Investigation of Opportunities for Nuclear Power Development in the Far East of Russia (Using MESSAGE)

Workshop to Exchange Experience on Energy System Modelling for Planning Zagreb, Croatia , 1 to 5 July 2019

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The Content

1. Introduction of the modeling region
2. Features of modeling and considered cases
3. Results of the modeling cases
4. Problems with modeling
5. Students and MESSAGE. Experience

The Power Sector of Russia

Country	Electricity production, bln kWh (2016)	Share of world electricity production
China	6187	24,8
USA	4300	17,2
India	1478	5,9
Russia	**1089**	**4,4**
Japan	1052	4,2
World	**24973**	**100**

Coal[1]	TWh
People's Rep. of China	4 242
United States	1 354
India	1 105
Japan	349
Germany	273
Korea	235
South Africa	2
Russian Federation	1
Australia	1
Indonesia	1
Rest of the world	1 3
World	**9 5**

2016 data

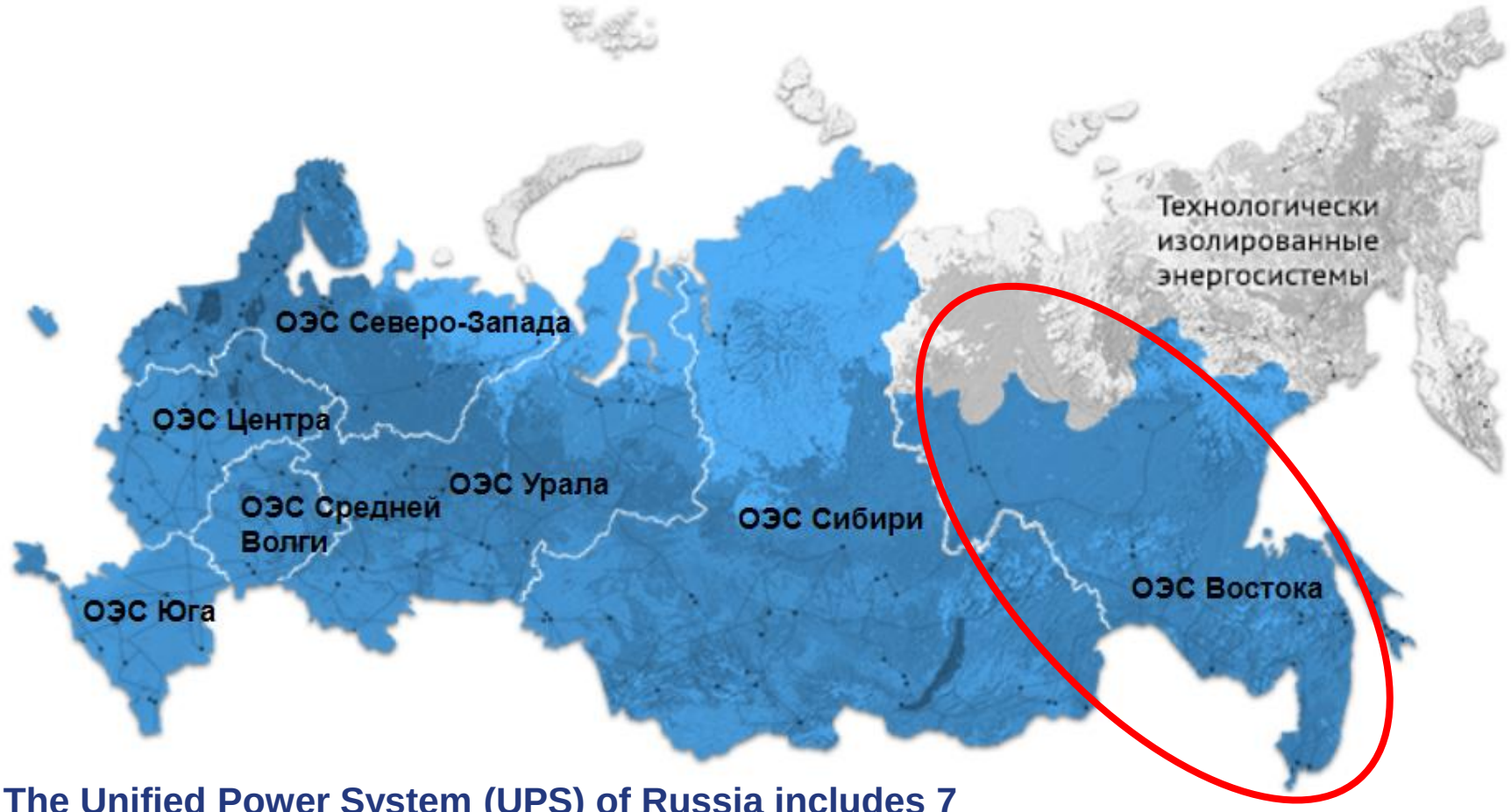
Natural gas	TWh
United States	1 418
Russian Federation	522
Japan	406
Islamic Rep. of Iran	233
Saudi Arabia	205
Mexico	192
People's Rep. of	170

Producers	TWh	% of world total
United States	840	32.2
France	403	15.5
People's Rep. of China	213	8.2
Russian Federation	197	7.6
Korea	162	6.2
Canada	101	3.9
Germany	85	3.3
Ukraine	81	3.1
United Kingdom	72	2.8
Sweden	63	2.4
Rest of the world	389	14.8
World	**2 606**	**100.0**

Country (top ten producers)	% of nuclear in total domestic electricity generation
France	73.1
Ukraine	49.7
Sweden	40.5
Korea	29.0
United Kingdom	21.3
United States	19.5
Russian Federation	18.1
World	**10.4**

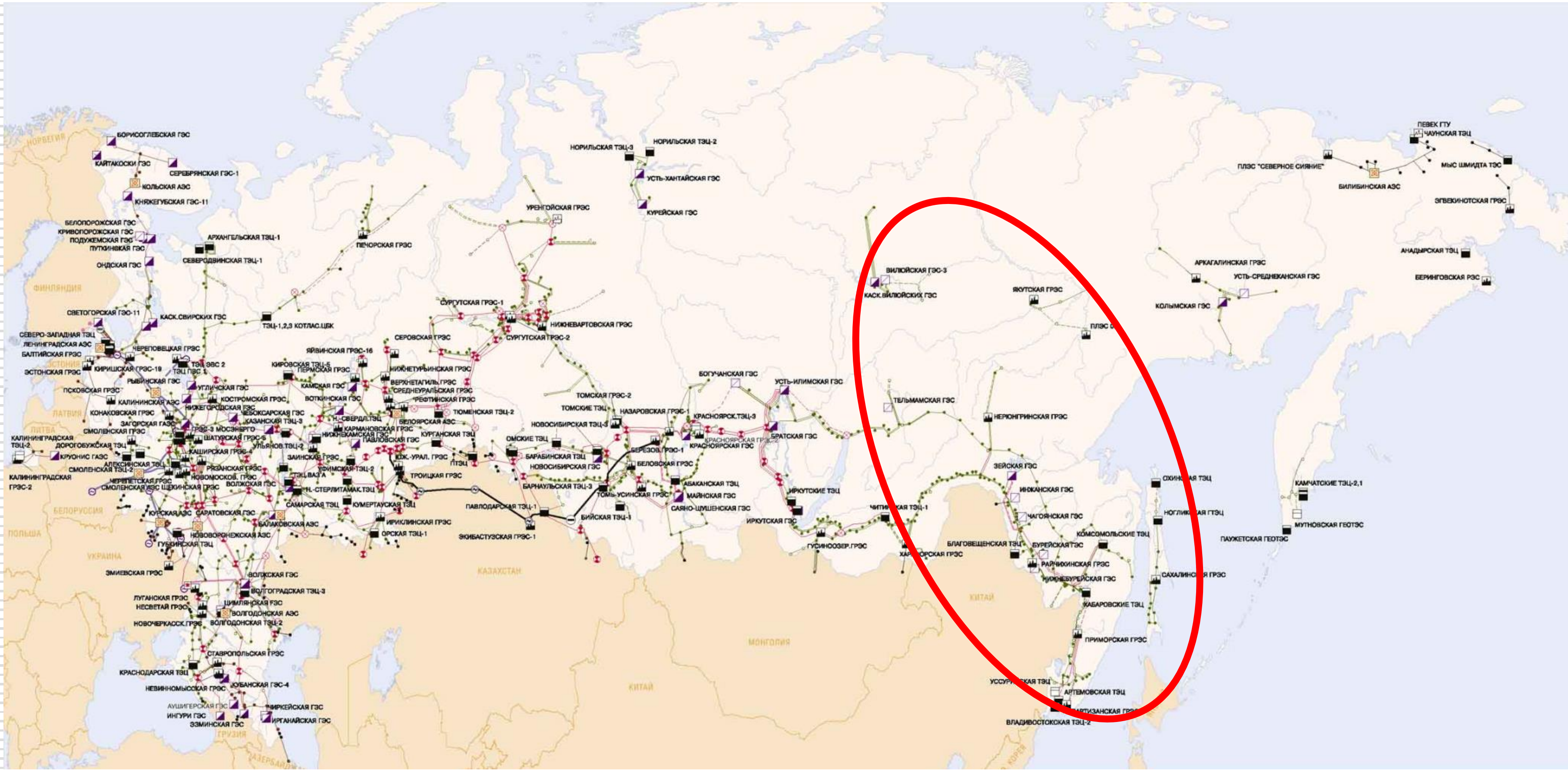
IEA, Key world Energy statistics, 2018

The UPS of Russia

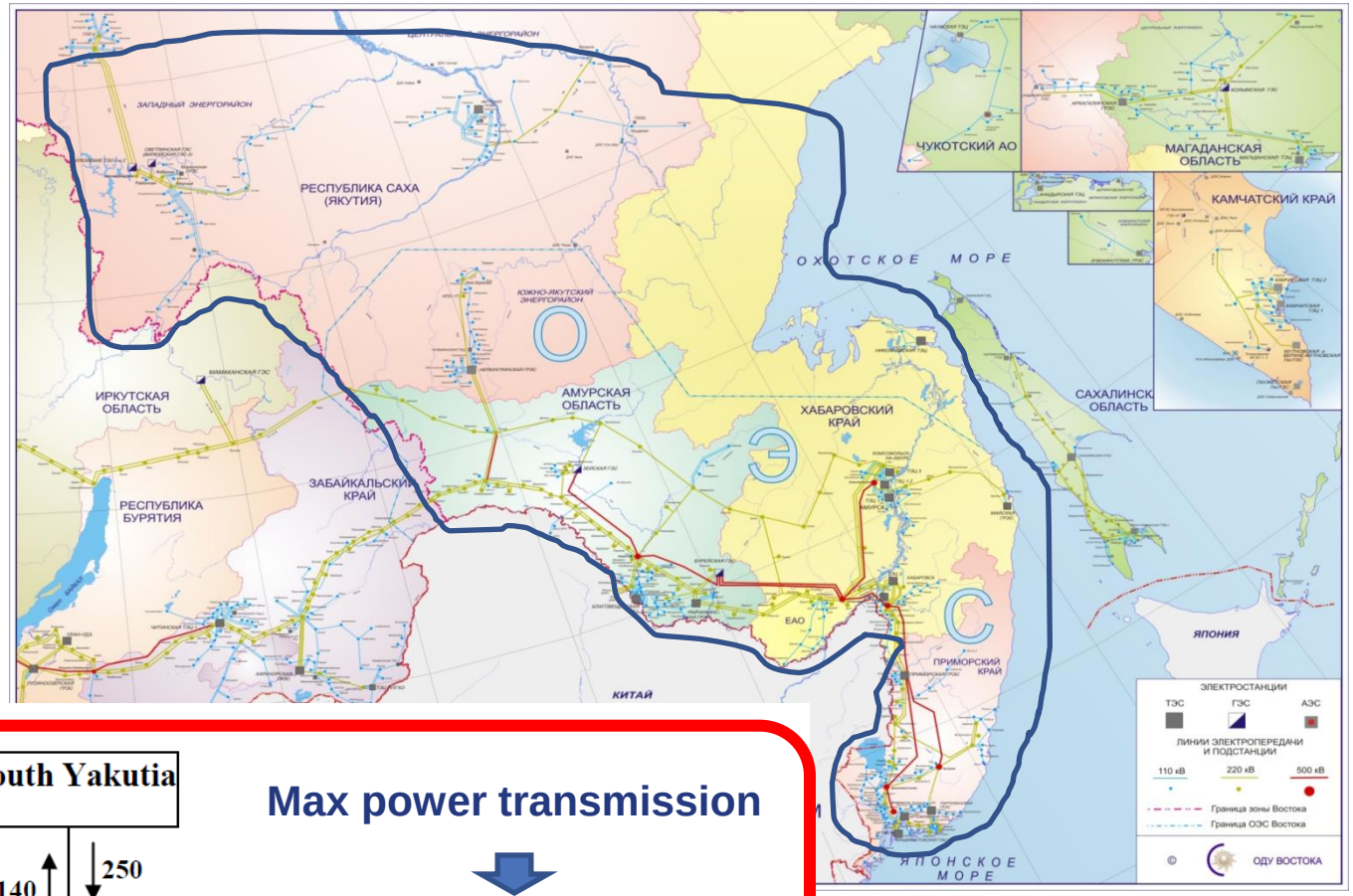


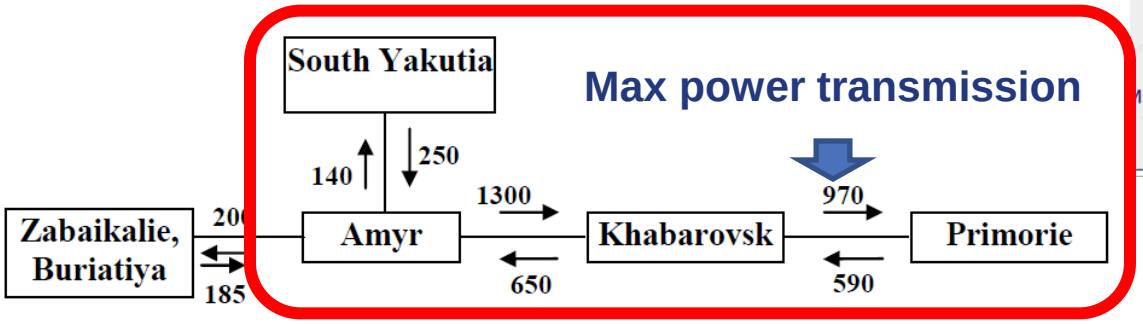
The Unified Power System (UPS) of Russia includes 7 Integrated Power Systems (IPS) and decentralized and isolated regions

The National Grid



The IPS of The Far East of Russia





The IPS of The Far East of Russia

Key figures of total installed capacity in 2017, GW

	Russia	The Far East of Russia	Share of the Far East, %
Total installed Capacity	**260,4**	**9,5**	**3,6**
Thermal PP	180,0	5,8	3,2
incl. CHP	92,7	3,4	3,7
CPP	87,2	2,5	2,9
Nuclear PP	28,0	-	
Hydro PP	51,6	3,7	7,2
Renewable	0,9	-	

Key figures of electricity production in 2017, bln kWh

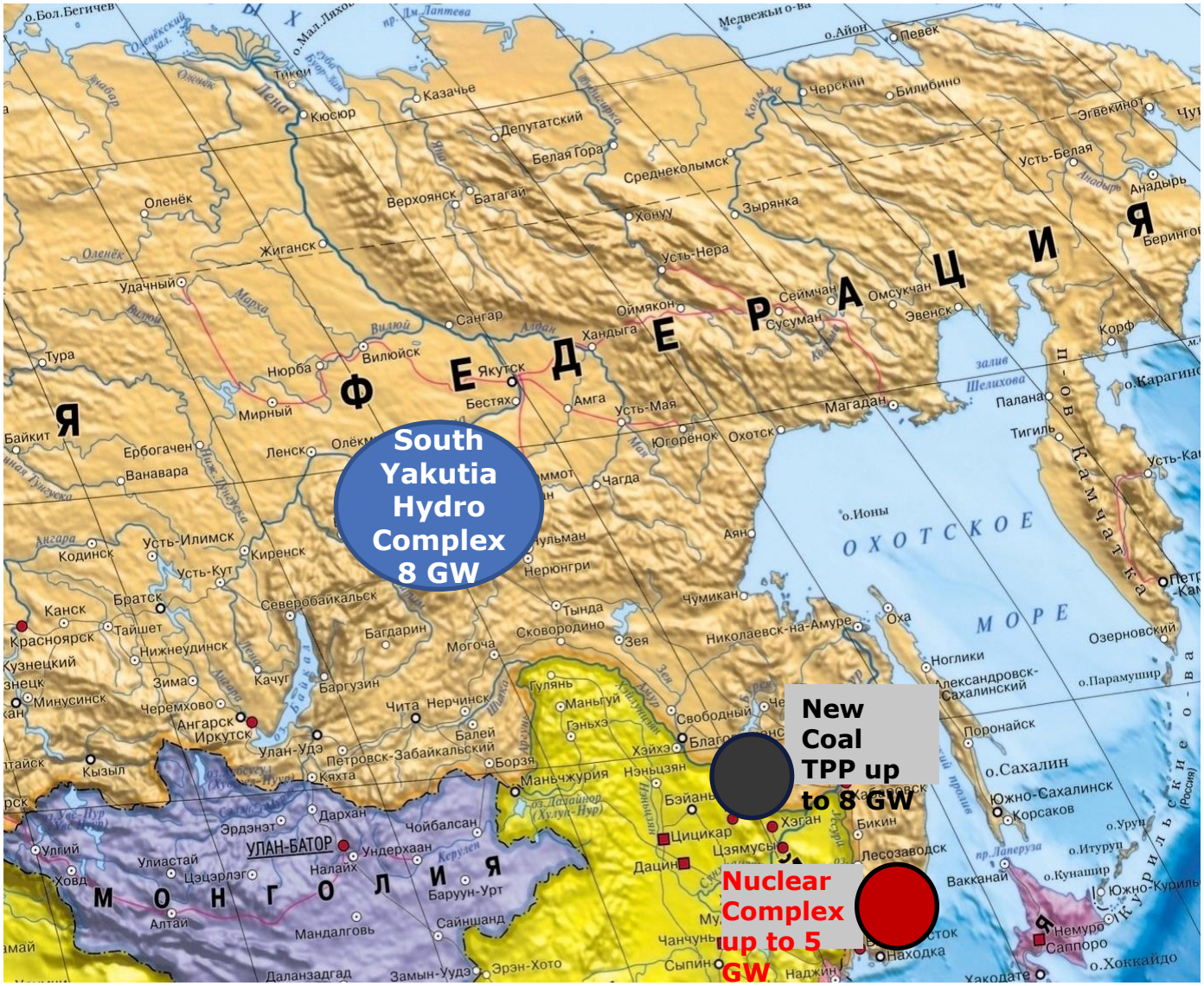
	Russia	The Far East of Russia	Share of the Far East, %
Total electricity production	**1053,9**	**36,9**	**3,5**
Thermal PP	671,3	24,6	3,7
Nuclear PP	196,4	-	
Hydro PP	178,3	12,3	6,9
Renewable	0,1	-	

The IPS of the Far East is in 7th (the last) place in the UPS of Russia

Total Installed Capacity (2017)

	The IPS of the Far East	Amyr PS	Khabarovsk PS	Primorie PS	South Yakutia	West and Northern part of Yakutia (joined in 2019)
Total installed capacity, MW	**9502**	**4166**	**2101**	**2617**	**618**	**1859**
Hydro PP	3660	**3660**				**958**
Thermal PP	**5842**	506	2101	2617	618	901
CHP (total)	**3382**	404	**2023**	547	**408**	221
gas	410		360	50		221
coal	**2972**	404	**1663**	497	**408**	
CPP (total)	2460	102	78	**2070**	210	680
gas	48		48			**680**
coal	2412	102	30	**2070**	210	

Possible location of Nuclear PP



The cost and performance data of power plants. Fuel prices

Large “system-based” power plants

Indicator	Units	Nuclear	CCGT	Coal SC	Coal USC	Coal CHP	Gas CHP
Unit capacity	MW	1255	400	660	660	115	115-450
Overnight capital costs*	$ 2018/kW	1300	550	1020	1200	1170	610-730
Fixed O&M	% of cap. costs	2.4	3.0	3.0	3.5	4.0	4.5
Efficiency	%	-	56.5	41.3	46.2		

*) *Capital costs indicated without a territorial coefficient*

Distributed co-generation

Indicator	Units	gas reciprocating engine	gas turbine
Unit capacity	MW	1	1
Overnight capital costs*	$ 2018/kW	1250	1140
Fixed O&M	% of cap. costs	5	4,5

CO_2 tax, $/t$CO_2$

	Min	Max
2025	18,5	18,5
2030	18,5	25
2035	18,5	35
2040	18,5	50
2045	18,5	77
2050	18,5	100

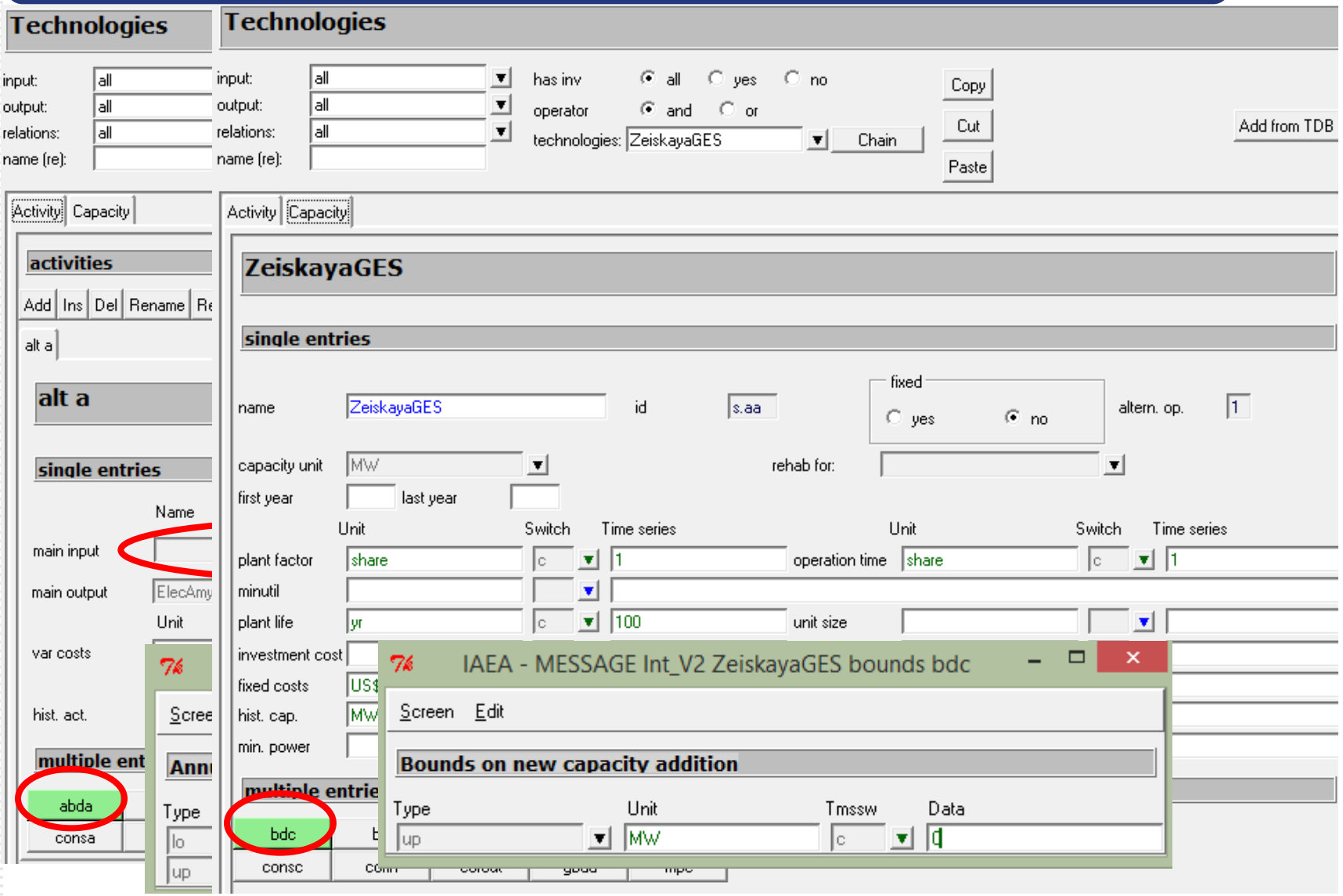
Gas prices, $/tce

	2015	2020	2030	2040
Min	96 - 132	92-133	78-121	85-123
Max		101-146	185-243	197-261

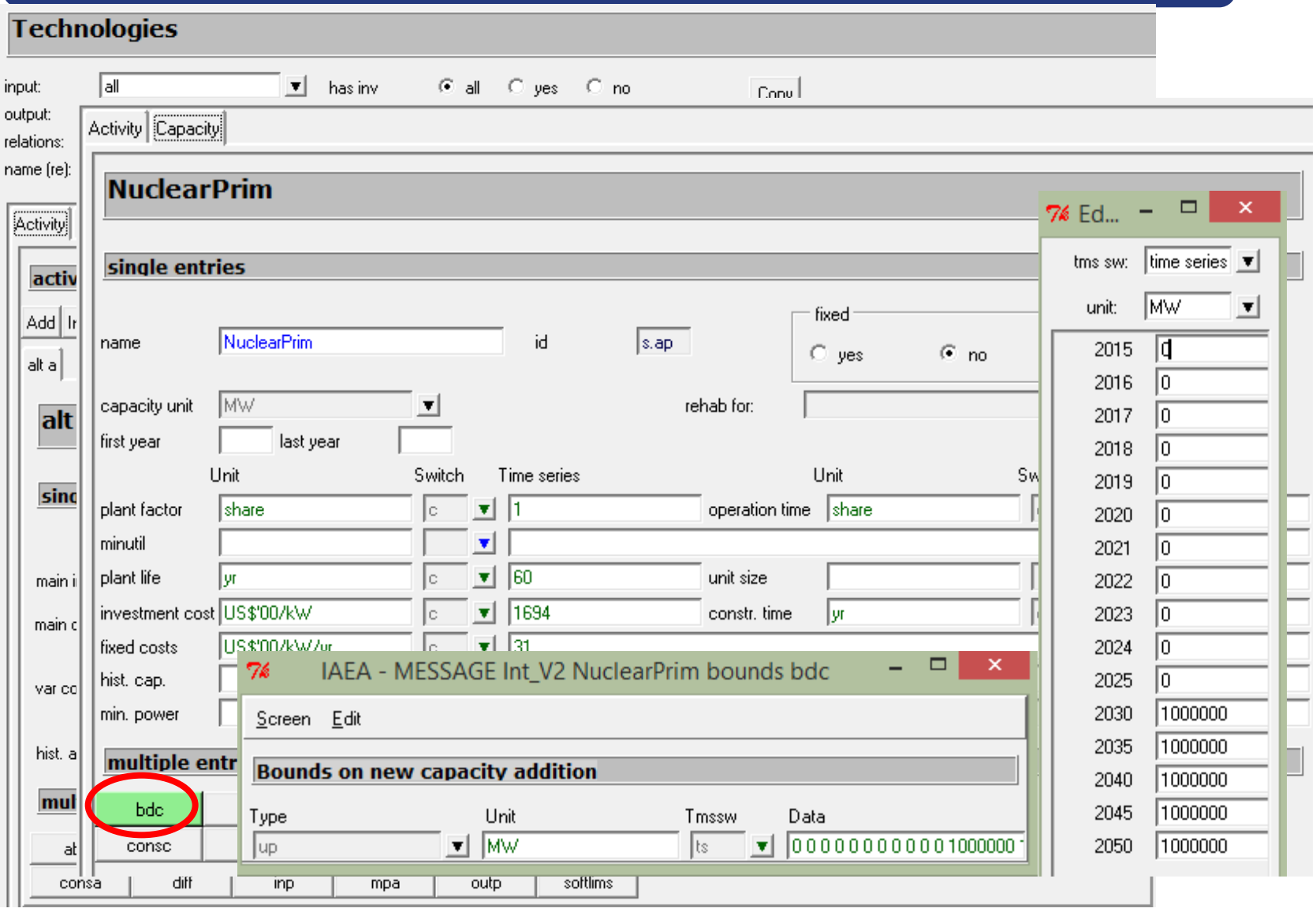
Coal prices, $/tce

	2015	2020	2030	2040
Min	63-97	51-135	48-101	49-117
Max		57-112	55-106	53-121

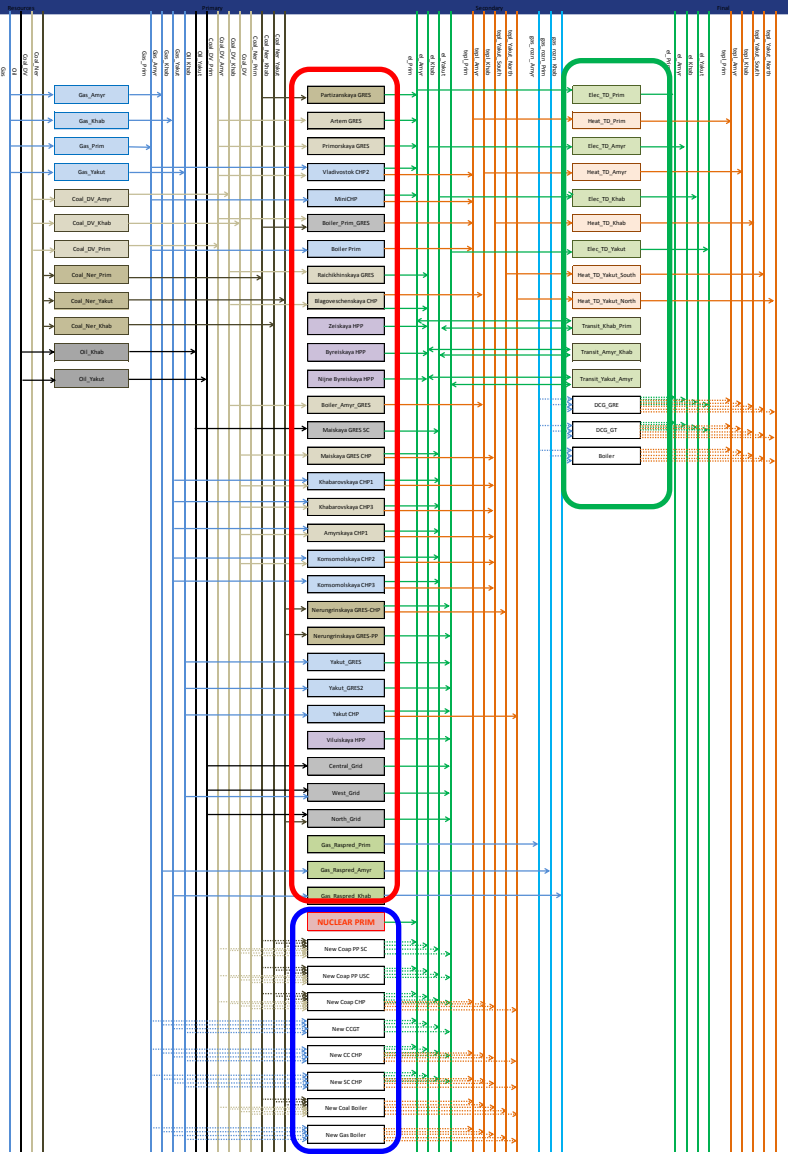
The features of Hydro PP modeling

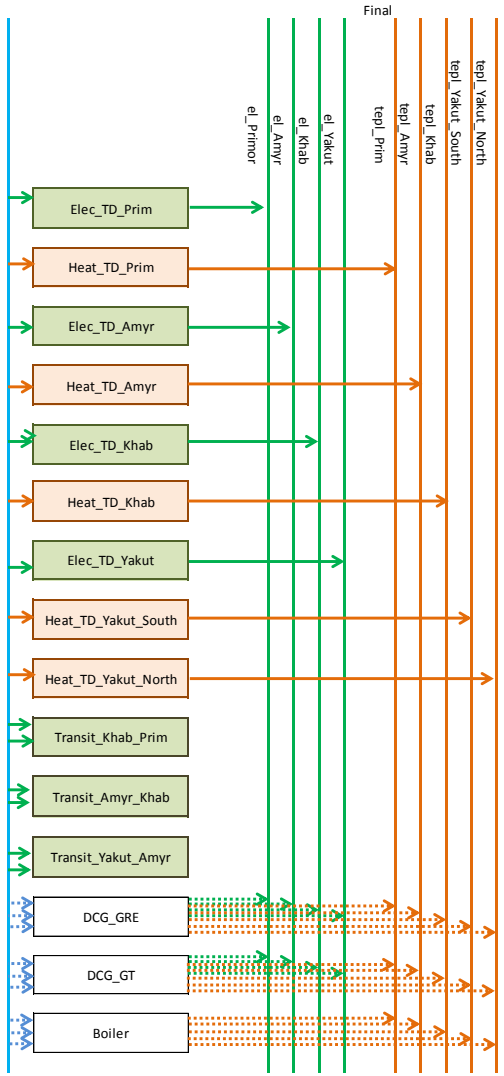


The features of Nuclear PP modeling



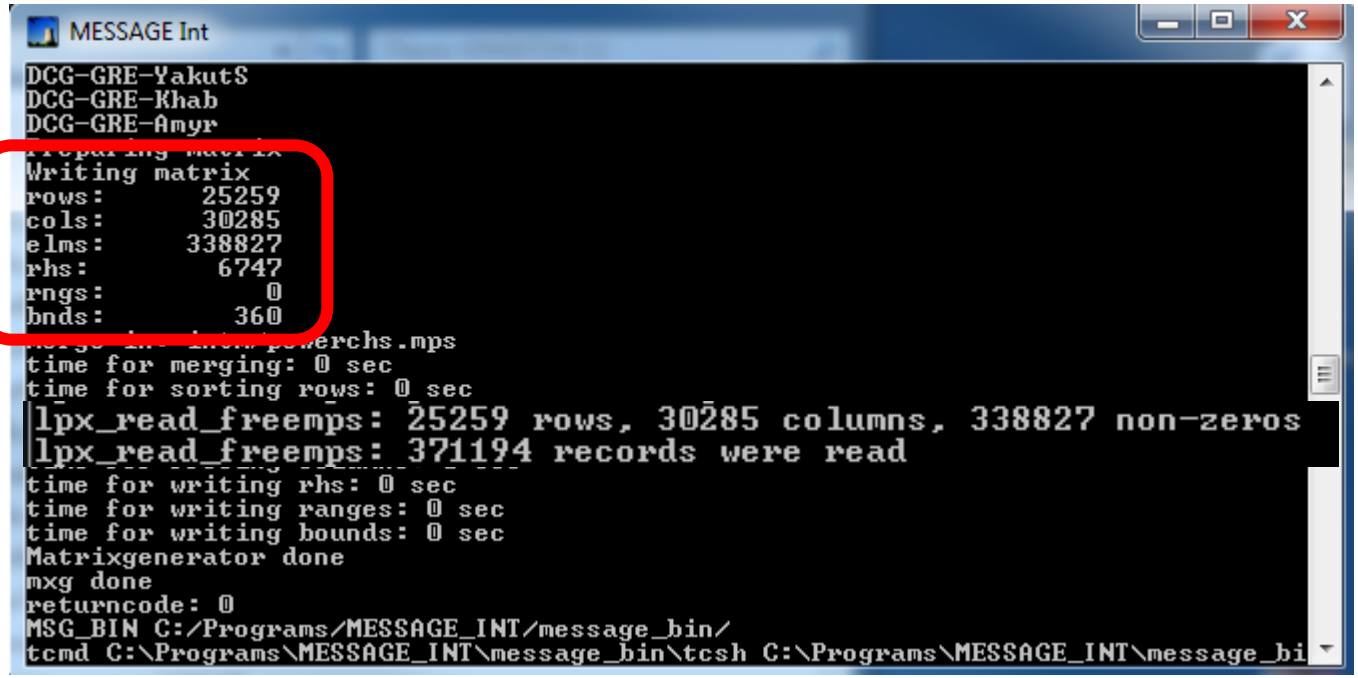
The IPS of the Far East of Russia - CHAIN



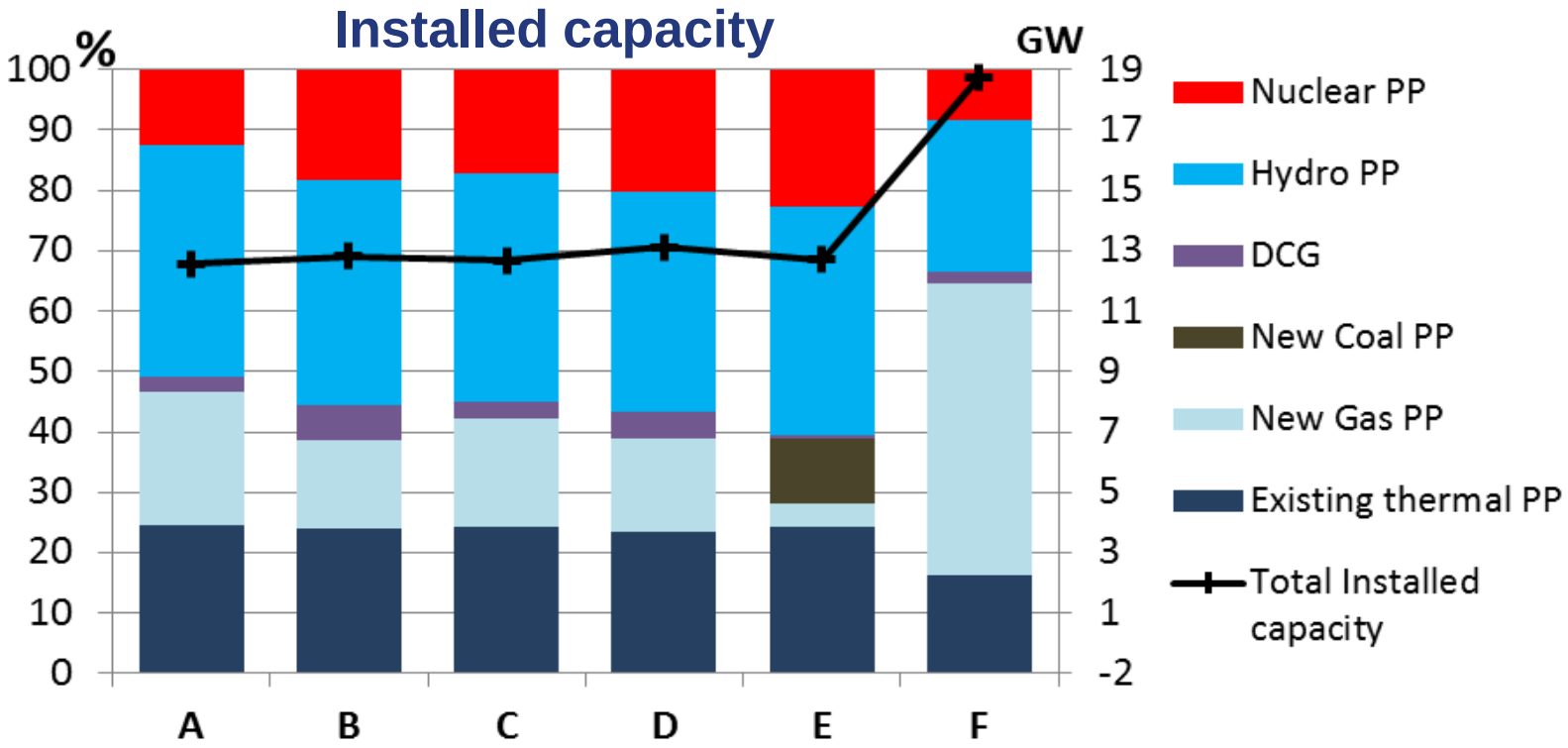


The combinations of uncertainty factors values

Factor	Cases					
	A	B	C	D	E	F
Discount rate, %	7,5	**5**	7,5	7,5	7,5	7,5
Carbon tax, $2018/t CO_2	-	-	**Min**	**Max (up to 2050)**	-	-
Fuel prices	Min	Min	Min	Min	**Max**	Min
Export	Min	Min	Min	Min	Min	**Max**

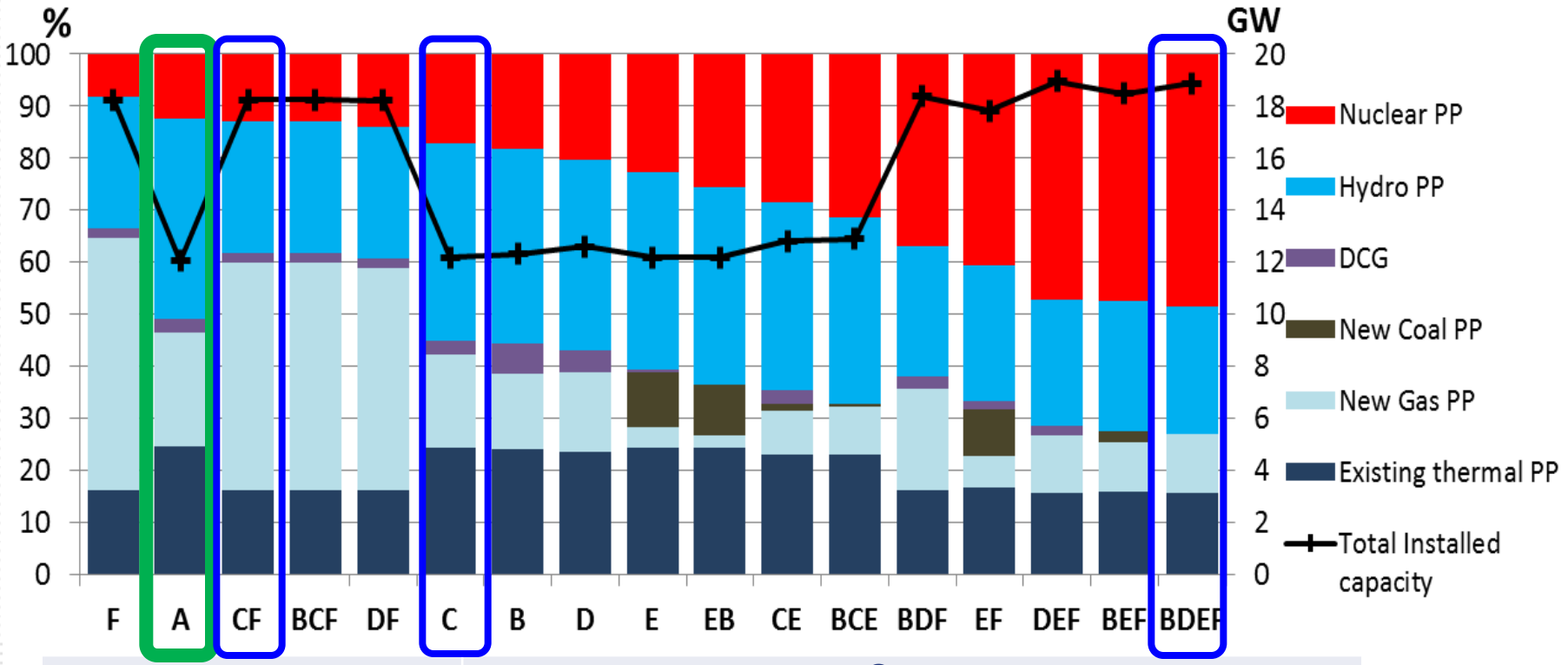


The analysis of each factor contribution (2040)



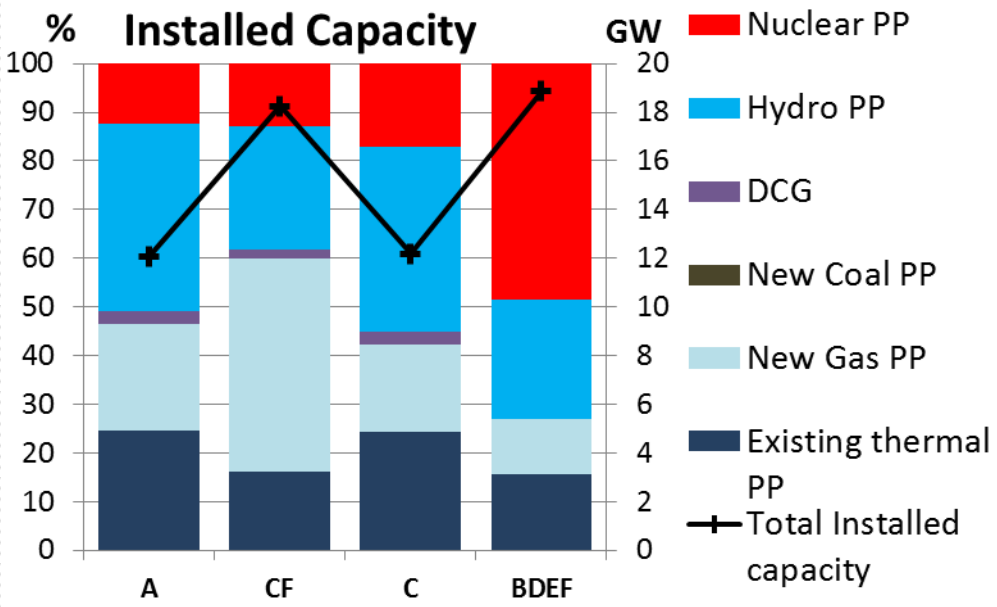
Factor	Cases					
	A	B	C	D	E	F
Discount rate, %	7,5	**5**	7,5	7,5	7,5	7,5
Carbon tax, $2018/t CO_2	-	-	**Min**	**Max (up to 2050)**	-	-
Fuel prices	Min	Min	Min	Min	**Max**	Min
Export	Min	Min	Min	Min	Min	**Max**

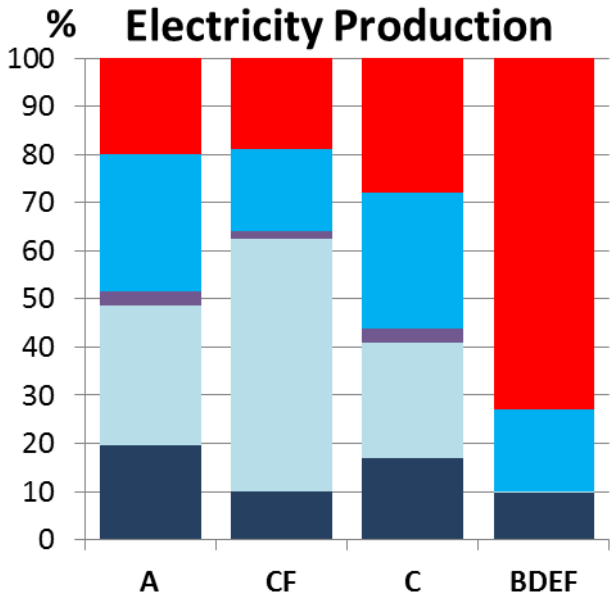
The analysis of possible Nuclear PP development scale (2040)



Factor	Cases					
	A	B	C	D	E	F
Discount rate, %	7,5	**5**	7,5	7,5	7,5	7,5
Carbon tax, $2018/t CO_2	-	-	**Min**	**Max (up to 2050)**	-	-
Fuel prices	Min	Min	Min	Min	**Max**	Min
Export	Min	Min	Min	Min	Min	**Max**

The results comparison (2040)



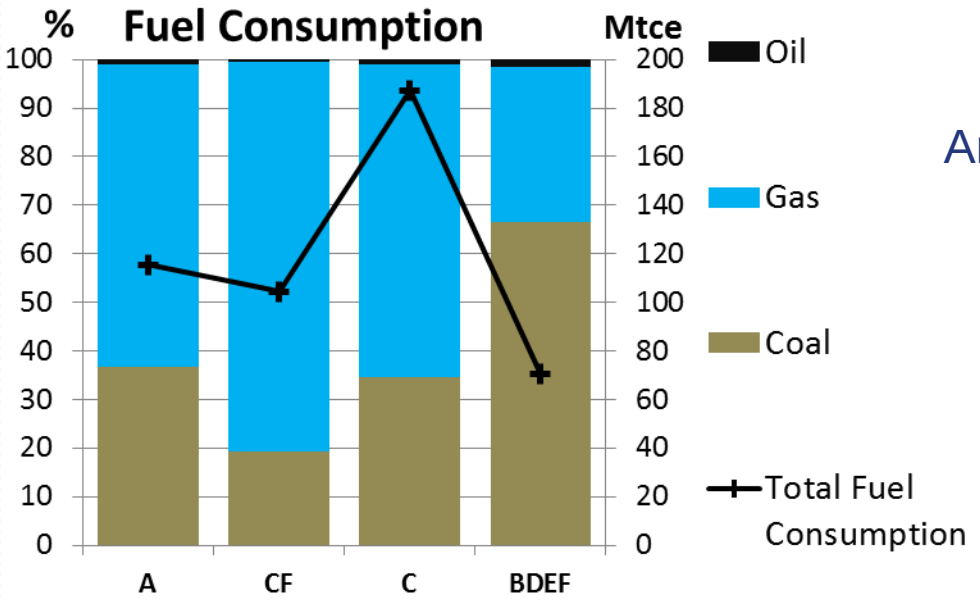


Total installed capacity of Nuclear PP, MW

	A	CF	C	BDEF
2035	1046	1520	1046	5487
2040	**1506**	**2365**	**2093**	**9162**
2045	2392	3379	3379	10270

Factor	Cases			
	A	C	CF	BDEF
Discount rate, %	7,5	7,5	7,5	5
Carbon tax, $2018/t CO_2	-	**Min**	**Min**	**Max (up to 2050)**
Fuel prices	Min	Min	Min	**Max**
Export	Min	Min	**Max**	**Max**

The results comparison (2040)



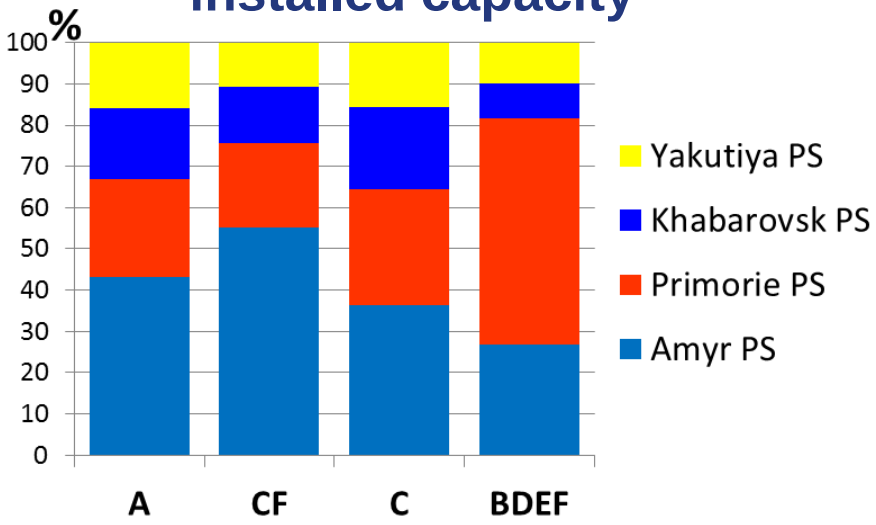
Annual emissions of CO2, mln tCO_2

A	23,5
CF	34,5
C	21,1
BDEF	16,7

Factor	Cases			
	A	C	CF	BDEF
Discount rate, %	7,5	7,5	7,5	5
Carbon tax, \$2018/t CO_2	-	**Min**	**Min**	**Max (up to 2050)**
Fuel prices	Min	Min	Min	**Max**
Export	Min	Min	**Max**	**Max**

The results comparison (2040)

Shares of regional PS in total installed capacity

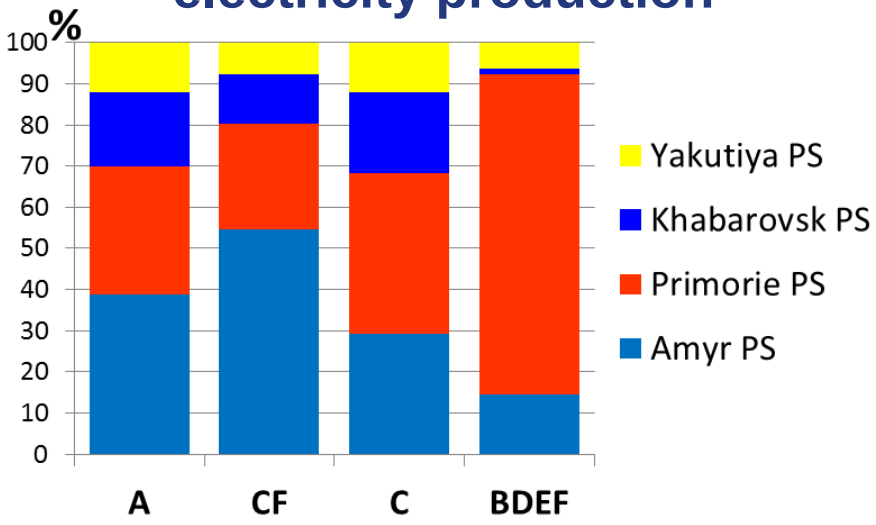


Installed capacity in 2017

	Amyr PS	Khabarovsk PS	Primorie PS	Yakutia (sum)
Total installed capacity, MW	**4166**	**2101**	**2617**	**2477**
Share, %	**36,7**	**18,5**	**23,0**	**21,8**

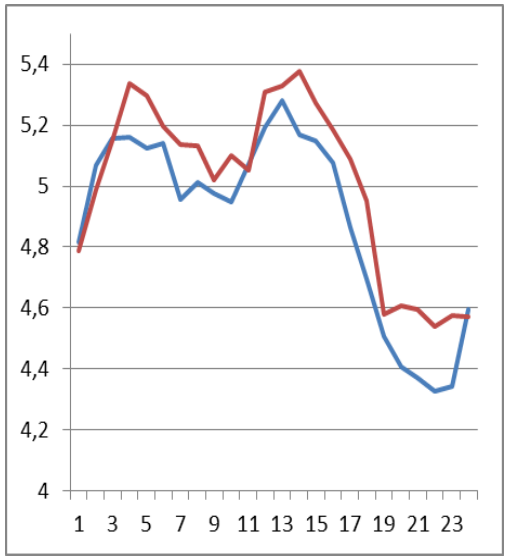
Factor	Cases			
	A	C	CF	BDEF
Discount rate, %	7,5	7,5	7,5	5
Carbon tax, $2018/t CO_2	-	**Min**	**Min**	**Max (up to 2050)**
Fuel prices	Min	Min	Min	**Max**
Export	Min	Min	**Max**	**Max**

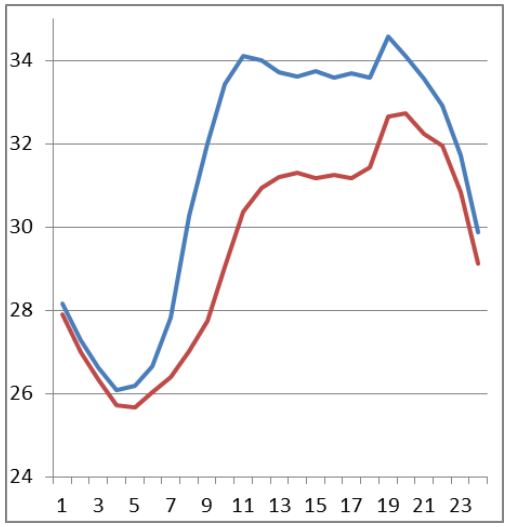
Shares of regional PS in electricity production



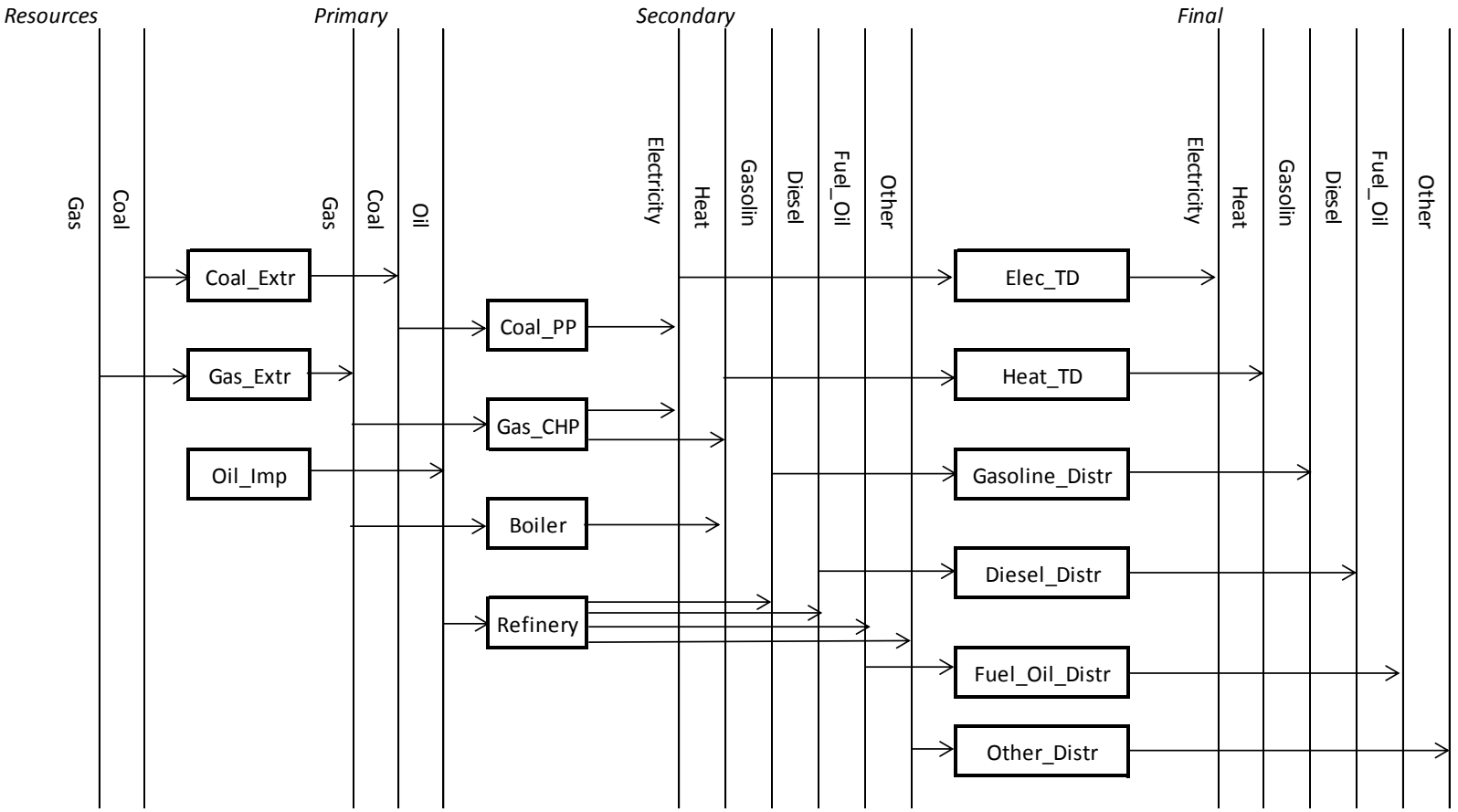
Problems with modeling

1. Holidays. No opportunity to introduce real schedule.
2. Unable to sort technologies by input and output after copying the scenario.
3. Randomly resets values of Load regions and curves to default.
4. How to set capacity reserve requirement correctly, taking into account transmission limits (capacity flows).





Students and MESSAGE - Case



All students have remote access to MESSAGE

Students and MESSAGE
Problems and Success

The main types of mistakes:

1. **Load regions ⇔ Load curves**
2. **Variable ⇔ Fix Costs**
3. **Types of data set (cg, ts)**
4. **Operation time**

18 students in group

10 students try to do their best in MESSAGE

2 students completed the case without mistakes

6 students have 4-6 minor mistakes

2 students have 1-2 serious mistakes and 4-5 minor mistakes

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Thank for your attention!