PETER THE GREAT ST. PETERSBURG POLYTECHNIC UNIVERSITY

Research and Education Center

«RENEWABLE ENERGY TECHNOLOGIES»

DESIGN OF HIGH-PENETRATION WIND DIESEL POWER PLANTS FOR REMOTE VILLAGES IN THE NORTHERN REGIONS

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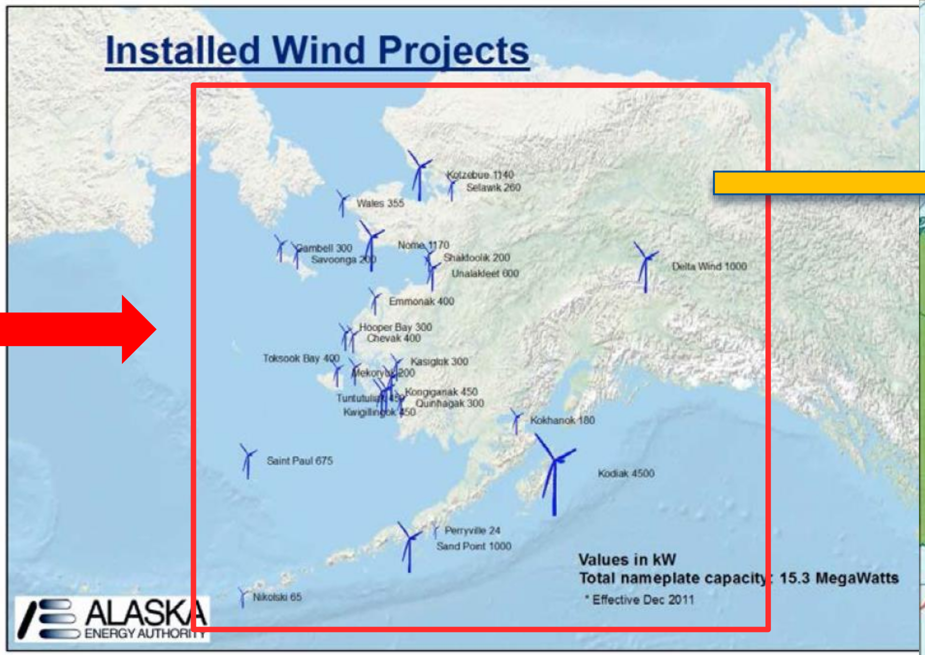
Winterwind 2017, Skellefteå
Sweden, 2017

World experience of stand-alone wind-diesel hybrid systems operating

Alyaska, USA
Total capacity 15,3 MW

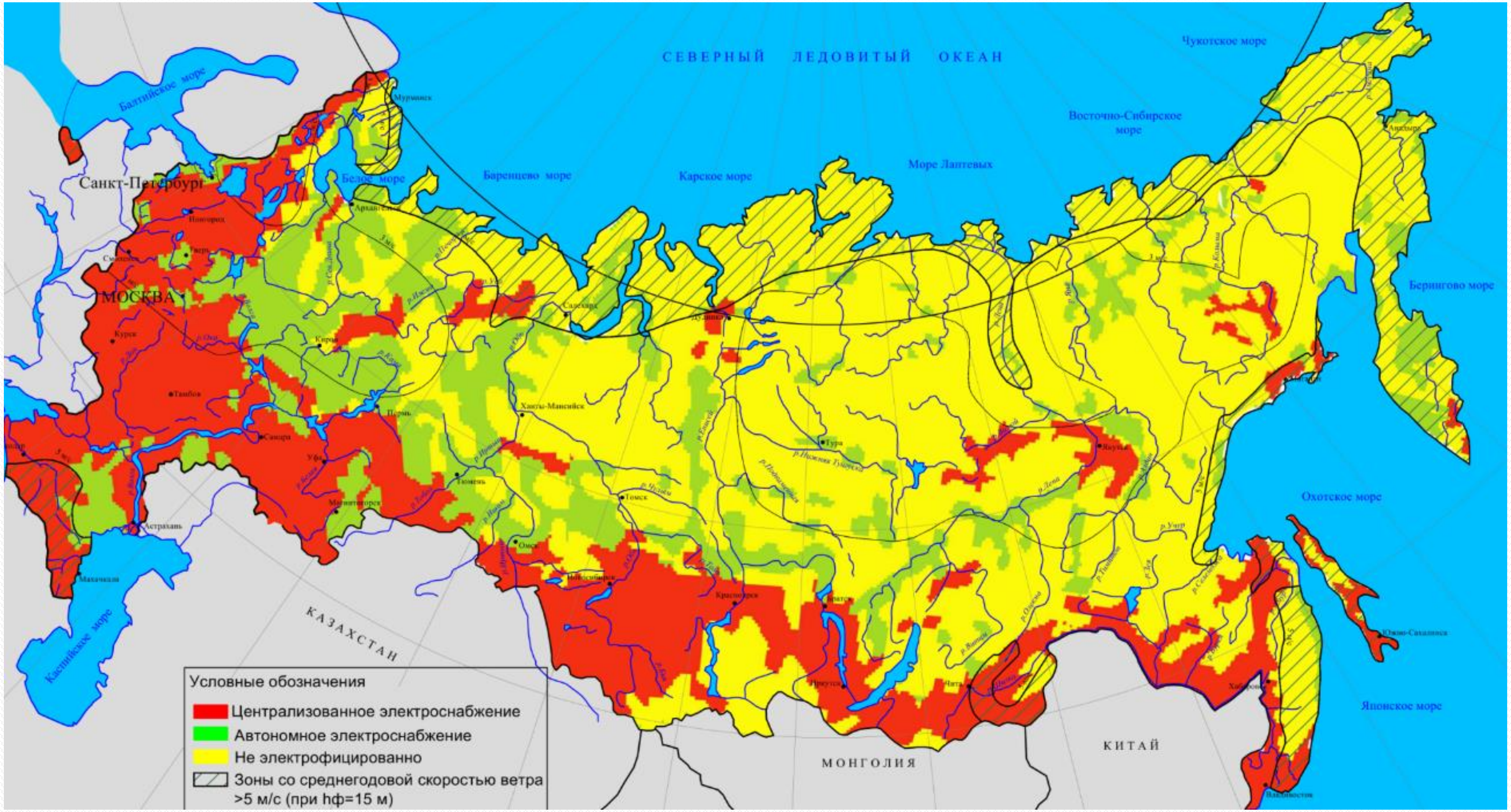


Environmental effect that system

Russia
Estimated capacity 1,5 GW

Characteristics of remote consumption

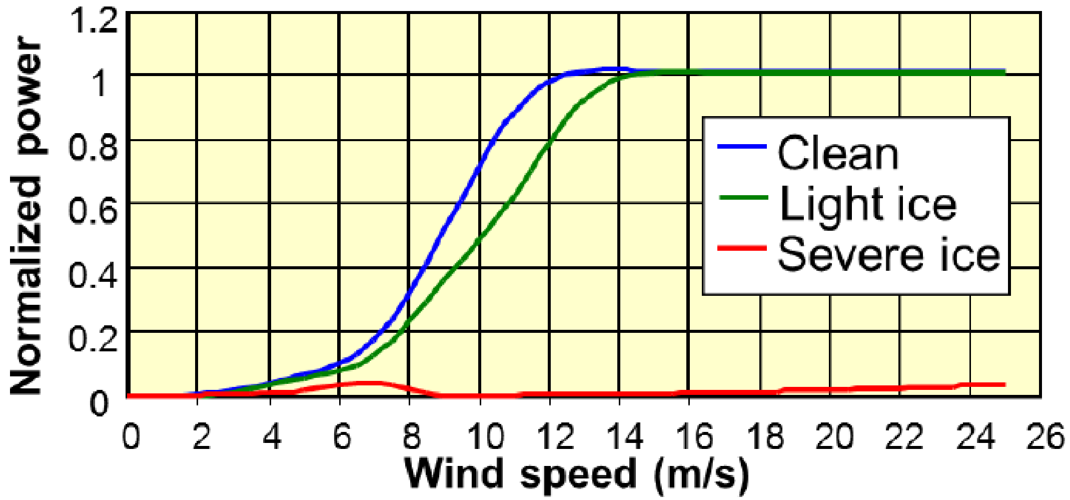
Diesel power plants (DPPs), consisting of one or more diesel generator sets (DGSs). The number of DGSs working in that isolated areas of energy supply in Russia is about 50’000 with total capacity of more than 500’000 kW; DPP produce about 2.5 billion kWh, which requires the consumption of approximately 1 million tons of diesel fuel per year.



Difficulties arising from the wind turbines in harsh environments

Negative effects from the wind turbines in harsh environments:

- Icing surface and wind turbine components.
- Changes in physical properties of materials under the influence of low temperatures.
- Moisture in the power equipment, which leads to short circuits.
- Thawing of permafrost soil and destruction due to high loads.



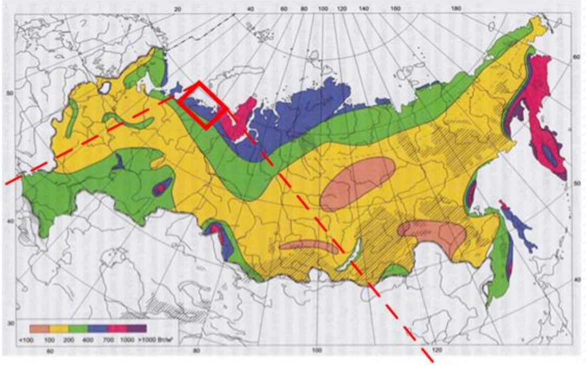
Methodology for optimization of the autonomous system based on renewable energy sources in the harsh climatic conditions

Block 1. Analysis and preparation of data	- Resources evaluation - Site Selection	Prepared level
Block 2. Selection of the equipment	- Adapted wind turbines - Storage system	Optimization level
Block 3. Calculation modes	- Imitation of models - Transient modes	Calculation level
Block 4. Efficiency evaluation	- Cost estimate - LCOE	Efficiency level

Assessment of wind energy resources in case of insufficient climate information

Level 1. Large-scale

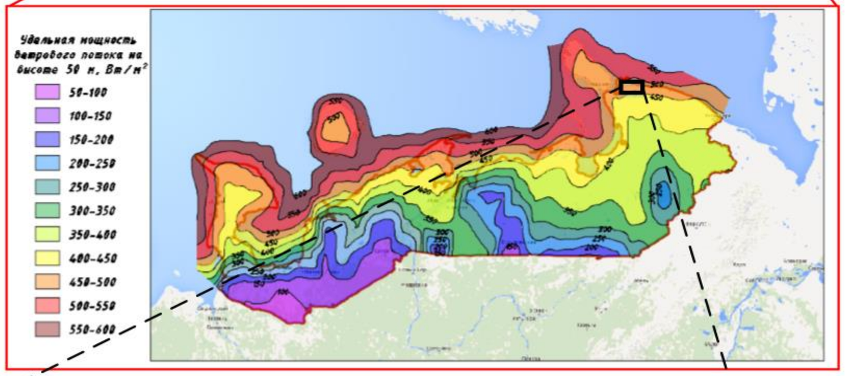
Крупномасштабная оценка ВЭР 1



Integrated and generalized assessment of resources in the region.

Level 2. Meso-scale

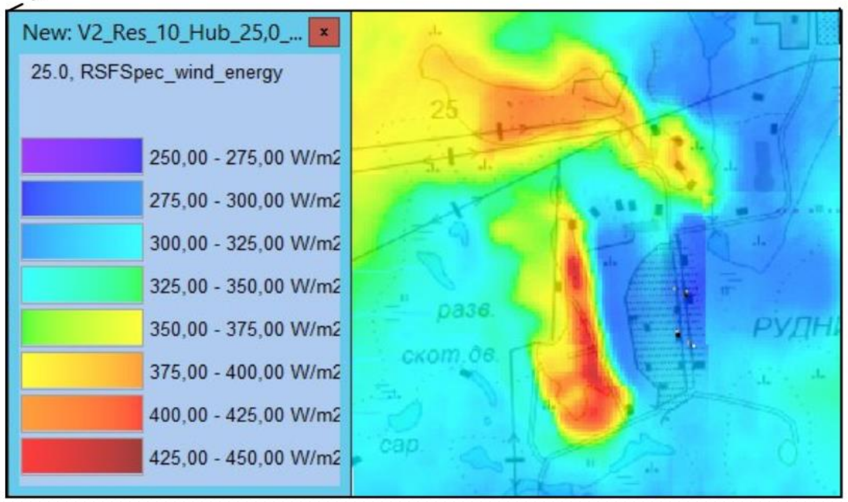
Мезомасштабная оценка ВЭР 2



Numerical simulations of the wind flow at an arbitrary height above ground level (satellite data).
Reliability - 85-90%.

Level 3. Micro-scale

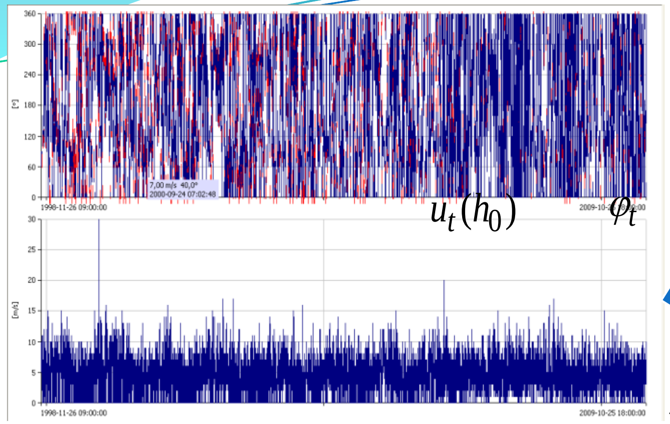
Микромасштабная оценка ВЭР 3



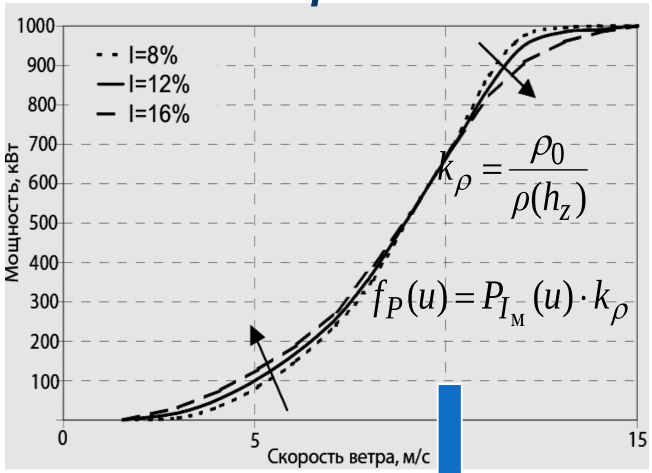
Using of reanalysis data from MERRA databases, CFSR, satellite observations NCAR / NCEP in thesoftware (WindPRO).
Reliability - 90-95%

Mathematical model of wind turbine

Wind conditions

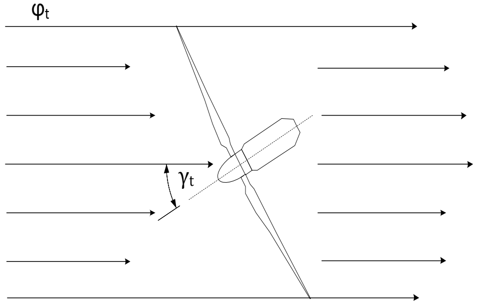


Wind turbine power curve



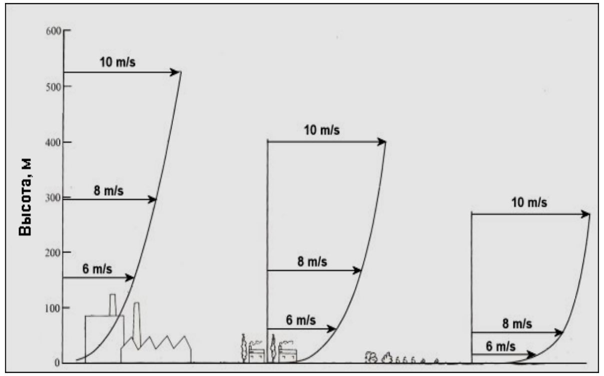
Losses at orientation

$$k_П = \frac{\cos(\gamma_t)}{2} \cdot \frac{\gamma_t}{\Delta t_{изм} \cdot T_Г}$$



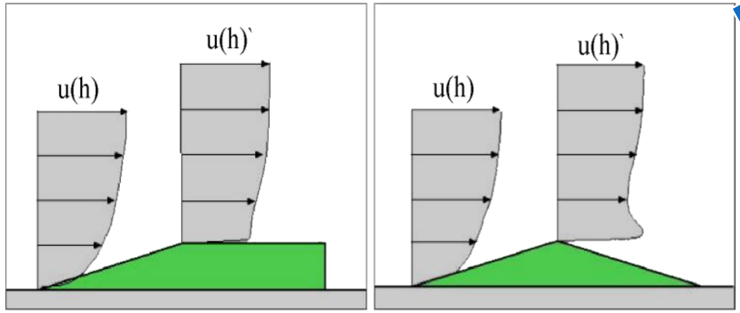
Roughness

$$u(h,\varphi) = u(h_0,\varphi)\frac{\ln[h/z_0(\varphi)]}{\ln[h_0/z_0 z_0(\varphi)]}$$



Orography

$$k_i^o(\varphi) = \frac{u(h,\varphi)}{u_i(h,\varphi)'}$$



$$N_{вэсt}(m,u,\varphi,\alpha) = \sum_{i=1}^{m}\left(f_{P_i}(u_i^r) \cdot \alpha_i \cdot k_П(\varphi)\right)$$

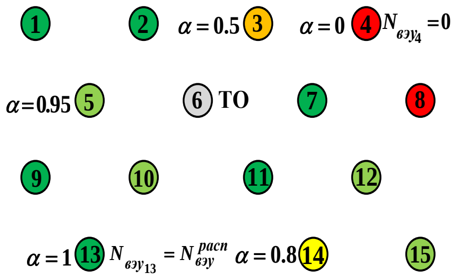
$$Э_{вэс} = 0,613\ 10^{-3} 8760 \int u^3 f(u)du$$

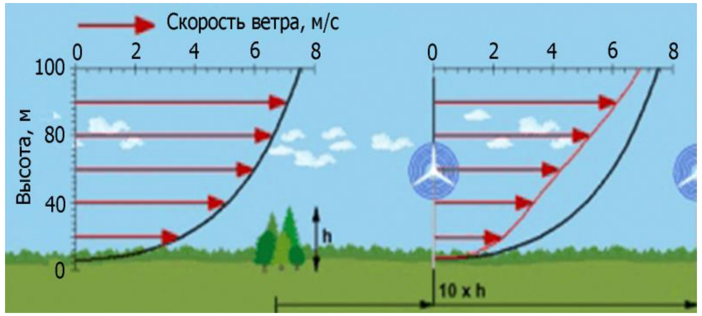
$$u_i^r(h_i,\varphi) = u(h,\varphi) \cdot k_i^w(\varphi,h_i)$$

$$k_i^w(\varphi,h_i) = k_i^o(\varphi) \cdot k_i^b(\varphi) \cdot k_i^B(\varphi)$$

Load balancing of wind turbines

$$0 \le \alpha_i = N_{вэу_i} / N_{вэу_i}^{расп} \le 1$$





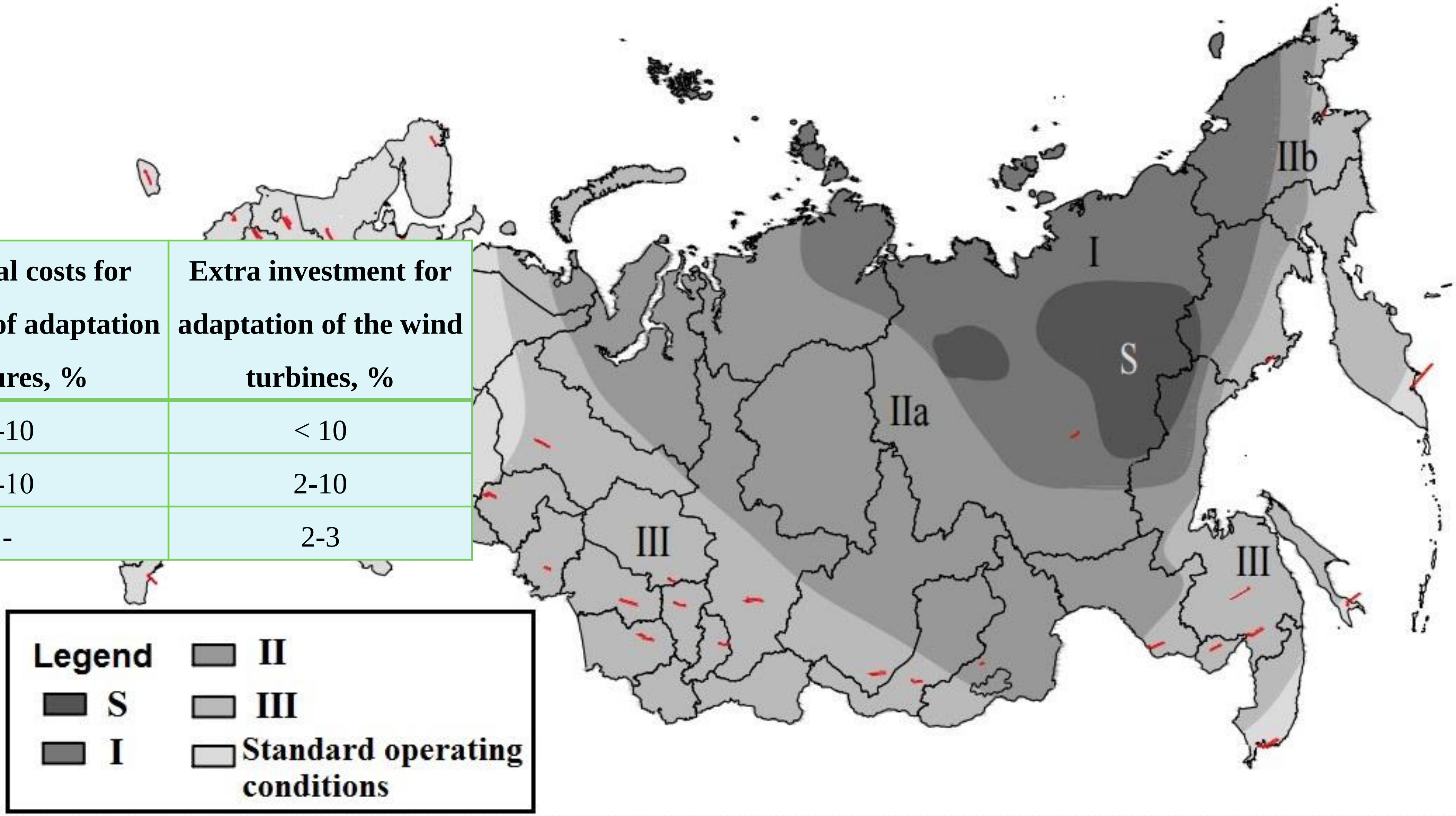
Obstacles and the impact of turbines on each other

$$k_i^B(\varphi) = u_i^r(h_i^r,\varphi) / u_i(h_i^r,\varphi)$$

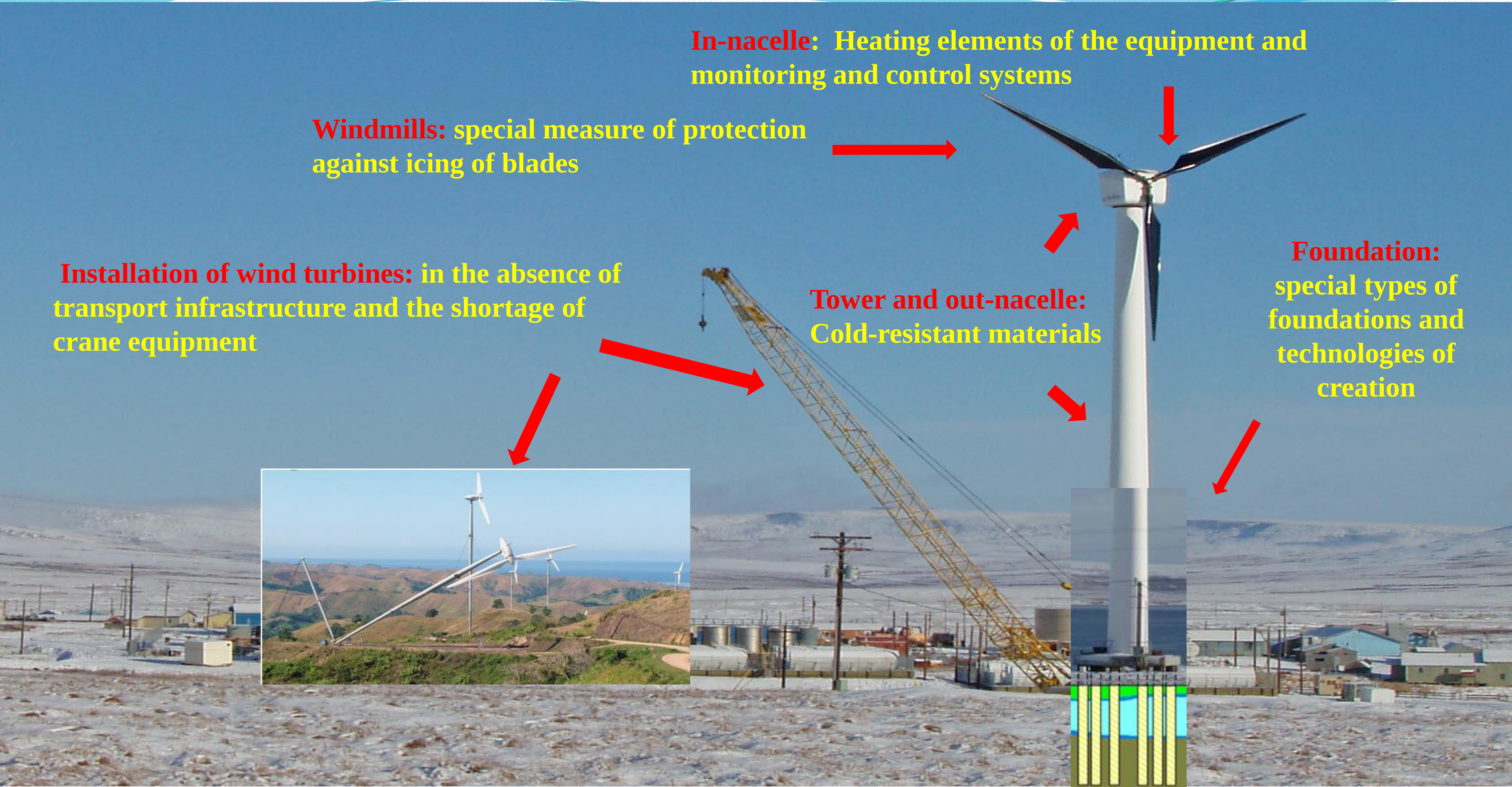
$$k_i^b(\varphi) = u_i(h,\varphi)/u_i(h,\varphi)'$$

Calculation of losses in the icing

Zone	Additional costs for own needs of adaptation measures, %	Extra investment for adaptation of the wind turbines, %
I	5-10	< 10
II	0-10	2-10
III	-	2-3

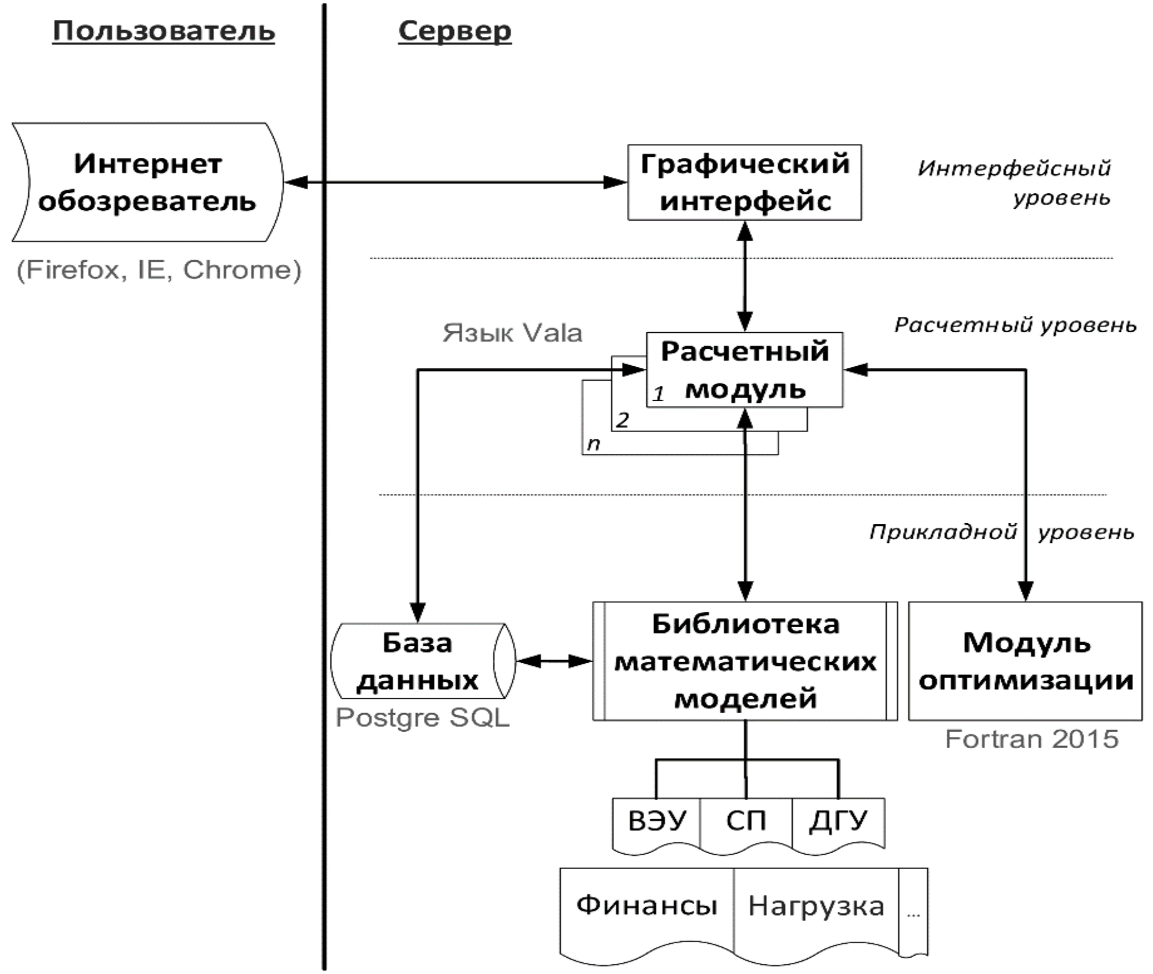


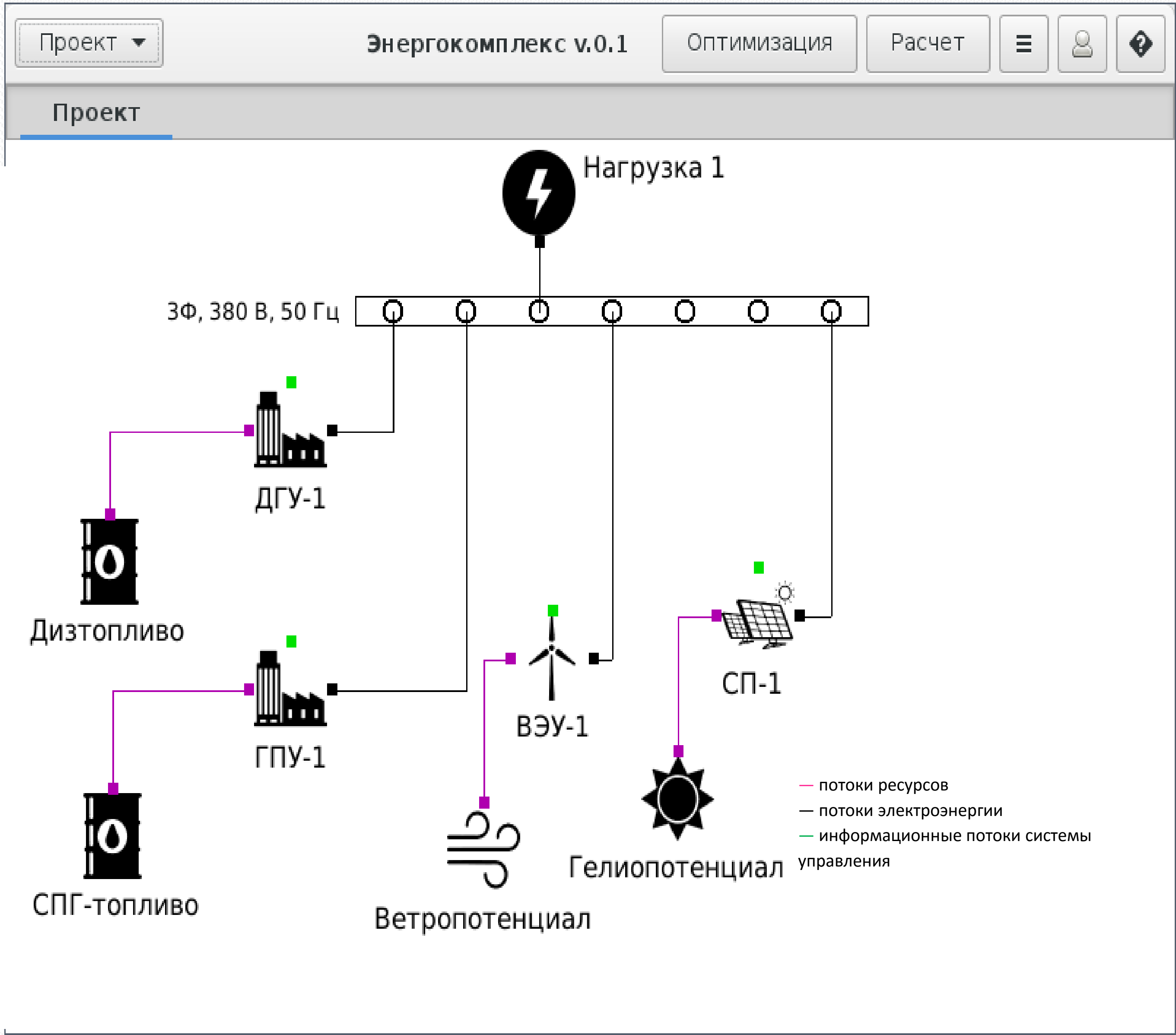
Adapted wind turbines



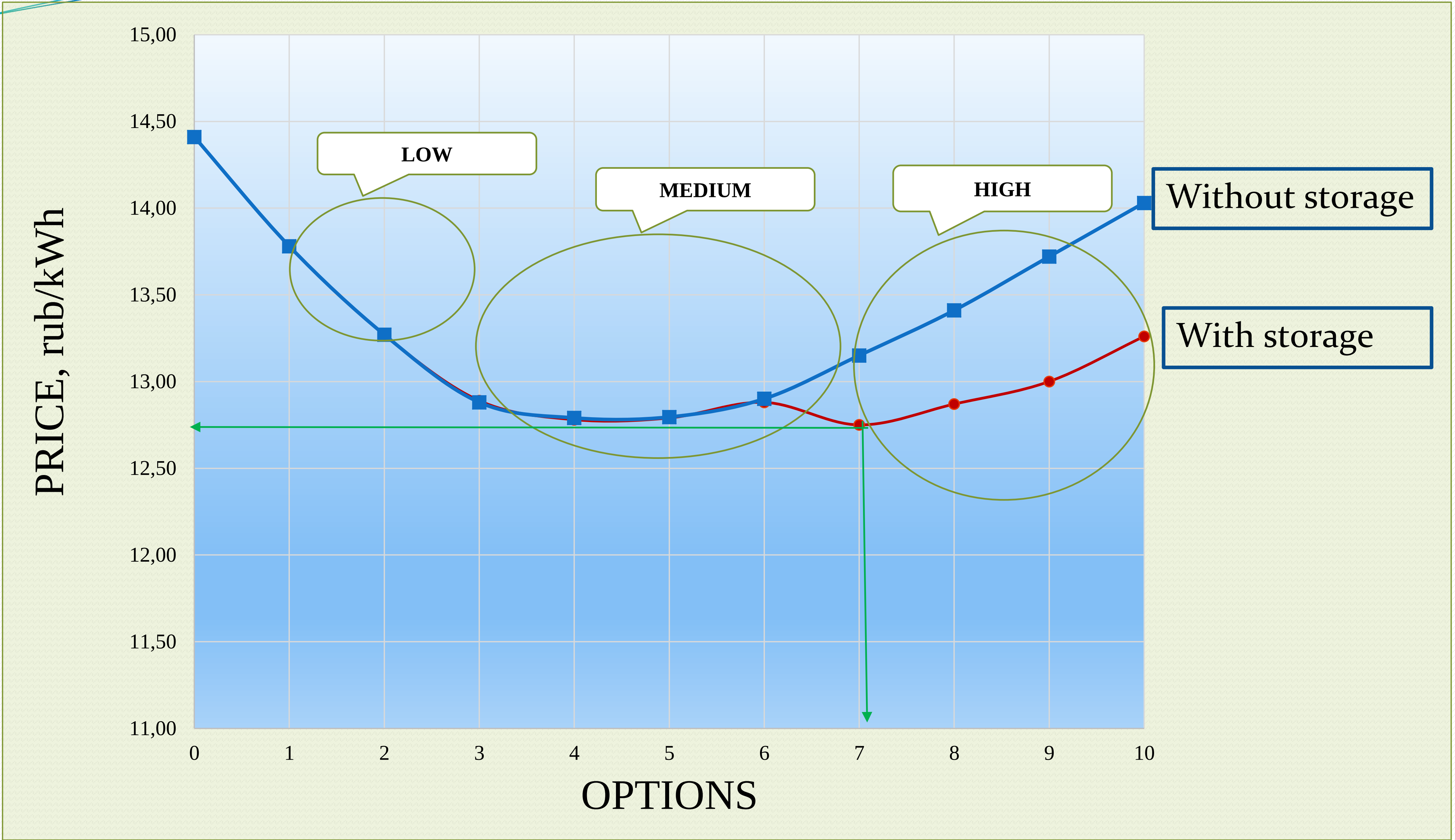
Intelligent control system of autonomous power plants (ver.1 – with Russian interface)

Comparable with another software, e.g. Homer.



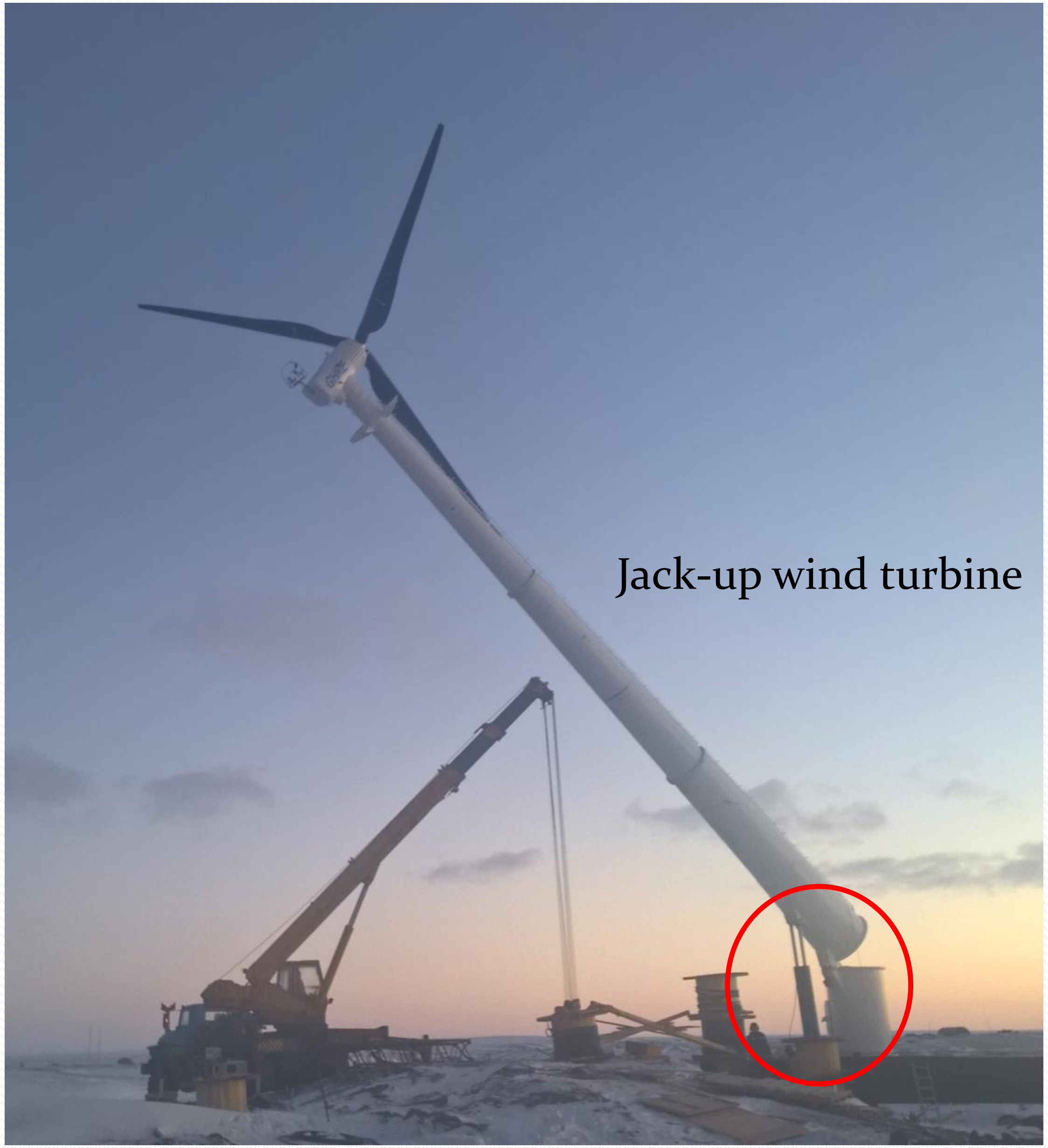


Technical and economic comparison of options



Example of hybrid system in Amderma (Nenets AO)

- Wind farms 200 kW (4 arctic version turbines Ghrepower-50 with unit capacity of 50 kW)
- Diesel power plant - 800 kW



Effects:
Volume of the imported diesel fuel was reduced by 50%,
CO_2 emissions was reduced by 600 tons
+ effect = 45 million rubles (750 000 $)

Technical recommendations on the adaptation of wind turbines Nordic conditions in Russia

1. Hydrophobic coating of blades, including painting in black

2. Replacement of pneumatic braking system electromechanical

3. Corrosion-resistant coating of the stator and the rotor of the generator

4. Reservations wind parameters sensors

5. Strengthen design of cold-resistant steel tower wind turbines (C345).

6. Partitioning tower by weight not more than 3 tons / section

7. System Ros installation of wind turbines special type

8. Install the inverter box and the wind turbine control in a thermostatic container.

9. Designing a special foundation for the conditions of permafrost

Conclusion

1. Improving the reliability of the assessment of wind energy resources in northern regions of Russia in conditions of reduced climate information developed the technique of wind resource assessment

2. Developed the map of zoning of the territory of Russia for hardware adaptation methods to harsh climatic conditions

3. Developed technical proposals and recommendations for adaptation to Russian severe climate equipment (propeller, power equipment inside the nacelle, the power transmission system from wind turbines), structures (towers, foundations and others.), The construction methods and installation of the main elements of the wind turbine.

4. The results of the project used in scientific and technical support to the design and construction of wind-diesel power plant in n. Amderma NAO regarding the use of the parameters of study methods and modes of adaptation recommendations and installation of equipment, intelligent management system, etc.

Thank you for your attention!

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