CLIMATE CHANGE IMPACTS ON THE ENERGY SYSTEM UNDER THE FOSSIL FUEL CURSE

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BACKGROUND

Technical physics + data science

**Area of interest:** research of power and heat supply technologies [transfer processes in a solid oxide fuel cell, thermal modelling of (SOFC + thermal power) units]

**Subject of the study:** national energy system under the climate change
MOTIVATION

1. **Adaptation knowledge** is still limited
2. Energy transformation processes are quite **long-termed**
3. **Need for renovations/innovations** in power industry is evident
4. Trying to get advantages of a **traditional system approach**

Is there a way to put decarbonising steps among adaptation measures?
PROBLEMS CONSIDERED

1. Heating/cooling demand
2. Thermal efficiency deterioration
3. Renewables potential
4. Cogeneration
5. Electricity load
6. Reliability assessment
7. Renewables integration

Integral effects
“Typical-day” effects
Operating mode effects
INTEGRAL EFFECTS

1. Heating/cooling demand
2. Thermal efficiency deterioration
3. Renewables potential

Effect of the climate change on

- the national energy balance
- an overall renewables potential
INTEGRAL EFFECTS-1

1. Heating/cooling demand
2. Thermal efficiency deterioration

Climate modelling

Carbon box model + Regression model

*Comparison with General Climate Models projections (CMIP5 simulations data, RCP2.6 & RCP4.5 scenarios)
The most recent Assessment Report of the Russian Meteorological Institute has stated the importance of the climate-related impacts of climate change. However, the study was restricted to the climate change itself and did not analyze a deterioration of thermal generation efficiency under the climate change, but a quantitative estimation of the climate change impacts was beyond the scope of the analysis. An attempt to incorporate regional climate change into the energy sector was presented, but the scope of this work is rather the climate change itself.

Projected trends of the mean annual temperatures in various Russian regions in the first half of the twenty-first century were presented. The temperature increases were significant during the twentieth and first half of the twenty-first centuries, and the warming trends were found to be slightly positive for Siberian hydropower stations. Climate change was done in effect was found to be slightly positive for Siberian hydropower stations. Climate change was done in effect was found to be slightly positive for Siberian hydropower stations. Climate change was done in effect was found to be slightly positive for Siberian hydropower stations.

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![Temperature anomalies](image)

- North-West
- Center
- Volga
- South
- Urals
- Siberia
- Far East

Temperature anomalies, °C

1960 1980 2000 2020 2040
Energy modelling

- Heating/cooling **degrees-days** concept

Integral of the heat/cold deficit throughout the year
Energy modelling

- Heating/cooling degrees-days concept
- Technical characteristics of industrial gas turbines

![Graph showing the efficiency of different gas turbines as a function of air temperature.](image)
Energy modelling

- Heating/cooling degrees-days concept
- Technical characteristics of industrial gas turbines
- Implementation of the condenser model* representing two-phase heat transfer in the steam power unit circuit

*Available via github: @ekatef energy-VulnPowInd
Heating demand has decreased significantly

Rather minor effect on the annual cooling demand.

Steam turbines are impacted noticeably

Power drop of the steam turbines operating on thermal power plants to 2050
Renewables potential (hydropower and wind)

Assess the *sign* and an *order of magnitude* of the climate change impact

Energy modelling

Technical characteristics of industrial power plants
Renewables potential (hydropower and wind)

Assess the sign and an order of magnitude of the climate change impact

Climate modelling

Ensemble estimations based on the General Climate Models projections (CMIP5 simulations data, RCP2.6 & RCP4.5 scenarios)

+ Models discrimination
Projections of the relative change of the annual average wind speed to 2050 (optimistic climate scenario RCP2.6)
Projections of the relative change of the annual precipitation amount to 2050 (optimistic climate scenario RCP2.6)
Some increase in runoff and improve conditions of the hydropower operation across Russia is likely, except for the most southern regions.

A tendency to wind speed decrease in the European part of the country and in the southern part of West Siberia may be concluded with a certain confidence. The robust finding for the wind speed is the increasing trend in Primorye region.
INTEGRAL EFFECTS: SUMMARY

- The power drop of the steam turbines* and gas turbines** is quite noticeable.
- A space heating demand decrease clearly dominates the climate change impact of the national energy balance.
- The climate change seem to be quite safe in terms of an impact on the renewable potential.

* 0.2..0.3 and 0.4..0.6 percent points per 1°C for the thermal and nuclear power plants respectively.
** 0.1 percent points per 1°C.
“TYPICAL-DAY” EFFECTS

1. Cogeneration
2. Electricity load

What adaptation challenges are the “united” power systems likely to face?
“TYPICAL-DAY” EFFECTS-1

Cogeneration

Centralised structure of the power systems

Focus on the stations observation records

Climate modelling

Assessment of the probability distribution functions for the past

Morphing approach for the future
Cogeneration

Cluster groups

1
2
3
4
5
6
7
Energy modelling

Engineering-level model of the thermal power plant

- Heat and mass transfer
- Design of the plant elements
- Technical characteristics of the real power equipment
Cogeneration

Decrease of the heating demand means a considerable CHPs’ efficiency drop

CHPs’ efficiency drop per 1°C annual warming
“TYPICAL-DAY” EFFECTS–2

Electricity load

Mean 10-years ($T_m$) and threshold ($T_h$) daily ambient air temperature of the warm period

<table>
<thead>
<tr>
<th>Power system</th>
<th>$T_m$, deg. C</th>
<th>$T_h$, deg. C</th>
<th>Years used in $T_h$ estimation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noth-West</td>
<td>13.9</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Center</td>
<td>18.1</td>
<td>20</td>
<td>2010, 2013, 2016, 2018</td>
</tr>
<tr>
<td>South</td>
<td>23.6</td>
<td>20</td>
<td>2009-2018</td>
</tr>
<tr>
<td>Urals</td>
<td>18.5</td>
<td>22</td>
<td>2012, 2015, 2016</td>
</tr>
<tr>
<td>Siberia</td>
<td>15.8</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>East</td>
<td>15.5</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

Dependence of the electricity demand on the daily ambient air temperature in the South energy system (5-days moving average filter applied)
"TYPICAL-DAY" EFFECTS-2

Electricity load

The annual profiles of the dimensionless diurnal electricity demand amplitude
Electricity load

The dimensionless diurnal electricity demand amplitude across the national power systems in 2002-2018.
“TYPICAL-DAY” EFFECTS-2

Electricity load

➤ Electricity load patterns are changing both on the large (annual) and short (daily) time scales

➤ A part of these changes is very likely associated with the climate change
“TYPICAL-DAY” EFFECTS: SUMMARY

➢ Winter climate change is still resulting in an efficiency decrease of the cogeneration use

➢ Summer changes might result in reliability problems

Energy systems modelling is needed urgently
OPERATING MODE EFFECTS

1. Electricity load
2. Reliability assessment
3. Renewables integration

Climate modelling

Gridded datasets of good quality are essential

Energy modelling

Energy system models
THANK YOU FOR YOUR ATTENTION!

Any questions?

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