

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	221
Russian Federation	171
Australia	161
Indonesia	151
Rest of the world	1 341
World	9 561

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 China	170

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

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

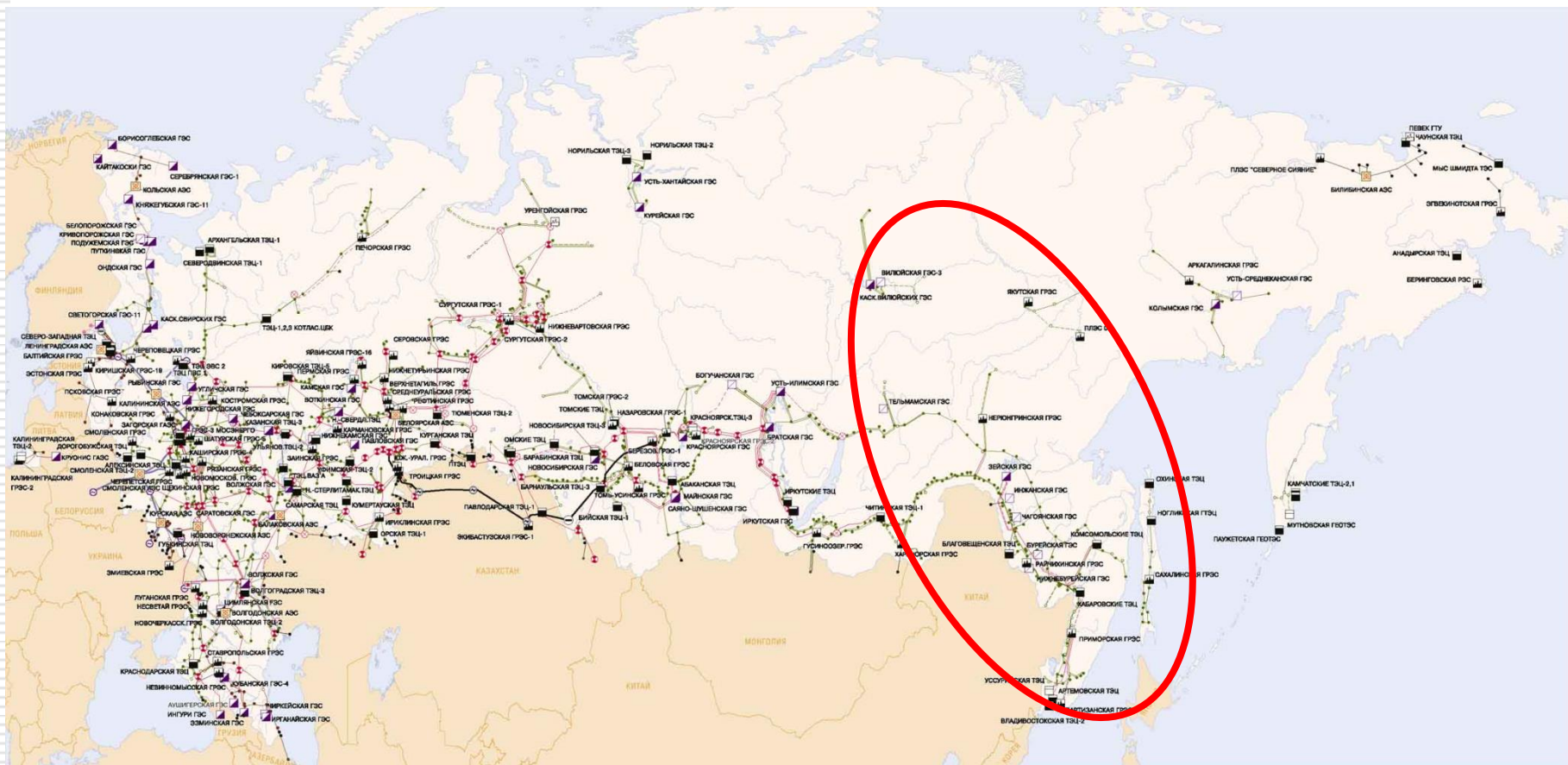
IEA, Key world Energy statistics, 2018

The UPS of Russia

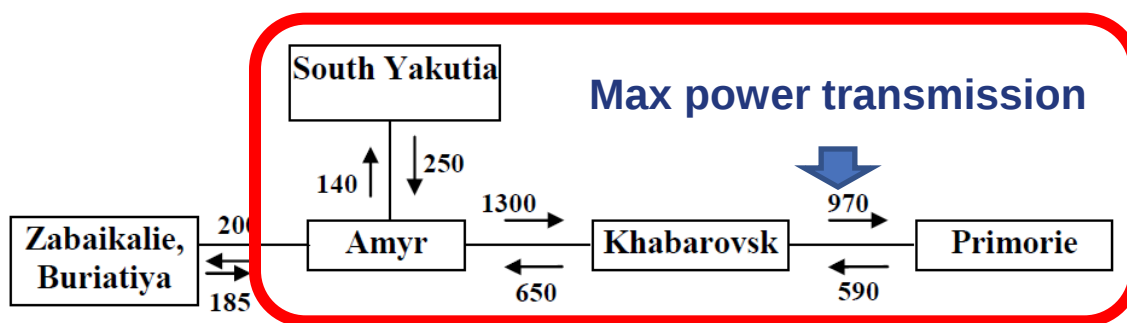
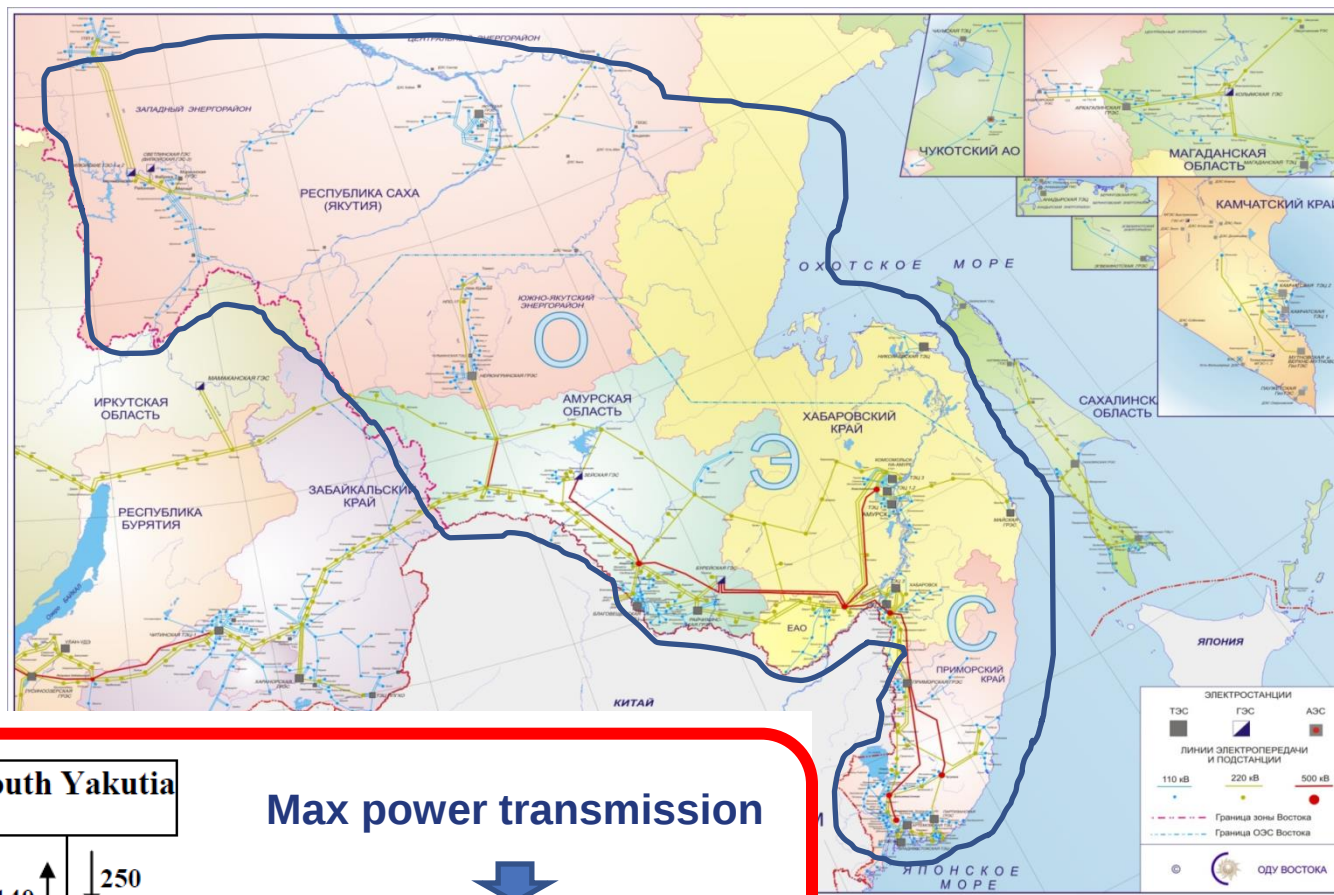


The Unified Power System (UPS) of Russia includes 7 Integrated Power Systems (IPS) and decentralized and isolated regions

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	-	

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

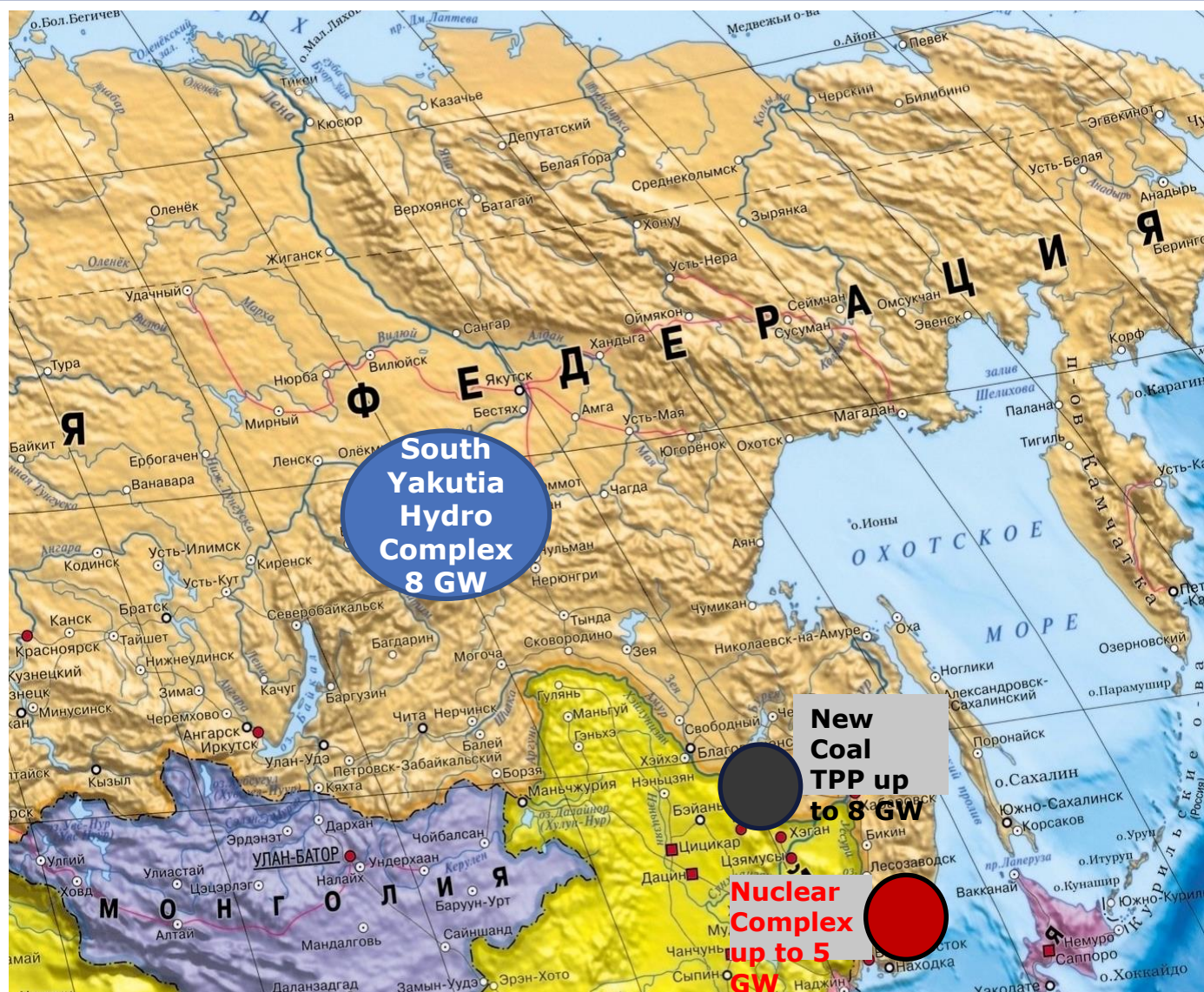
Key figures of electricity production in 2017, bln kWh

	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	-	

Total Installed Capacity (2017)

	The IPS of the Far East	Amur 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

CO₂ tax, \$/tCO₂

	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

Technologies

input:
output:
relations:
name (re):

Technologies

input:
output:
relations:
name (re):

has inv ☒ all ☐ yes ☐ no
operator ☒ and ☐ or
technologies: Chain
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Activity

Capacity

activities

Add Ins Del Rename Re
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single entries
Name
main input
main output
var costs
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Activity

Capacity

ZeiskayaGES

single entries

name id fixed ☐ yes ☒ no altern. op.
capacity unit rehab for:
first year last year
Unit Switch Time series Unit Switch Time series
plant factor c 1 operation time c 1
minutil
plant life c 100 unit size
investment cost 7% IAEA - MESSAGE Int_V2 ZeiskayaGES bounds bdc
fixed costs Screen Edit
hist. cap.
min. power
multiple entrie
bdc
consc
comm
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good
mpc

The features of Nuclear PP modeling

Technologies

input: has inv ☒ all ☐ yes ☐ no

output:

relations:

name (re):

Activity:

Capacity:

NuclearPrim

single entries

name: id: fixed: ☐ yes ☒ no

capacity unit: rehab for:

first year: last year:

	Unit	Switch	Time series	Unit	Sw
plant factor	share	c	1	operation time	share
minutil					
plant life	yr	c	60	unit size	
investment cost	US\$100/kW	c	1694	constr. time	yr
fixed costs	US\$100/kW/yr	c	31		
hist. cap.					
min. power					

multiple entr

bdc

consc

IAEA - MESSAGE Int_V2 NuclearPrim bounds bdc

Screen Edit

Bounds on new capacity addition

Type	Unit	Tmssw	Data
up	MW	ts	000000000001000000

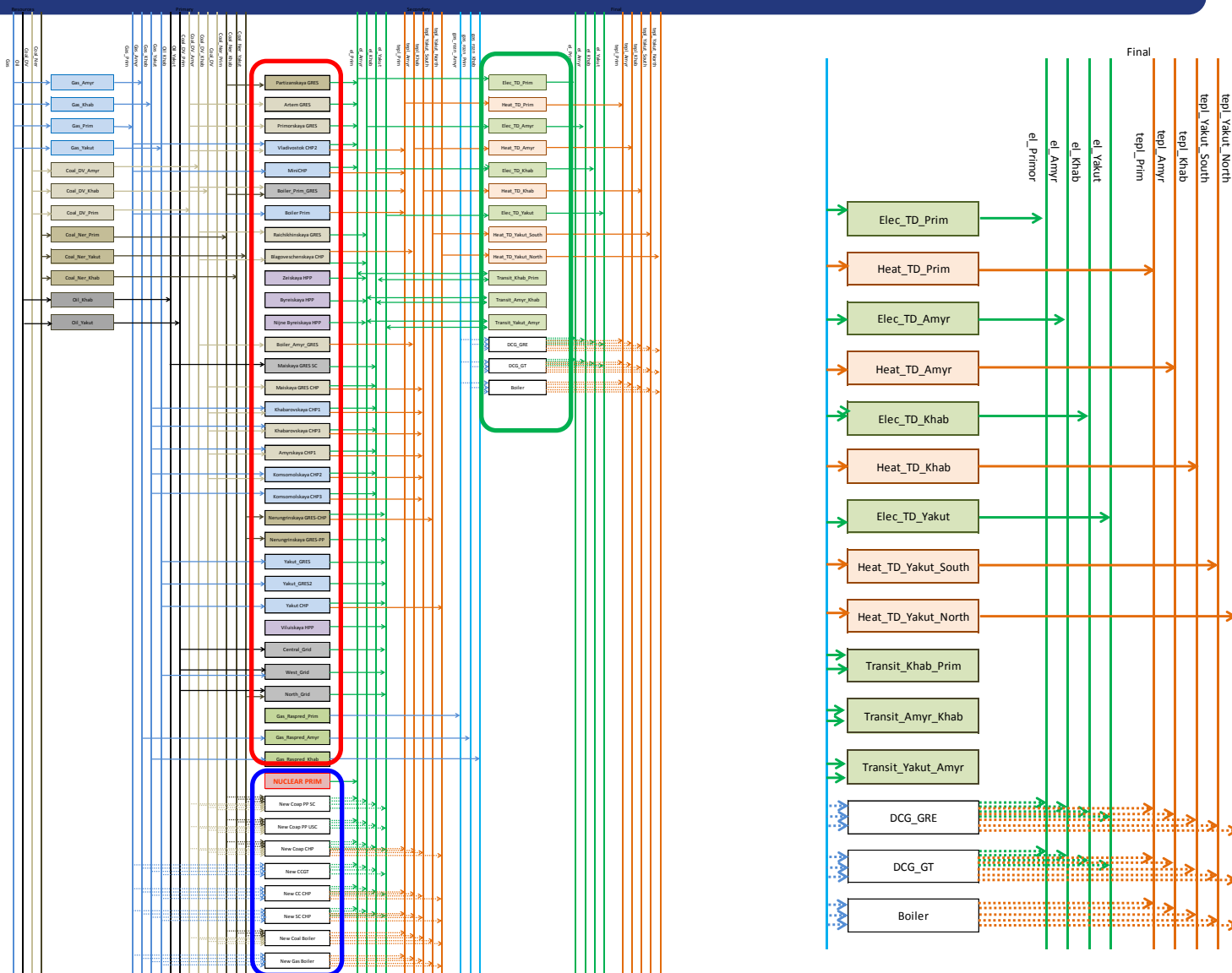
7% Ed... - x

tms sw: unit:

2015	0
2016	0
2017	0
2018	0
2019	0
2020	0
2021	0
2022	0
2023	0
2024	0
2025	0
2030	1000000
2035	1000000
2040	1000000
2045	1000000
2050	1000000

consa diff inp mpa outp softlms

The IPS of the Far East of Russia - CHAIN



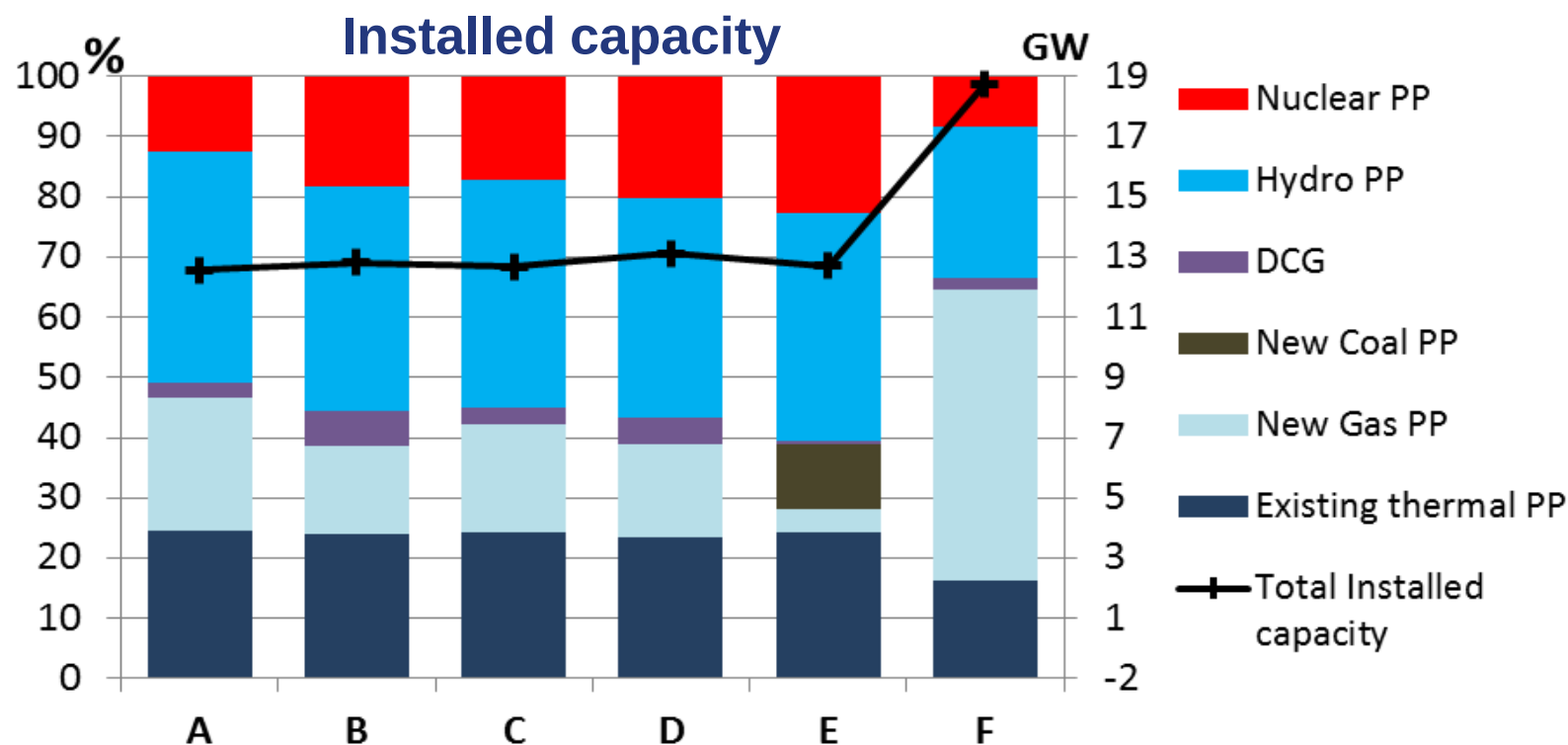
The combinations of uncertainty factors values

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

```

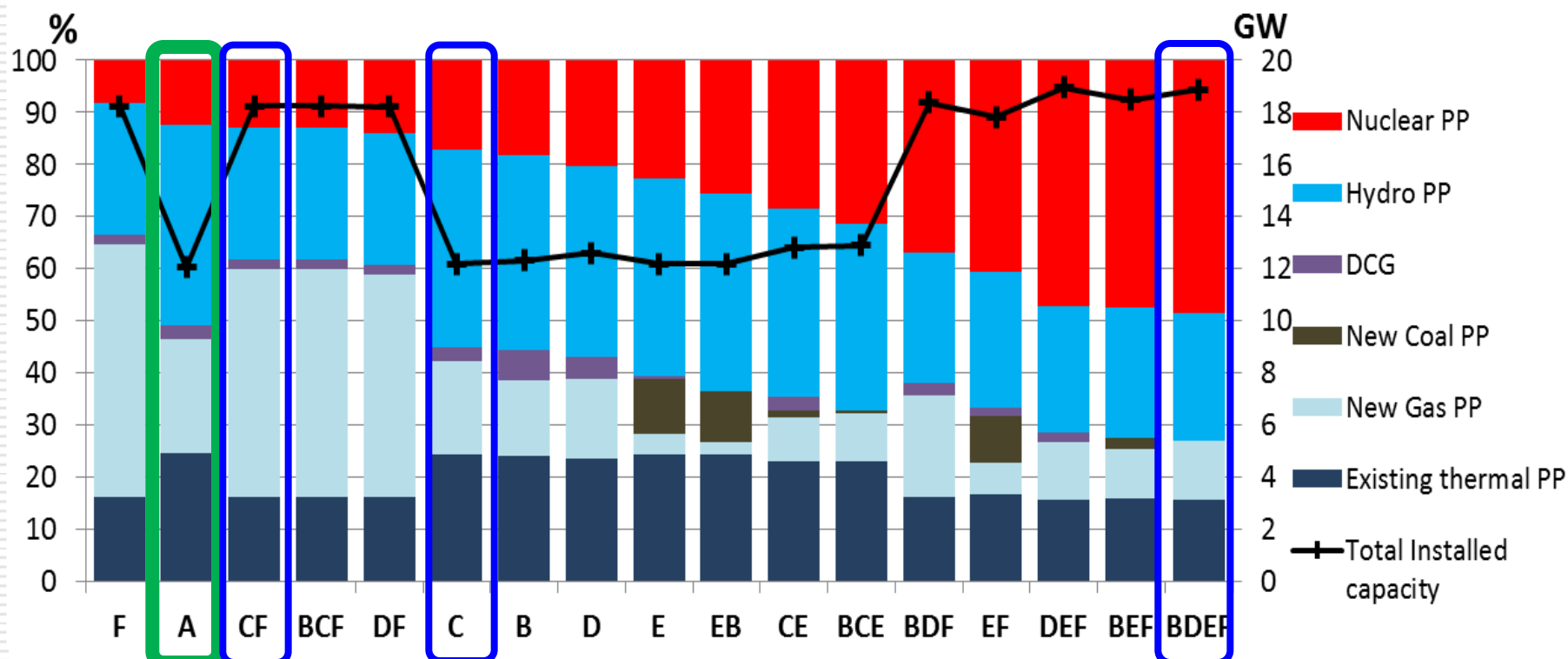
MESSAGE Int
DCG-GRE-YakutS
DCG-GRE-Khab
DCG-GRE-Amyr
Preparing matrix
Writing matrix
rows:      25259
cols:      30285
elms:      338827
rhs:        6747
rngs:        0
bnds:       360
Merge into powers.mps
time for merging: 0 sec
time for sorting rows: 0 sec
lpx_read_freemps: 25259 rows, 30285 columns, 338827 non-zeros
lpx_read_freemps: 371194 records were read
time for writing rhs: 0 sec
time for writing ranges: 0 sec
time for writing bounds: 0 sec
Matrixgenerator done
mxg done
returncode: 0
MSG_BIN C:/Programs/MESSAGE_INT/message_bin/
tcmd C:\Programs\MESSAGE_INT\message_bin\tcsh C:\Programs\MESSAGE_INT\message_bi
  
```

The analysis of each factor contribution (2040)



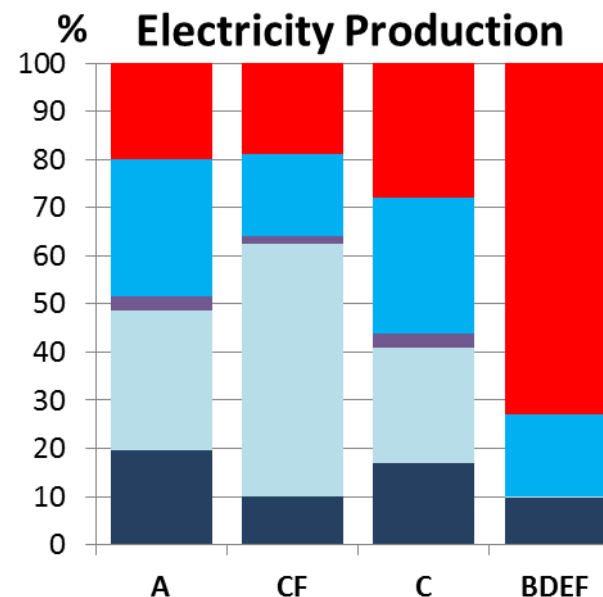
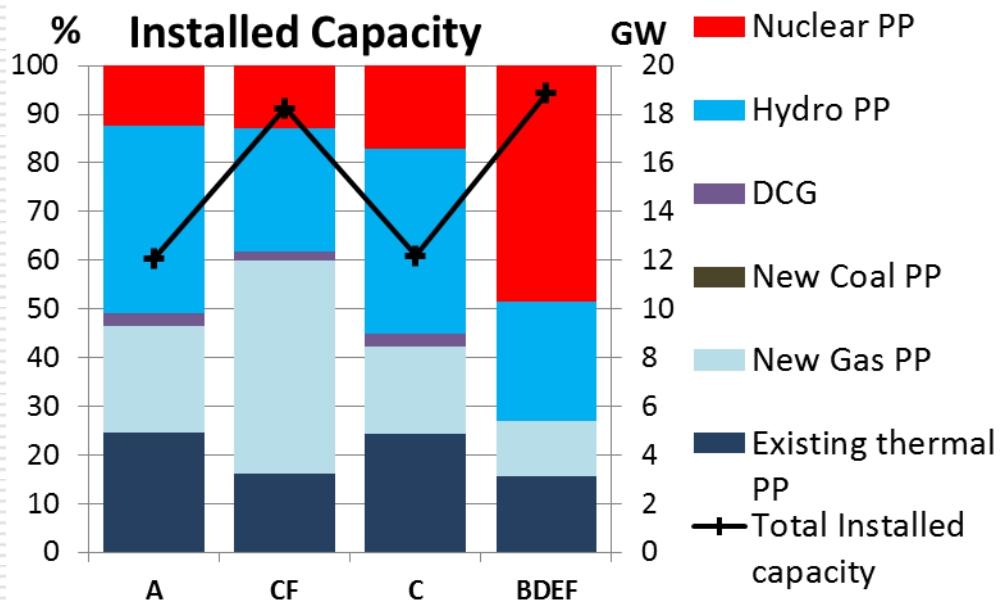
Factor	Cases					
	A	B	C	D	E	F
Discount rate, %	7,5	5	7,5	7,5	7,5	7,5
Carbon tax, \$2018/t CO ₂	-	-	Min	Max (up to 2050)	-	-
Fuel prices	Min	Min	Min	Min	Max	Min
Export	Min	Min	Min	Min	Min	Max

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)

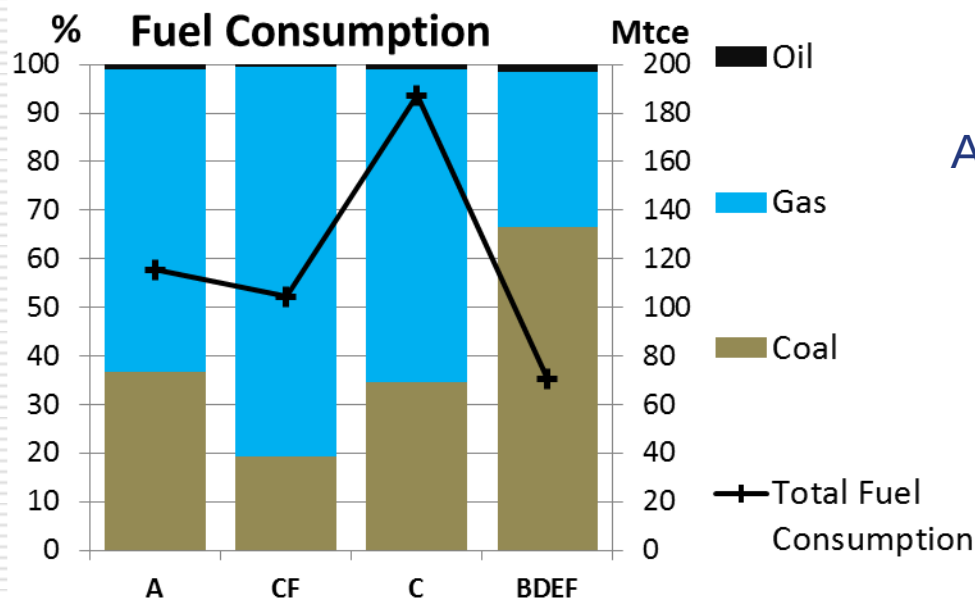


Total installed capacity of Nuclear PP, MW

	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)



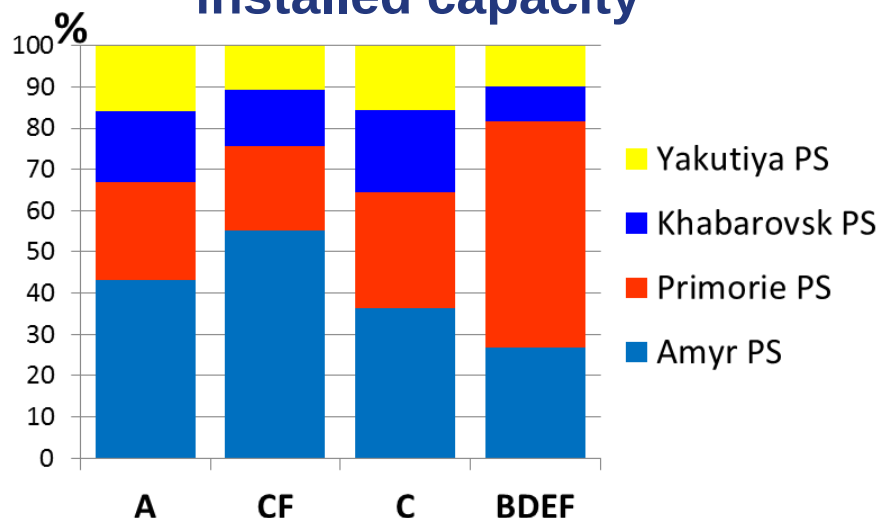
Annual emissions of CO₂, mln tCO₂

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)

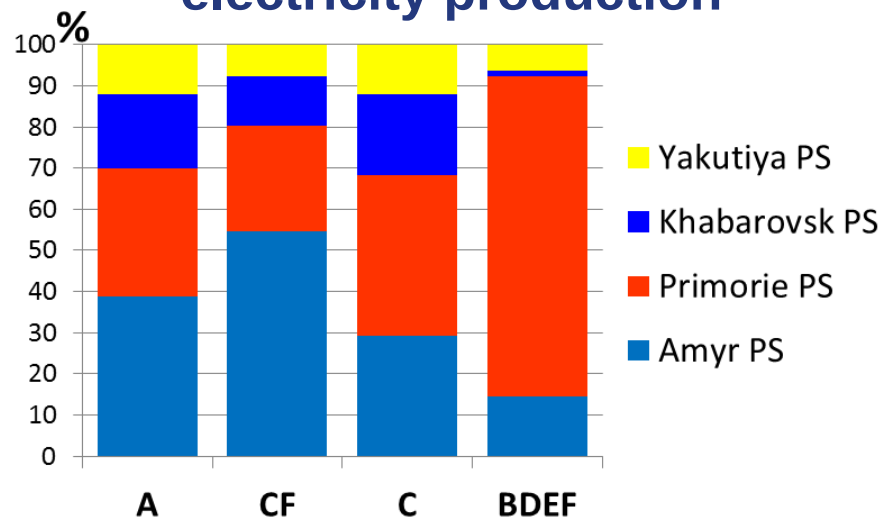
Shares of regional PS in total installed capacity



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

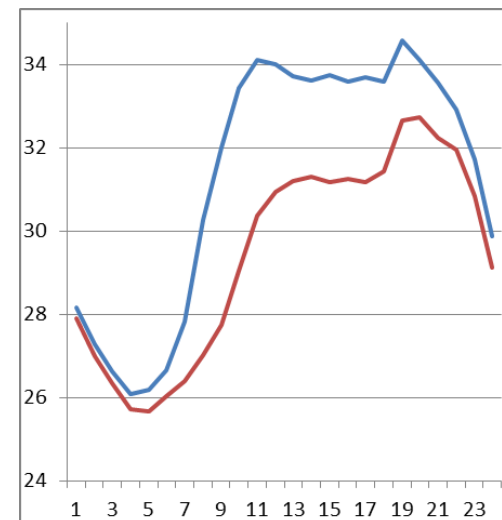
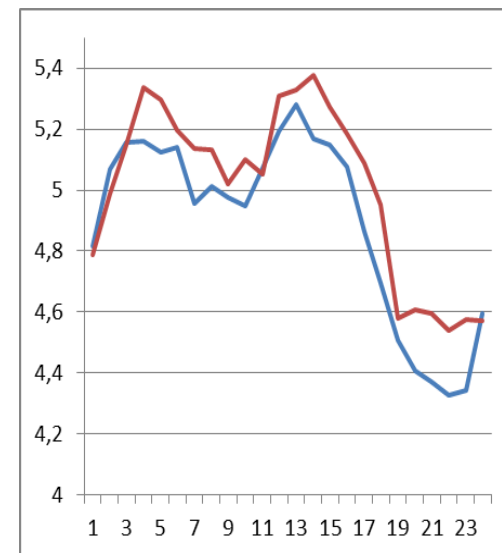
Shares of regional PS in electricity production



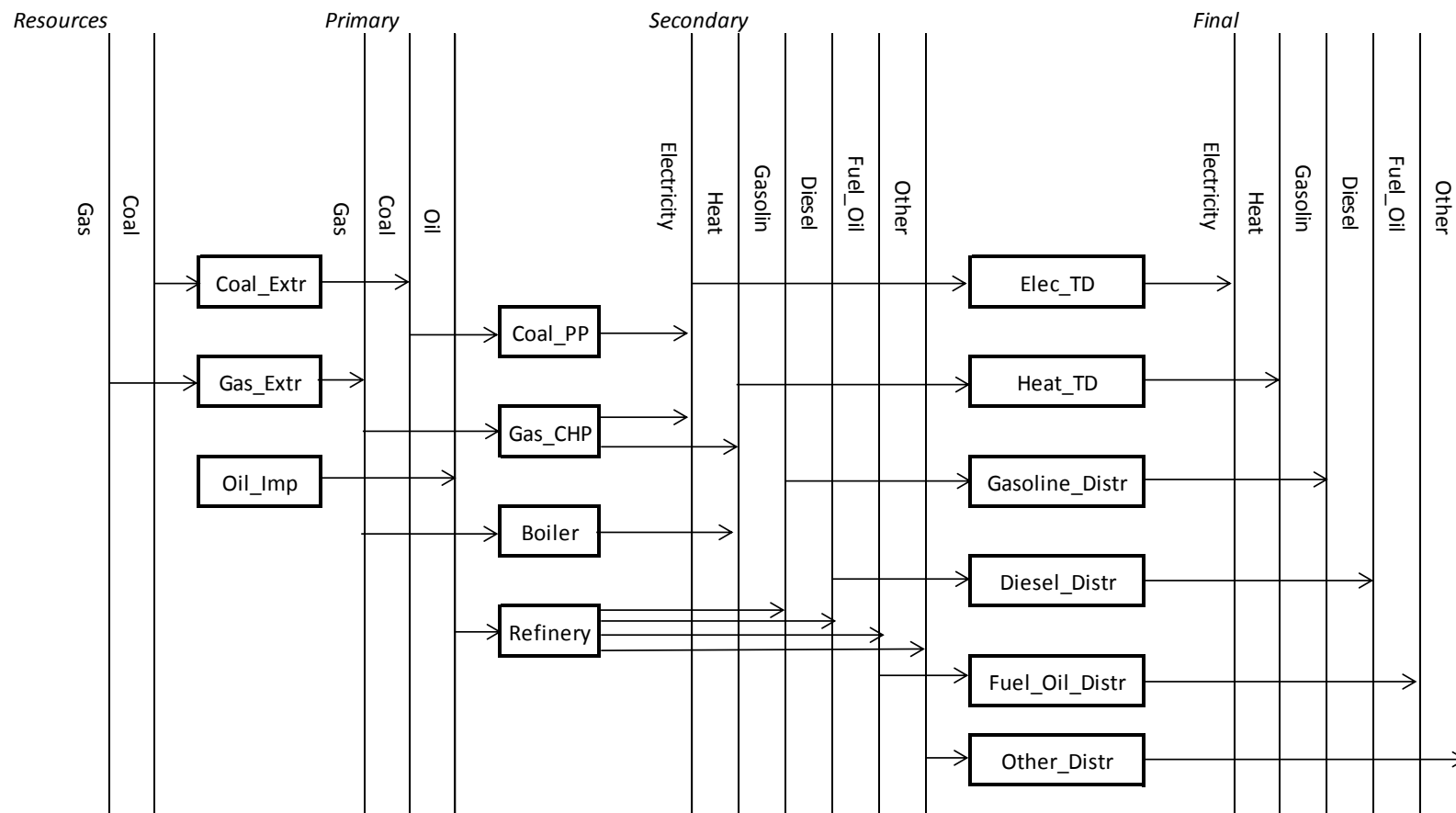
Factor	Cases			
	A	C	CF	BDE F
Discount rate, %	7,5	7,5	7,5	5
Carbon tax, \$2018/t CO ₂	-	Min	Min	Max (up to 2050)
Fuel prices	Min	Min	Min	Max
Export	Min	Min	Max	Max

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 $\Leftrightarrow$ Load curves
2. Variable $\Leftrightarrow$ 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

6 students have 4-6 minor mistakes

2 students completed the case without mistakes

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



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Thank for your attention!