor

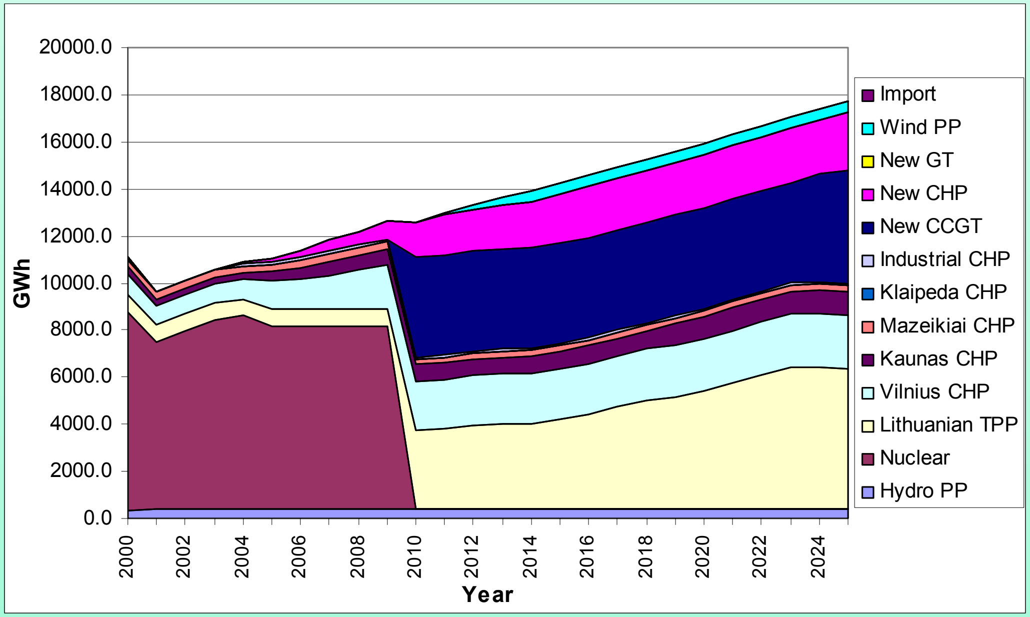


Impact of fuel prices

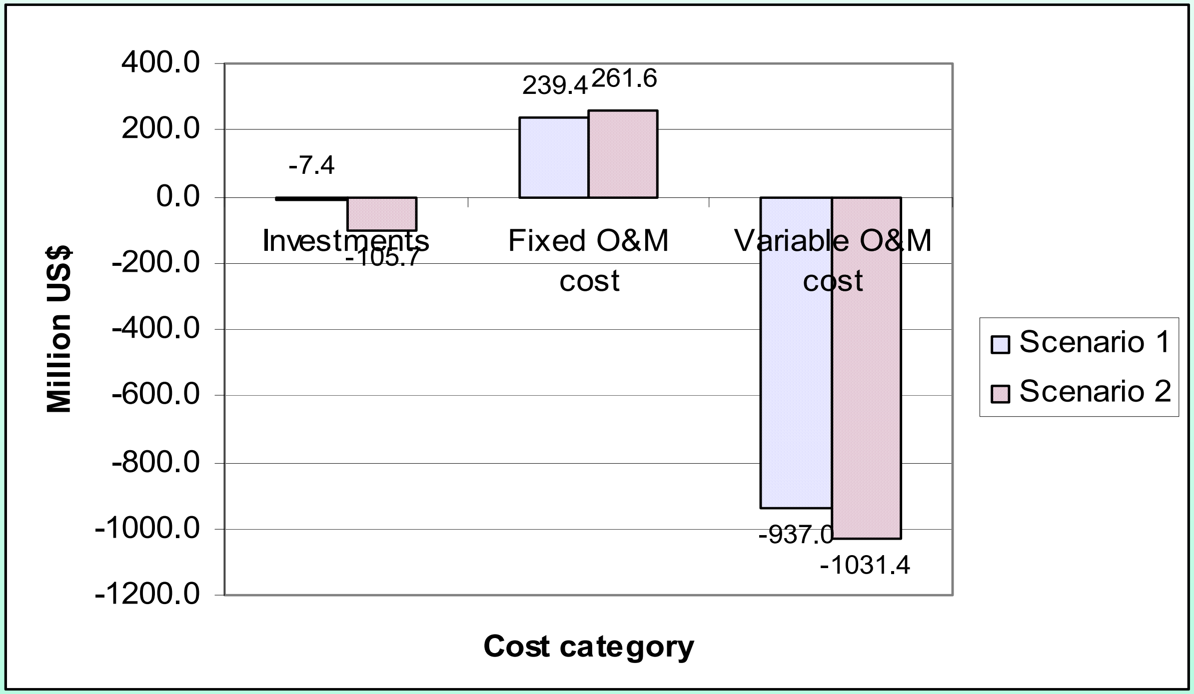
High fuel prices



Stable fuel prices



Comparison of Undiscounted Cost of Scenario 1 and 2 with scenario of Ignalina NPP operation until the end of 2017



Operation of the second unit of the Ignalina NPP until the end of 2017 allows saving of total discounted cost in the scope of US$ 378-390 million in comparison with scenario 1 and 2 respectively.

Conclusions

Construction of new CCGT units at existing site of the Lithuanian TPP or modernization of the existing 300 MW units at Lithuanian TPP are two economically similar alternatives for substitution of the Ignalina NPP. Option of the new CCGT units leads to lower emissions into atmosphere, but significantly increases dependence on natural gas. Option of further operation of the Lithuanian TPP requires lower investment cost, leads to considerably extended diversity of fuel supply, secures from fuel price dictate from the side of fuel suppliers.

Low discounting factor (5-6%) creates more favorable economic conditions for new units (CCGT, CHP and others), while increasing price of natural gas or high discounting factors (more than 10%) leads to higher economical attractiveness of the Lithuanian TPP due to lower investment cost and possibility of burning comparatively cheep fuel - orimulsion.

Conclusions

Replacement of the Ignalina NPP by the new nuclear power plant would cause higher cost of Lithuanian energy system operation and development.
Total discounted cost in comparison with fossil fuel scenarios would be US$ 158-170 million higher if new nuclear power plant would start operation immediately after closure of the second unit of the Ignalina NPP in the case of basic demand growth scenario, assuming investment cost for new nuclear plant 1500 US$/kW and applying 10% discount rate. In the case when commissioning of the new nuclear power plant occurs in 2015 discounted cost of energy system operation and development will exceed discounted cost of scenarios based on fossil fuel utilization by US$ 60-84 million. Lower difference in total discounted cost in this case is caused by postponed investments into new nuclear plant. Decommissioning cost and insurance of nuclear power plant that has not been included into this analysis would further reduce economical effectiveness of new nuclear plant.

Conclusions

According results of calculations, construction of the new nuclear power plant is economically attractive option in Lithuania if investment cost is below 800 $/kW in the case when discounting factor is about 10% or below 1100 $/kW in the case when discounting factor is about 6%. Only in this case construction of the new nuclear power plant after closure of the Ignalina NPP causes lower total discounted cost of Lithuanian energy system operation and development in comparison with scenarios in which further development of power system is based on fossil fuel power plants.

In the case if new 1000 MW capacity nuclear unit would be built for Lithuanian needs it would cover 55% of total electricity production in 2010 and 40% in 2025 in the case of basic demand scenario. Remaining electricity would be produced by existing and new CHP. Contribution of new CCGT would be needed only after 2017-2018 when its share will start growing from 5-7% until about 17% in 2025. Electricity production at Lithuanian TPP will be limited by heat demand of Elektrenai town (combined heat and electricity production at 150 MW unit) and by reservation requirements of the nuclear unit.

Conclusions

Construction of the new nuclear unit, as in the case of further operation of the Lithuanian TPP, will also lead to diversification of primary energy requirements. However, power plants used for electricity generation will be more tightly linked to the specific fuel type in comparison with scenario where Lithuanian TPP is modernized and remain in operation. This means that power plants will have less space for manoeuvre in selecting fuel types, suppliers and for negotiation of fuel prices.

Average electricity production cost in Lithuanian power system may decrease after closure of the first unit of the Ignalina NPP if fixed O&M cost related to that unit will be avoided. After closure of the second unit of the Ignalina NPP average electricity production cost increases by 2.5 – 3.5 Lct/kWh in comparison with year 2002. The lowest rise of electricity production cost is in the case when new CCGT units are constructed at the site of the Lithuanian TPP, the highest growth is related with construction of new nuclear unit. Average electricity production cost after closure of the Ignalina NPP is in a range of 12.1 – 12.7 Lct/kWh in the case of basic electricity demand, 10% of discounting factor and constant fuel prices during the whole analysed period (Capacity of new nuclear unit for nuclear scenarios in this case is set to 600MW).

Conclusions

High electricity demand has the main impact on operation of the Lithuanian TPP. High electricity demand leads to much higher electricity production at that plant. It also favours (about 240 MW) development of new CHP in the time period 2005-2009. In addition, two new CCGT power plants (2*600 MW) would be necessary to construct at existing sites (one in 2010, another after 2018-2020) in order to cover internal Lithuanian electricity demand during the analysed time period. Availability of free electricity in the market at the price below 13-13.5 Lct/kWh will promote electricity import and will postpone investments.

Conclusions

Major changes in heat production structure are in district heating systems that do not have CHP. In those systems fast penetration of new CHP will occur. The fastest growth of heat output is typical from new CHP based on renewables (because of big heat/power ratio) and from new small CHP operating on natural gas. Installed electrical capacity of mentioned CHP types correspondingly is about 90 MW and 110-140 MW in scenarios of the basic economy growth. Significant contribution of heat production is from boiler-houses converted into CHP by installation of steam turbines after steam boilers or additional gas turbines in front of boilers. Installed electrical capacity of such units is in the range of 70-160 MW. (The smallest number of installed capacity is typical for nuclear scenarios). Independently which further development path will be selected for Lithuanian power sector (fossil fuel or nuclear), it will not have significant impact on operation of existing CHP. Existing CHP becomes economically competitive after closure of the first unit of the Ignalina NPP and already before closure of the second nuclear unit their capacity will be utilized by 75 –80%.

Conclusions

After decommissioning of the second unit of the Ignalina NPP, emissions of CO2 (in the case of basic economy growth scenarios) in Lithuania increases by 4.0 million tons in the case if the new CCGT power plant is built or by 5.5 million tons if Lithuanian TPP is operated at full capacity. If the new nuclear power plant starts operation immediately after closure of the Ignalina NPP CO_2 emissions will increase only by 1.7 million tons. Due to installation of flue gas desulphurisation equipments amount of SO_2 emissions practically is independent which further development path will be selected for Lithuanian power sector – based on fossil fuel or with continuation of nuclear energy in the future. Emissions of NOx during study period increase 2 times. However, requirements of the Kyoto and Gothenburg protocol for the electricity and district heating sectors, as well as for the whole Lithuanian energy sector will be not violated neither for CO_2, SO_2 or NOx.