LAPPEENRANTA UNIVERSITY OF TECHNOLOGY
LUT School of Energy Technology
Degree Programme of Bioenergy

Master’s thesis

GREEN CAMPUS IN PETER THE GREAT POLYTECHNIC UNIVERSITY

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ABSTRACT

Lappeenranta University of Technology
School of Energy System
Degree Program in Bioenergy

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Green Campus in Peter the Great Polytechnic University

Master’s Thesis

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Keywords: green campus, green strategy, sustainability in Russia, carport solar plant, sustainable solutions for buildings, roof solar power plant, environment management program

The goal of the master's thesis is a detailed research of the existing position of renewable energy in the world’s and Russian energy balance and develop projects of renewable energy for Peter the Great Saint Petersburg Polytechnic University. The main attention of the thesis is devoted to experience gained in the field of energy practice for students and priority problems of humanity, such as environmental pollution, provision of energy resources and global warming. Implementation of different sources of renewable energy, devices for energy efficiency and promotion of sustainable life will be as the living laboratory for research, education, and operations. The review of existent and projected Green Campuses around the world and assessed the potential of the project in the weather conditions of Saint Petersburg. The modern renewable energy facilities for Polytechnic University Campus were developed.
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Daria Vylegzhanina
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ABBREVIATIONS

AC - Agricultural complex
CSPP - Carport Solar Power Plant
FIC - Forest industry complex and woodworking
HUS - Housing and utilities sector
GHG - Greenhouse gas
LUT - Lappeenranta University of Technology
PV - Photovoltaic
RES - Renewable energy sources
SPbPU - Saint-Petersburg Polytechnic University

t.o.e. – Tonne of oil equivalent
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1. INTRODUCTION

1.1 Background

Today the fossil fuels trio of coal, oil and natural gas provides over 80% of the world’s energy. Society current use of fossil fuels and nuclear fuels has many adverse consequences. These include air pollution, acid rains, depletion of natural resources and the danger of nuclear radiation.

The government and large corporations have realized the importance of investing in renewable energy with the aim of preserving the Earth’s environment and prevent global climate change. As a result increases the need to improve the efficiency of production from renewable sources, to continue the development of electric motors, engines based on biofuels, and to learn more about energy storage in order to satisfy customers. The concept of "clever power engineering" (Smart Grid) is actively developed and implemented all over the world.

Almost all federal districts of Russia have one of the major, renewable energy sources (solar, wind, small hydro, biomass, with the exception of thermal waters), and are potentially the necessary features to create integrated energy systems for the production of heat and electricity, and motor fuel for the full maintenance of the population (the life and production of) any kind of fuel and energy, thus the solution to all social problems of the rural population of any region in Russia. Mentioned sources by volume constitute approximately 30% of the total energy resources consumption in Russia, that is 916 million t.o.e. per year, what creates favorable prospects for solving energy, social and environmental problems in the future (Elistratov V., 2008).

The Master’s thesis reflects the role of the student in the green lifestyle all over the planet. Students have tremendous opportunities to implement different ideas on environmental preservation and motivation. Such projects in the universities as a Green Campus could popularize green lifestyle ideas among the youth and a correct and responsible attitude to
the environment, to engage students to participate in environmental and socially important actions related to the preservation of our planet. The University as a whole is a huge structure that consumes huge amounts of resources and produces tens of garbage tons per year.

Because of the global warming threat, the trend of the environment preservation becomes more and more popular every year. People all around the world are trying to reduce harm to the planet by making a great number of steps. Green technology is not only a respect for the power consumption, landscaping, and ecological food grown in the local area, but also a separate waste collection. It is the personal realization that you are a part of the whole way of life ensures greater stability of the economy.

Nowadays the University campus is the urban environment development center, as well as the integral part of the modern metropolis. The campus almost always comprises parklands, forests, and one of the most promising concepts, that adhere to developing well-known universities, – the "Green campus" concept. The concept involves the eco buildings construction, the waste separation and recycling, use of "zero emission of heat" buildings and landscape areas, that both serve recreational purposes and are considered as the reserves for the further development. The concept of "green" Universities suggests that the University could implement beneficial practices as follows: separate waste collection, energy efficiency, bicycles promotion, territories improvement, and the comfortable conditions creation for study and work. A student life in campus and the idea of sustainable development is a joint effort of students and campus in general – professors, curriculum, rules and opportunities for implementation.

Polytechnic University today is a diverse institution comprising a wide range of specialists, students, postgraduates, and teachers. The collaboration of all Polytechnic departments and the concentration of knowledge and effort are possibilities to develop an absolutely unique project for Russia - Green Campus. The idea of Green Campus will help to unite everything on the way to the new technical solutions and decarbonization of the future. A high percentage of foreign students will allow to make an invaluable contribution to the campus
development and to learn from the world’s experience, ensuring that the renewable energy is the energy of the future. Polytechnic University will become a platform for young professionals development (Tobi T., 2008).

The Green Campus is supposed to bring together any projects and developments that could be imagined, among which are the carport solar power plant. Furthermore, it is supposed to provide a great opportunity for the business projects development in the energy sector. In the areas like the Far East, people are in the power supply need, so specialists will be trained to understand and implement the projects related to the renewable sources (IFC, 2017).

The University is unique as an organization itself in that way, that it has diversified professionals that ensure the project life from a development to a completion, and the following life maintenance. Perceiving the Green Campus as a business model, this energy facility will create a promising platform for specialists in the power engineering sector, as well as for builders, engineers, designers, economists, business people, etc.

1.2 Objectives and restrictions

The purpose of this master’s thesis is to consider the possibilities and conditions for Green Campus creation at the Polytechnic University that will fulfil all the scientific and educational goals for the development of renewable sources in Russia (Federal Law № 35-FZ, 2007). In addition, in the thesis all the benefits and drawbacks of the Green Campus project are considered and a feasibility conclusion is stated.

One of the current project goals is to provide a critical view on the fossil fuels use in Russia, and, even considering the high cost of energy from renewable sources, not to abandon such projects and developments around the world, to promote the future and the status of Russia as a leader in this industry.

In accordance with the stated purpose and objectives, the subject of the research is the renewable energy industry in Russia and the renewable energy facilities - the roof solar
power plant, carport solar power plant and a list of sustainable solutions for Campus, that could be installed on the Polytechnic University territory.

The methodological basis of the study is to analyze the similar existing projects around the world and to create an absolutely new project for Russia, where renewable energy technologies are on the development stage. The major information base for the study was compiled from the existing Green Campus facilities in Lappeenranta University of Technology. Furthermore, another information sources are as follows: the technologies development in the solar energy field, standards for compliance with the green universities standards, scientific publications of Russian and foreign scientists devoted to the renewable energy sources development, and information resources in the Internet. The Green Campus goal is to increase the number of specialists, manufacture components, and equipment; accumulate experience, and make Russia one of the leaders in the renewable energy technologies.

Green Campus of the Polytechnic University will apply the experience gained in the energy field for the students practice and education, and will provide solutions to the priority humanity problems – environmental pollution, provision of energy resources and global warming. Implementation of renewable energy different sources, devices for the energy efficiency, and promotion of sustainable life will act as a “living” laboratory for research, education, environment, and sustainability development.

Over time, the Green Campus at the Polytechnic University could become the largest in Russia platform for training and further progress, as well as for the renewable energy development. The historic location outside the city center allows to make the renewable energy a part of the University life and serve as the successful implementation example of such projects in Russia.

The practical significance of the work is that the results and projects could be used in Peter the Great Saint Petersburg Polytechnic University for further investment and development of the real Green Campus. The existence of required laboratories and renewable energy
researches in Russia could be used by legislative and executive authorities to assess the efficiency of renewable energy policies in Russia, to compile economic and non-economic consequences of the renewable energy development, and to develop a national strategy for the industry development.

1.3 Structure of thesis

Master's work includes an introduction, 5 chapters, and a conclusion, as well as applications where an environment management program for SPbPU and the location of Green Campus facilities on the territory of the university are developed.

In the second chapter, an analysis was made of the state of renewable energy for today in Russia and the world, an analysis of the percentage of renewable energy sources availability was made and the prerequisites for development were discussed. The factors influencing the change in the world energy balance and major megatrends, leading to a constant increase in the needs of mankind, are analyzed. Barriers and obstacles to the development of renewable energy in Russia are analyzed.

In the third chapter, the weather conditions of the cities of Lappeenranta and St. Petersburg were analyzed, the main factors and requirements for solar and wind power stations were described. The potential of solar and wind energy in Saint Petersburg is described, as well as ways to introduce renewable energy into Russia's energy balance. Made a conclusion about importance of the universities role in the future sustainable development and the comparison between Polytechnic University and Lappeenranta University of Technology was held.

The fourth chapter is considered the overall design of Green Campus and studied the design of carport power plant, flat roof solar power plant and implementation of sustainable facilities. The characteristics of the research building, which will be the main building for energy optimization at the University, are also analyzed. The fifth chapter analyses the
green campus strategy and algorithm of progressive introduction of the Green Campus in the University life as well in the region in the future.

The conclusion and discussion of the work was done, the strategy and future of the Green Campus, as well as the necessary actions that need to be taken to further develop. All the main activities are set out in the environment management program.
2. THE RENEWABLE ENERGY FUTURE

2.1 Prerequisites for the green technologies development

Since the beginning of the XXI century the world has witnessed the emergence of a new technological platform for the global energy industry development, due to the need in fulfilment a number of economic, demographic, climatic and technological requirements. One of the most important features of this process is to change the structure of balances of energy production and energy consumption due to the increase in the share of carbon-free technologies, technologies based on renewable energy sources in particular (Grechuhina I., 2016)

Renewable Energy Sources - solar energy, wind energy, water energy (including wastewater energy), tidal energy, wave energy of water objects, including water bodies, rivers, seas, oceans, as well as geothermal energy with the use of natural underground coolants; low-potential thermal energy of the earth, air, water with the use of special coolants. In addition, biomass including specially grown plants and trees for the energy production, as well as the production and consumption wastes (with the exception of waste produced in the process of using hydrocarbon feedstocks and fuel), biogas, gas produced by production and consumption of wastes, gas produced on coal mines are studied (Bezrukih P. 2008)
At the moment, the renewable energy is the fastest growing sector of the world energy: in 2014 the share of the renewable energy accounted for 59% of the increase in the world generating capacity, and the share of global renewable energy power generation exceeded the 22.8% (Fig.2.1). However, as a general rule (Willems P. 2015), the renewable energy sources development is only possible with some form of government support.

Traditional generation of energy in Russia, a country where gas, oil and coal reserves are enough for decades to come, the most common and expensive experiments with the renewable energy are very difficult to implement (Aliev R. 2013). Final electricity consumers are forced to pay for the lack of financing during a difficult economic situation. It is generally accepted (Boyle G. 2013) that under the conditions of large organic fuels reserves, the energy efficiency issues, energy conservation and the introduction of non-fuel technologies based on the renewable energy sources are not considered as the most urgent issues. Thus, in Russia it is widely believed (Willems P. 2015) that the renewable energy is expensive, economically inefficient and should not be developed, at least in the short term.

However, the environmental safety improvement in the energy production and the introduction of local and renewable resources increase the environmental sustainability, since both fossil and renewable energy resources are distributed unevenly throughout the country. The important feature of the existing energy system in Russia is its high
centralization degree. Approximately 90% of the total amount of electricity is produced by large power plants, that provide electricity to a branched electrical network (IEA, 2015). Taking it into consideration, the energy system centralization is the distinctive feature of the densely-populated regions of the European part of the country and several regions in Siberia. The most part of the territory in Russia (about 60% with 10 million people living) is not connected to centralized energy systems (Fig.2.2). They receive electricity mainly from autonomous low power diesel generators.

\[ \text{Figure 2.2 Energy supply areas in Russia: centralized, self-generated and decentralized.} \]

The negative sides of such centralization are transportation costs and significant energy losses during the transportation and transmission over long distances.

These circumstances make the renewable energy sources one of the most promising resources types. RES, as local, dispersed energy resources, could be efficiently used for such a decentralized energy supply. The renewable energy sources introduction makes it possible to increase the energy security of the regions in Russia and to increase the self-sustainment ratio. Despite the fact that Russia possesses huge resources of wind, geothermal energy, solar energy, biomass energy, hydropower resources, at present renewable energy sources (except for large hydropower facilities) are not commonly used
in the country (Table 1). Russia seriously lags behind both the implementation rate and the technologies for the various renewable energy types conversion. Contemporary situation in implementation rate constitutes less than 1% of the total energy production. (Sobolev S. 2015).

Table 1. General information on the renewable energy resources by Federal Districts of Russia (Purgusin S, 2006).

| Federal district | Types of resources, billions t.o.e. |  |  |  |  |  |  |
|------------------|-------------------------------------|---|---|---|---|---|
|                  | Solar energy | Wind energy | Hydro energy | Bioenergy | Geothermal energy |
|                  | FIC | AC | HUS | FIC | AC | HUS |
| Northwestern     | 178.2 | 58.8 | 54.55 | 8.6 | 1.7 | 1.095 | - |
| Central          | 84.9 | 9.8 | 2.9 | 1.5 | 14.5 | 3.22 | - |
| Southern         | 100.7 | 24.0 | 20.6 | 0.37 | 24.8 | 1.956 | 29.5 |
| Privolzskii      | 140.8 | 32.1 | 11.9 | 4.24 | 24.9 | 2.65 | - |
| Uralian          | 215.6 | 219.9 | 45.9 | 4.23 | 3.35 | 1.049 | - |
| Siberian         | 672.0 | 205.8 | 147.9 | 18.13 | 11.82 | 1.48 | - |
| Far Eastern      | 813.2 | 335.8 | 153.7 | 11.4 | 0.73 | 0.56 | 1.3 |

Almost all Russian federal districts have sustainability solutions as follows:

- major renewable energy sources (solar, wind, small hydro, biomass, with the exception of thermal waters);
- potentially necessary features for the integrated energy systems creation for the heat and electricity production;
- motor fuel for the full maintenance of the population (the life and production of) any kind of fuel and energy;
- the solution to all social problems of the rural population of any Russian region.
Nevertheless, the total renewable energy share in the global energy balance remains limited, and the prospects for its expansion are uncertain in particular, providing the tendency to reduce investments, introducing counterproductive changes in the national RES development strategies in a number of countries, and developing new relatively competitive non-traditional resources, oil, and gas.

In Russia, the economic, environmental and social efficiency of the renewable resources usage is estimated by the contribution that this sector could provide the features as follows (Grechuhina I., 2016):

- Organization of sustainable energy supply for the population and the production in the areas with the decentralized energy supply.
- Provision of a guaranteed energy supply minimum to the population and the production (especially agricultural) in zones of unsustainable centralized energy supply.
- Prevention of damage from emergency and limiting outages, especially in rural areas and rural processing industry.
- Reduction of harmful emissions from power plants in certain cities and towns with a complex environmental situation, as well as in places of mass recreation.

### 2.2 Factors affecting the change in the world's energy balance

The transformation of the global energy is conditioned by the need to fulfil several economic, demographic, climatic and technological challenges. All this demand for energy services is significantly increased by the population growth, urbanization, and general improvement in the life quality.

The main directions for the changes in the energy priorities were fixed in the UN concept papers adopted at the conferences of this organization (Grechuhina I., 2016):
• in 2012 (transition to sustainable development and green economy)
• in September 2015 (adoption of the Sustainable Development Goals for humanity and all countries before 2030)
• in December 2015 (ways to reduce GHG emissions due to the problem of global climate change).

All the mentioned documents were accepted by all countries in the world, including Russia. Changes in the world affect everything, including the energy system of the Earth, therefore, developing an energy strategy, all countries should focus on 10 major megatrends:

• Diverging global population trend.
  The main factors of this trend are economic growth, the growth of fertility and life expectancy, the growth of the level of medical care and education, as well as climatic changes due to the global warming.

• Moving towards a more urban world.
  The urbanization of cities is becoming one of the most significant problem in the modern world. In an effort to improve the standard of living, opportunities for work, people move to cities. Increase in energy consumption, resources consumption, that create huge problems for the environment.

• Changing disease burdens and risk of pandemics.
  The deterioration of the environment leads to a weakening of the population health; economic growth creates conditions for competition for people in the medical field and also affects the consumption patterns and life expectancy.

• Accelerating technological change.
  Continuous researches and developments of new technologies, improvements of the present technologies are conducted, as information and communication advances are growing. The role of human in a routine life is constantly decreasing.

• Continued economic growth.
Factors for the development of economic growth are expressed in labor availability, educational level, technological innovations, market globalization and international marketing depending on the labor cost and consumption patterns.

- An increasing multipolar world.
  An increase in the standard of living allows people to move around the world and to increase a communication and development. The exchange of experience leads to the scientific progress and the increase in foreign direct investments. The economy structure and international relations are changing, as well as the trade liberalization and international cooperation.

- Intensified global competition for resources.
  Life-saving resources are depleted with the increase in population, energy consumption, and quality of life. More and more competition for water, energy resources and territories is growing. Under these conditions, a human should try to save the planet for future generations, taking care of the environment and finding solutions for sustainable development.

- Growing pressures on ecosystems.
  Every year the pressure on eco-resources increases, and the main factors influencing on it are the consumption patterns, urbanization, continuous climate change and bioenergy demand.

- Increasingly severe consequences of climate change.
  The development of technologies does not allow to achieve the most efficient level of the renewable sources usage; and in the energy need people continue to burn actively fossil fuels. In the pursuit of the lands there is an active deforestation, that harms the ozone layer.

- Increasing environmental pollution.
  New technologies and development require more and more energy, and humanity is on the verge of a new energy crisis, because of the annual increase in the fossil fuels consumption. Resources are depleted and the Earth is affected irreparably. The
burial of hazardous wastes, disasters, agricultural practices and chemicals break the ozone layer and carry the danger.

- Diversifying approaches to governance.

  The main factors are as follows: the population trends, globalization, innovation in social community, informational and communicational technologies, as well as the economic growth and public awareness. (IEA, 2015)

Under the influence of the factors mentioned above, new trends in the development of the global energy are emerging. There is a change in the structure of the balance sheets of electricity production and consumption due to the increase in the share of carbonless technologies (nuclear and renewable energy). At the same time, the prime cost of the traditional fossil fuels extraction is increased with the reduction of the economically justified hydrocarbon reserves. Moreover, the forecast indicators of the increase in the electricity consumption and production, primarily in developing countries, make it obvious that the increase in the production of hydrocarbons in the same volume is impossible (Ageev V., 2004).

The structure of electricity consumption changes: household consumption growth is almost double the growth in business, that causes large fluctuations in the demand and need to change the load management technologies. In addition, the distributed generation share is growing, the number of generation points is increasing, and the geography of electricity supply is expanding. In response to these changes, the improvement of smart grids and automated control systems is required. In the light of these trends, the energy supply is one of the most optimal answers to the challenges of the modern world, that is substantiated and confirmed by the role and place of RES in the global agenda.
2.3 The key importance of renewable energy facilities

The growing global threats such as climate change, energy security, exhaustive resources, and regional conflicts require brand new solutions and the integration of the entire world community efforts.

The growing efficiency of renewable energy technologies, the reduction in their cost, on the one hand, and the rise in electricity prices, on the other, have enabled photovoltaic systems and ground-based wind generators to reach the new levels of cost competitiveness based on the lower production costs in comparison with the conventional energy production from the fossil fuels. In many countries, the network parity has been achieved, the price equality state of 1 kWh of electricity obtained from solar and wind power, with the price available using traditional fuel energy (Hossain M., 2017)

The most renewable energy technologies are also becoming cheaper. Despite the 22% reduction in the global investments in RES in 2013, the reduction in the level of capital costs (cost of technology) allowed the RES to maintain an exceptionally high growth rate. The geography of the renewable energy spread has also expanded significantly. Today, the renewable energy usage is one of the most cost-effective solutions in the areas, that are not covered by the electric grid infrastructure, and is considerably cheaper than diesel power plants. In many mature markets, the rapid development of the decentralized renewable energy supply transforms conventional ownership structures in the energy sector (Grechuhina I., 2016).

One more important fact is the development of a network capacity and an energy conservation technologies. As is known (Boyle G., 2013), the electricity generation based on the RES has a variable nature, since, as a rule, it depends on the weather conditions: the intensity of solar radiation and wind force. Therefore, the supply of renewable energy is unstable, as it is impossible to accurately predict, and even more so, to adjust the supply depending on fluctuations in demand. And this is a reality that we have to reconcile until
the development in technologies that allows to store the surplus electricity and consume it when generation, due to weather conditions, becomes scarce. Smart grid battery systems would significantly reduce the need for a peak power supply and the use of traditional power plants in periods of scarce electricity production based on the RES. However, the number of available storage technologies remains limited.

The RES technologies could be used in various energy supply areas: in power generation, heating and transport. In the electric power industry, as a result of the spread of renewable energy technologies, the transition from a single centralized power supply to a multiple decentralized one begins.

The autonomous renewable energy systems are alternatives to the centralized energy supply in developing regions where access to the electricity is difficult or impossible. The RES generators are decentralized in nature and could be easily adapted to local conditions and local demand. Thus, the need for the centralized energy supply of the region due to the RES could be completely excluded.

2.4 Potential of renewable energy in Russia.

A common factor constraining the technology of using the renewable energy generation is its non-competitiveness with classical generation in the existing regulatory environment, with the exception of the autonomous generation sector in remote areas where the high imported fossil fuels cost reduces the advantages of the traditional generation. In this regard, the dominant factor in the development of the renewable energy sources is the adoption of an appropriate regulatory and legal framework and, on this basis, the development of a national market for generating the RES (Table 2).
Table 2. Potential of the renewable energy in Russia (Grechuhina I., 2016.

<table>
<thead>
<tr>
<th>Resource</th>
<th>Gross potential, bill.t.o.e./year</th>
<th>Technical potential bill.t.o.e./year</th>
<th>Economical potential bill.t.o.e./year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind energy</td>
<td>44326</td>
<td>2216</td>
<td>110</td>
</tr>
<tr>
<td>Hydro energy small</td>
<td>402</td>
<td>126</td>
<td>70</td>
</tr>
<tr>
<td>Solar energy</td>
<td>2205400</td>
<td>9695</td>
<td>30</td>
</tr>
<tr>
<td>Biomass energy</td>
<td>467</td>
<td>129</td>
<td>69</td>
</tr>
<tr>
<td>Geothermal energy</td>
<td>22900</td>
<td>11869</td>
<td>114</td>
</tr>
<tr>
<td>Low potential heat</td>
<td>563</td>
<td>194</td>
<td>53</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>2274058</strong></td>
<td><strong>24229</strong></td>
<td><strong>446</strong></td>
</tr>
</tbody>
</table>

The renewable energy sources contribution to the solution of the tasks faced by the Russian society will be determined by the reform rate of society and the economy. A clear economic policy, that takes into account all possible forms of primary energy, is needed, while the reforms to be implemented will radically change their relative profitability. The profitability of the RES usage should be considered in the context of the ongoing changes in the energy sector (Sinitcina T., 2007)

The combination of the electricity shortage and favorable natural conditions creates the prerequisites for the transformation of Saint Petersburg and the Leningrad Region into one of the leading regions in the usage of renewable energy sources in Russia.

2.4.1 Prospects for solar energy in Saint Petersburg

The sun the inexhaustible, environmentally friendly and cheap energy source. As the experts say (Boyle G. 2013), the amount of solar energy that enters the Earth's surface during the week, higher than the energy of the world's reserves of oil, gas, coal, and
uranium. The solar energy is one of the most promising areas of the renewable energy, based on the direct usage of the solar radiation for the energy production for heating, electricity and hot water. Solar cells as an energy source could be used: in industry, in agriculture, in domestic sphere, in construction industry, in solar power, in stand-alone video surveillance systems, in autonomous lighting systems, in the space industry.

Many nations are trying to cut on carbon dioxide emissions by using different methods. One of the methods is the electricity production using CO2 free or almost free energy sources. The energy produced by solar batteries does not necessarily meet the needs of the society and cannot cover all the needs of the university, but it helps to locally reduce the basic energy resources consumption. The possibility of using locally produced energy by the Polytechnic University is the unique project for Russia.

Figure 2.3 Beam and diffuse irradiation in Saint Petersburg (System Advisor Model.)
Along with the need and willingness of some organizations to create their own green energy, the Green Campus will promote the development of photovoltaic solar panels in Russia and in the world (Fig.2.3).

Climate conditions in Saint Petersburg result only in about the 20% smaller annual solar heat production compared to south Europe’s countries (Druzhinin P. 2016). Technically these irradiation levels enable significant potential to the more self-sufficient, domestic and ecological heat and power production. The technical potential to utilize the solar energy in Russia and even in Saint Petersburg is several times more than energy consumption in these regions (Aliev R., 2013). The main technical challenges are related to the available solar energy intermittency (day-night and summer-winter cycles).

Systems with the renewable energy sources are very profitable, as they do not require fuel supplies. However, the renewable sources of energy are unstable, because they are considerably dependent on weather and natural conditions. Considering solar panels the problems with the cloudy weather, day duration and radiation intensity arise. Therefore, the system requires a battery for the additional power, when there is not enough sunlight.

### 2.4.2 Prospects for wind energy in Saint Petersburg

Today all economically available potential of the renewable energy in Russia is estimated at about 30% of the total energy balance. The characteristics allow presenting the full picture of a wind conditions for the certain region (Purgusin S., 2006)

In Saint Petersburg, the wind is the second most promising sector of the renewable energy in the region, its resources are significant on the coast of the Gulf of Finland and the Ladoga Lake and achieve its maximum during the winter period (Minina A., 2009).
The stated design procedure of the technical wind energy potential is based on the concept that the technical wind energy potential is a part of the natural wind energy resources that are possible to implement with the use of modern engineering tools in the territory of the SPbPU campus.

The wind is characterized by the two measured parameters: the speed expressed in m/s, km/h, knots (miles/h) or standard units (points), and a direction, whence it blows. The direction is defined either in points or in corners, that are formed by the vector of speed with a meridian and counted from a direction on the north clockwise.

The technical potential of the region is represented with the sum of technical potential of zones making it. The wind potential in the North West region of Russia is presented in the Table 3.

Table 3. The general characteristic of northwest federal district (Minina A., 2009)

<table>
<thead>
<tr>
<th>Subject name of the Russian Federation</th>
<th>Main city</th>
<th>Area, 1000 km²</th>
<th>Population, 1000 foreheads</th>
<th>Specific gross potential of the wind power, kWh/m² per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Republic of Karelia</td>
<td>Petrozavodsk</td>
<td>172.4</td>
<td>697.5</td>
<td>44</td>
</tr>
<tr>
<td>Republic of Komi</td>
<td>Syktyvkar</td>
<td>415.9</td>
<td>985.0</td>
<td>66</td>
</tr>
<tr>
<td>The Arkhangelsk oblast</td>
<td>Arkhangelsk</td>
<td>410.7</td>
<td>1249.3</td>
<td>66</td>
</tr>
<tr>
<td>The Vologda oblast</td>
<td>Vologda</td>
<td>145.7</td>
<td>1235.4</td>
<td>66</td>
</tr>
<tr>
<td>The Kaliningrad oblast</td>
<td>Kaliningrad</td>
<td>15.1</td>
<td>939.9</td>
<td>33</td>
</tr>
<tr>
<td>Leningrad oblast</td>
<td>Saint Petersburg</td>
<td>84.6</td>
<td>1643.9</td>
<td>33</td>
</tr>
<tr>
<td>The Murmansk oblast</td>
<td>Murmansk</td>
<td>144.9</td>
<td>864.6</td>
<td>310</td>
</tr>
<tr>
<td>Subject name of the Russian Federation</td>
<td>Main city</td>
<td>Area, 1000 km²</td>
<td>Population, 1000 foreheads</td>
<td>Specific gross potential of the wind power, kWh/m² per year</td>
</tr>
<tr>
<td>--------------------------------------</td>
<td>-----------------</td>
<td>----------------</td>
<td>----------------------------</td>
<td>-----------------------------------------------------------</td>
</tr>
<tr>
<td>The Novgorod oblast</td>
<td>Novgorod</td>
<td>55.3</td>
<td>665.4</td>
<td>110</td>
</tr>
<tr>
<td>The Pskov oblast</td>
<td>Pskov</td>
<td>55.3</td>
<td>724.6</td>
<td>66</td>
</tr>
<tr>
<td>Saint Petersburg</td>
<td>Saint Petersburg</td>
<td>1.3</td>
<td>4580.6</td>
<td>33</td>
</tr>
<tr>
<td>Nenets Autonomous District</td>
<td>Naryan-Mar</td>
<td>176.7</td>
<td>42.0</td>
<td>245</td>
</tr>
<tr>
<td>In total</td>
<td></td>
<td>1677.9</td>
<td>13628.3</td>
<td>-</td>
</tr>
</tbody>
</table>

Developing such projects as a Green Campus in the Polytechnic University will help to develop the renewable energy in the regions. Based on the Table 3, it can be seen that the wind energy cannot provide Saint Petersburg with its energy density, and some types of stations could be developed there for study. However, in such regions as the Republic of Karelia, the Komi Republic, the Murmansk region, local wind power projects have their place.

Having their own wind turbine puts the real research tool and real operating conditions at the disposal of researchers. The wind turbine is the modern product development laboratory that is well suited as a tool for researches, training and students' work. The turbine provides high energy output, thus, it is a good illustration of turbine technology at the megawatt class, operating principles, and equipment solutions. The electricity technology in particular is identical to the machines with the high output.

The Polytechnic University takes the leading position in the field of the energy projects development, therefore the generated energy could be transferred to the energy laboratory, what will allow to conduct the multifaceted researches in the field of electricity production.
and distribution. Possible areas for the turbine development are the further development of blades, as well as the measurement methods.

New blades that are more suitable for lower average wind speeds can improve the wind turbine power factor; and by developing measurement methods for the turbine, more detailed turbine measurement data can be obtained. The technology improvements will provide a new impetus to the wind power development in Russia.

The optimization of structures, structural vibration management, materials technology, maintenance, and economic manufacture of structures and components are also of interest to researchers and to companies in the wind power sector.

The increasing production of wind power leads to the need to increase the knowledge related to a maintenance and operating expertise. The SPbPU can be the first University in Russia and in North West Region in the wind energy field development.

2.5 Barriers and obstacles to the development of the renewable energy

Russia has all kinds of renewable energy resources. In general, their economic potential is about 25% of the domestic energy consumption. There are developments and small-scale production of all equipment types for the renewable energy. However, there are many existing barriers and obstacles. One of the major ones is the lack of any incentive for the development of the renewable energy at the state level.

The development acceleration of the RES in Russia requires the overcoming of the barriers as follows (Fig.2.2): psychological, economic, legislative (no financial and tax benefits), organizational and managerial (lack of federal and regional plans, federal agency for RES), information (weak public awareness of the RES opportunities, tendencies of the cost reduction, world experience), technical (diversity insufficiency, nomenclature, equipment, infrastructure).
Figure 2.4 Barriers and obstacles on the way of developing renewable energy sources in Russia (RES Center, 2014).

One of the major barriers to promoting renewable energy in Russia (Fig.2.4) is the technical backwardness and weak development of domestic technologies. There are practically no prerequisites and practically technologies that allow localizing production. The domestic industry does not produce turbines for wind generators or solar panels of decent quality; and western technology transfer does not develop, although negotiations on this are now conducted with a number of large Western producers. Since the localization degree in the RES is lower than necessary, then, respectively, production is subsidized with a lowering factor (RES Center, 2014).

The technologies development for the RES conversion is highly intellectual, science-intensive and innovative in nature, ensuring a steady efficiency increase and material intensity and cost reduction in the energy production. The renewable energy in Russia is underestimated from the point of view of political, economic and social importance. Nowadays, the raw material model of a development prevails in Russia, and the renewable energy usage is marked as unfavorable due to the high cost and technical shortcomings of this energy type. At the same time, the renewable energy can and, most probably, will actively develop from the primary alternative to the major hydrocarbon resources employment.
The importance of the RES usage for Russia is determined by stimulated economic development, improvements in the life quality in the remote areas located in the autonomous power supply zones, inefficient construction and maintenance of electric grids, fossil fuels preservation and export potential increase, as well as the ecological situation improvement.

Despite the very contradictory attitude to the renewable energy in Russian society, there are objectively a number of factors that support the development of the latter.

The world practice shows that the market of renewable energy technologies is constantly developing and expanding, due to the continuous decrease in the unit cost of an equipment and energy production; investments in this industry constitutes more than $250 billion per year, more than 5.7 million workplaces have been created. Technologies are developed and become cheaper, the efficiency coefficient is increased (RES Center, 2014).

Modern power supply systems based on the RES, that carry out a significant increase in power in the electric power industry, even in the current state of the power system, despite the existing stereotypes, fully provide the reliable energy supply and electricity quality.
3. IMPORTANCE OF GREEN CAMPUS IN SPBPU

The modern power supply has a number of shortcomings, such as the environmental pollution and minerals usage. It is necessary to implement an energy supply for all urban facilities, that play an important role in people's lives, through the introduction of the renewable energy sources, as well as the Smart Grids. These types of energy do not require large investments, but it is necessary to create technologies that ensure the most efficient energy usage for consumer purposes without large financial costs.

There is still a number of economic and technical problems that hamper the large-scale development and dissemination of renewable energy technologies. To overcome these problems, the further progress is needed in costs reduction through training, scaling up activities, creation of flexible investment conditions, integration of renewable energy technologies into existing energy systems, building up researches and development. The Saint Petersburg Polytechnic University is ideal for these purposes.

The general need for energy is increased with the environment development. However, researches and innovation work is conducted all the time in such a way, that the material goods and services are produced as environmentally friendly as possible with the minimum amount of energy (preferably renewable energy) consumption, starting from the process of raw materials production.

Unlike other energy-deficient regions, such as Moscow and the Tyumen region, Saint Petersburg and the Leningrad region, are characterized by a favorable combination of the large energy consumers availability and the climatic conditions required for the development of the RES (Monzikova A., 2013)

Undoubtedly, small and alternative energy projects are not able to solve the accumulated for decades energy system problems of the region, though their implementation will contribute to the decentralization and the reliability improvement of energy supply to enterprises.
3.1 Role of universities in the sustainable future development

Every year the global warming threat grows, thus the trend of preserving the environment fits into people's lives and solutions for the sustainable development become more and more popular. People all over the world are trying to reduce harm for the planet and taking steps in the "Green" technologies development. "Green" technology means respect for the energy consumption, innovation based on the sustainable development principles and re-use of resources, as well as the separate waste collection and urban greening (Vylegzhanina D. 2017)

In the modern world, universities prepare a new generation of young professionals, who produce innovative ideas and intellectual thoughts. These allow to accumulate a huge scientific potential. A society with knowledge is an important step towards the sustainable development of the world. The Universities role as the intellectual society carriers is great, that forms not only professional competences, but also life guides – a certain perception of the young specialist. The solution of environmental problems in Russia and other countries is only possible with the environmental education development of the citizens and changes in their life principles based on the care of the environment and future generations.

The Green Campus enhances comfort and creates a healthier environment for students, using improved technology. Students will be able to learn and work using improved air quality, natural daylight and thermal comfort. One of the Green Campus main goals is to prove that using energy from minerals through depletion and CO2 emissions will bring environmental problems in the future. In the current crisis of 2014-2017, the energy markets instability and constant changes in oil prices give impetus to the environmental awareness development and creates a chance to make the renewable energy a priority (Egan T., 2017)

The environment groups in University communities can promote a construction and projects that fulfil high energy efficiency standards, help to develop technology and assign
requirements and standards for green buildings. The Green Campus is not only a new building made of high-quality materials with the renewable energy usage, but also educational courses and competent specialists that monitor and develop interest of the youth for the environment and planet protection (Aliev R., 2013).

Students, professors, engineers and designers are a part of the broad desire for sustainability, that is a modern direction in the planning and development of the surrounding world. The purpose of this direction is to use less natural resources, while maintaining a decent standard of living. Such ideas and movements are born in universities, that are homes to the new way of thinking and prosperity; student groups and sessions on sustainability are developing all over the world (Green reality, 2017).

3.2 Lappeenranta University of Technology and the LUT Green Campus idea

The city of Lappeenranta has set ambitious goals for improving the climate of the region, providing huge opportunities for the development of companies in the field of "green" technology and environmental protection.

Lappeenranta policy can be achieved by using renewable energy sources and increasing the overall energy efficiency. At the moment approximately 80% of the city's energy is produced from the RES. The city administration is actively encouraging local businesses to the "smart" the impact on the climate.

Most of the innovative-oriented companies in Lappeenranta are located in the Skinnarila Green Campus. In 2013, the Campus received the International Campaign for Sustainable Campus Network, in the category "Excellence, Campus Category", in other words, it was the most "green" campus in the world (Green reality, 2017).
Figure 3.1 Comparison of Lappeenranta University of Technology area and Peter the Great Saint Petersburg Polytechnic University area.

The Green Campus of Lappeenranta University of Technology is a unique research and the educational center in the energy efficiency and environmental protection fields (Fig.3.1). The Green Campus houses Finland's largest wind and solar energy parks, that generate energy for the researches and pilot projects. The proximity of Lappeenranta to the Russian border is another plus for the development of the international production activities. More than 350 companies established in the Lappeenranta region with the participation of Russian entrepreneurs are successfully operating in the European market. And the number of knowledge-intensive enterprises and enterprises in the manufacturing sector is steadily growing. The city's focus on international relations positively affects the whole economic sector (Green reality, 2017).
3.3 Weather analysis

The environment of Saint Petersburg refers to the Atlantic-continental region of the temperate zone. The climate of the city has both marine and continental features, with soft mild winters and moderately warm summers, as well as abundant rainfalls throughout the season. The average annual air temperature in Saint Petersburg for long-term observations is 5.6°C. In Saint Petersburg there are about 177 cloudy days in total for the year. In days with the sun, the average duration of the sunlight decreases from 10.1 hours in June to 2 hours in December (Meteoblue, 2013).

Saint Petersburg in its geographical location falls into an excessive humidity zone. The average annual rainfall in Saint Petersburg over the past 30 years is 653 mm. The precipitation in Saint Petersburg is mainly determined by the intensity of cyclonic activity.

During the first Green Campus creation in Saint Petersburg, it is necessary to take into account the fact that the LUT Green Campus has been successfully operating in neighboring Finland since 2013. The University consumes solar and wind energy, despite the fact that the LUT is located to the north of Saint Petersburg, and the distance between them is only 206 km. The weather conditions analysis of the two cities is presented in the Figure 3.1, the comparison is made from the main weather characteristics that affect the efficient operation of the Green Campus facilities.
Figure 3.2 Wind roses of Lappeenranta and Saint Petersburg (Meteoblue, 2017).

The rose of wind speeds indicates the number of hours per year the wind blows from a certain direction. The wind parameters of interest are registered, as a rule, at the one standard altitude of 10 m at meteorological stations near airports and cities – places, that are possibly the most sheltered from the wind.

The wind direction is determined by the side of the light, from which the wind is blowing. Diagrams about the direction of the wind are usually presented in the form of a wind rose, showing the average wind speed in different directions (Fig.3.2). On a wind rose, instead of the average speed, shown wind speed distribution power for each direction. Information about the direction of the wind is extremely important when wind turbines are placed in a mountainous area, near buildings or other wind farms, when it is possible to shade them in some wind directions.

Therefore, these data could be used only for a rough estimate of the wind energy resources in the region of question, though the data is not sufficient for making specific technical
decisions, such as, for example, the selection of a wind farm optimal design. For this, as a rule, more detailed observations are needed with a greater number of terrain points and at different altitudes in different months of the year. The results of these observations can be compared with the standard meteorological data, later the correlation between them is taken into account.

The turbine is surrounded on three sides by buildings and a hill; and the prevailing wind direction is from the southwest according to the wind rose of Lappeenranta (LUT Green Campus, 2017). Based on the wind rose of Saint Petersburg, the most advantageous location of the wind turbine on the territory of Polytechnic campus can be oriented to west south west direction.

![Figure 3.3 Wind speeds of Lappeenranta and Saint Petersburg (Meteoblue, 2017).](image)

In practical use of wind power plants it is important to know, not the total amount of energy that a wind power plant can produce, for example, per year, but the power it can provide continuously. With a strong wind of more than 12 m/s, wind turbines generate enough electricity, and often it has to be dropped or stored. Difficulties arise during the periods of prolonged calm or weak wind. Therefore, for wind power, it is the general law to consider the regions with the average wind speed of less than 5 m/s not suitable for wind turbines. But regardless of this, in all cases, a careful choice of the wind farm parameters for the local weather conditions is required (Resolution №400, 2013).
The wind speed diagrams in the cities of Lappeenranta and Saint Petersburg (Fig.3.3) have many common features due to the fact that both cities are located on the coasts of the Saimaa Lake and the Gulf of Finland, respectively. As can be seen from the diagrams, the wind speed maximum is achieved in the winter months, but throughout the year the prevailing wind is more than 5 m/s, what indicates a favorable environment for the wind power development.

![Figure 3.4 Precipitation amount for Lappeenranta and Saint Petersburg (Meteoblue, 2017).](image)

The precipitation diagram in Saint Petersburg and Lappeenranta (Fig.3.4) indicates the number of days in a month a certain precipitation amount is reached. In areas with the tropical or monsoon climate, the forecast for precipitation may be underestimated. It is obvious that in these climatic conditions the utilization factor of the installed capacity in the annual cycle is not high enough, which is caused by the low solar radiation intensity during a significant part of the year (Ecology portal, 2017)

At the same time, the utilization factor of the installed capacity in the spring-summer period can reach high values and a research laboratory operating under the severe climatic conditions will be able to achieve high efficiency in the large facilities construction in the south of the country. The solar panels operation is complicated with the fact that the snow cover begins in October and lasts until April, adding to the maintenance cost during the winter.
The graph indicates the number of sunny, partly cloudy and overcast days, as well as the days of precipitation. The days when the cloud layer does not exceed 20% are considered to be solar; 20-80% of the cover is considered as a partial cloud cover, and more than 80% is considered as a continuous cloud cover. The Figure 3.5 illustrates that in both cities only half of all days in the year are sunny, the rest of the time the sky is cloudy.

The maximum electricity generation value is reached at the moment when the working surface of the solar panels is perpendicular to the solar radiation flux. With such a low number of sunny days given, the solar panels will not operate as efficiently as in the more southern regions. Nevertheless, the technological progress and technologies allow to install the tracking mechanisms. Dynamic mounting systems of PV panels provide automatic tracking of the sun position throughout a daylight and orient the solar panels in the direction of maximum energy production. Moreover, it provides the angle correction of the panel inclination depending on the time of year. The tracker system installation allows to increase the electricity generation by 30-40% compared to the solar power plants using fixed solar panels (Gevorkian P., 2011).

As can be seen in the figures above, Lappeenranta and Saint Petersburg have the similar annual production potential, with slight differences in the number of sunny days and wind roses. As in many northern cities, the best conditions for the solar energy production is
during the summer months, while the increase in wind speed occurs in the winter. The main difficulty in creating conditions for the effective solar energy generation is the day duration (Ecology portal, 2013).

The lengths of the day alternate more, the closer the Earth poles are. In Finland and Saint Petersburg, the day length is the longest in the summer and the shortest in the winter. In addition, during the winter months, the cities are covered with snow, what can impede the solar energy production. On the other hand, then solar radiation is weak, and, therefore, snow does not have a noticeable effect on the annual production.

3.4 Introduction to the Peter the Great Saint Petersburg Polytechnic University

Saint Petersburg Polytechnic University is well-known both in Russia and abroad, as the Polytechnic University was founded in 1899. After its foundation, it became one of the factors for the further successful country development, as there was the rapid development of the enterprises, economy stabilization and foreign investment growth. The main role of the university is the reproduction of economic, managerial, scientific and technical personnel, as well as the implementation of state scientific and technical activities (LUT Green Campus, 2017).

The university's extensive campus, located in the park zone in the north-west of the city, comprises 112 buildings (15 student dormitories, 10 residential buildings, the House of Scientists, medical and sports complexes, etc.) (Fig.3.6). A significant number of these buildings are monuments of the early 20th century architecture, and the Main building is one of the most outstanding examples of neoclassicism architecture.
The buildings of the Polytechnic University were conceived, built and designed very widely, humanely, with care for students, future Russian generation. The special majesty and solemnity of the hall, the architectural forms perfection and the unique acoustics made it one of the best university parade halls of Saint Petersburg at the beginning of the 20\textsuperscript{th} century.

Over time, the reconstructed buildings, as well as several facilities were awarded with the title of architectural monuments, what makes it difficult to install a modern equipment and upgrade existing systems, so as not to damage the architectural monuments.

\textit{Figure 3.6 Peter the Great Polytechnic University Campus.}
In the modern world, more space in the university is required for new research laboratories, so it was decided to build another university building. The Polytechnic University itself was the developer, who allocated federal funding for these purposes. The construction began in 2008. The building is located on the site of garages. In early 2014, the construction supervision service issued a permission to put the building into operation (Monzikova A., 2013).

The house is designed in the modest modern architecture spirit with a budget tiling. Its facade solution is similar to the neighboring historical building: the entrance is from the central university street along a semi-circular path, and the front door itself is recessed into the building.

Here, scientific and industrial laboratories are to be located, which were previously scattered over different buildings, as well as the "premises for scientific management, administration and management."

For more than 100 years of existence, SPbPU has undergone many changes: modern buildings have been built, the territory has changed, ownership and influence have expanded, monuments and laboratories have appeared. The renewable energy facilities installation in the campus will advantageously improve the overall impression of infrastructure facilities, attract investors and scientists, and illustrate that the university is ready to meet the future and adapt along with the younger generation and trends.

The territory of the Polytechnic University is very extensive and unified, it has a lot of free space and recreational zones. The total area is approximately 120 hectares. The Polytech is a small model of Saint Petersburg, therefore it is possible to develop and test new technologies on the campus basis, and then apply them on urban sites. The SPbPU act as a green island in the heart of Saint Petersburg.

Today, the university implements a strategic program for the modernization of the property complex, which was designed until 2025. It is planned to create a modern student campus,
including comfortable dormitories, spaces for study and recreation, a technology and innovation park and a sports complex with an ice skating rink(Table 4). Within the same program in 2016, a phased implementation of the Green Campus project has begun.

Table 4. Categories and plans of Green Campus strategy.

<table>
<thead>
<tr>
<th>Categories</th>
<th>Guidelines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Administration</td>
<td>- Organization of environmental management special department</td>
</tr>
<tr>
<td></td>
<td>- Sustainability center</td>
</tr>
<tr>
<td></td>
<td>- Long term plans for researchers in green energy facilities</td>
</tr>
<tr>
<td></td>
<td>- Funding</td>
</tr>
<tr>
<td></td>
<td>- Participation in world’s programs of protecting the environment</td>
</tr>
<tr>
<td>Energy</td>
<td>- District heating and cooling loop</td>
</tr>
<tr>
<td></td>
<td>- Natural ventilation</td>
</tr>
<tr>
<td></td>
<td>- Effective planning of learning environment</td>
</tr>
<tr>
<td></td>
<td>- Interactive information dashboards about the production and energy consumption</td>
</tr>
<tr>
<td></td>
<td>- Guide to reducing energy consumption</td>
</tr>
<tr>
<td></td>
<td>- Saving energy on non-academic time</td>
</tr>
<tr>
<td></td>
<td>- Preventing the blacklighting from the Polytechnic University to save energy</td>
</tr>
<tr>
<td></td>
<td>- Interactive solar panel on campus area</td>
</tr>
<tr>
<td></td>
<td>- Renewable energy facilities</td>
</tr>
<tr>
<td></td>
<td>- Smart grids introduction</td>
</tr>
</tbody>
</table>
Table 4. Categories and plans of Green Campus strategy... continued

<table>
<thead>
<tr>
<th>Categories</th>
<th>Plans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>- Green roof for water filtration</td>
</tr>
<tr>
<td></td>
<td>- Storm water plan</td>
</tr>
<tr>
<td></td>
<td>- Modernization of landscaping and buildings to help reduce pollutants in storm water</td>
</tr>
<tr>
<td></td>
<td>- Availability of drinking water in campus</td>
</tr>
<tr>
<td></td>
<td>- Optimizing the water resources usage</td>
</tr>
<tr>
<td>Green buildings</td>
<td>- Achieving design standards for eco buildings</td>
</tr>
<tr>
<td></td>
<td>- Achieving certifications for Green Campus</td>
</tr>
<tr>
<td>Waste reduction and recycling</td>
<td>- Waste audit</td>
</tr>
<tr>
<td></td>
<td>- Reduce the number of printing material. Paperless promotion and information on-line</td>
</tr>
<tr>
<td></td>
<td>- Separate waste collection in campus</td>
</tr>
<tr>
<td></td>
<td>- The garbage collection point for citizens</td>
</tr>
<tr>
<td></td>
<td>- Collection of hazardous wastes</td>
</tr>
<tr>
<td></td>
<td>- Outdoor compost bin</td>
</tr>
<tr>
<td>Food and dining services</td>
<td>- Cooking oil collected and recycled into bio-diesel in laboratories</td>
</tr>
<tr>
<td></td>
<td>- Decrease in food miles</td>
</tr>
<tr>
<td></td>
<td>- Organic products from Saint Petersburg and Leningrad region</td>
</tr>
<tr>
<td></td>
<td>- Healthy balanced food</td>
</tr>
<tr>
<td></td>
<td>- Sorting food waste</td>
</tr>
</tbody>
</table>
Table 4. Categories and plans of Green Campus strategy... continued

| Transportation       | - Ecology transportation through all campus area  
|                      | - Popularization of bicycles               
|                      | - Increase in the number of parking slots for bicycles  
|                      | - Cycle paths between University and a net of dormitories, bicycle transportation plan  
|                      | - Platform creation for electric cars       
|                      | - Increase in the number of charging stations for electric cars  
|                      | - Subsidies for environmentally friendly vehicles in the SPbPU motor fleet  
| Land usage           | - Students garden                           
|                      | - Integrated management plan of land usage  
|                      | - Park development and recreation zones     
|                      | - Farmers market and opportunities for community gardening  
|                      | - Decreased usage of hazardous chemicals in the gardening, such as pesticides  
|                      | - Ecology stabilization project             
|                      | - Infrastructure walking tours              
|                      | - Sensitive land use practice               
|                      | - Park as living laboratory of sustainability  
| Education and        | - Green Campus living laboratory           
| student activity     | - Volunteer program                        
|                      | - Special groups of students, focused on sustainability  
|                      | - Community work days in gardens            
|                      | - Sustainability leadership council         
|                      | - Sustainability related courses in the SPbPU programme  
|                      | - Campus gardens                            
|                      | - Qualification sustainability pledge       

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### 3.5 Overall potential of Green Campus

As a part of the work is to create an efficient environmental system, universities are a part of the environmental policy program. The environmental policy of the university's leadership helps not only to prevent environmental degradation and meet statutory and other requirements, but also to continually improve the environmental performance of the university. Environmental policy determines the University model for thinking and acting. In accordance with this, the cross-scientific research and teaching are used in an innovative way and are developed depending on the needs and requirements of the country. New technologies are born at the university, and it is the younger generation that can ensure a reliable and sustainable development. Therefore, at the University the space for new researches should be created, as well as the way of students thinking should be changed (Wirma, 2016). Following several actions on the strategy of matching the Green Campus, the Polytech will not only be able to reach the international level on Green Campuses and improve its position in the rating, but also to become the leading Russian institution of the green technologies creation (LUT Green Campus, 2017).

- **Environmental responsibility.** Decision-making in scientific research, academic education, social interaction and supporting functions should be accompanied by environmental responsibility and be traced in all areas of the university.
- **Research in favor of the environment.** On the basis of the University, studies should be conducted to protecting the environment and support sustainable development at the global, national and regional levels through the training of environmentally conscious academic experts and decision-makers.
- **Environmental protection.** Environmental protection must be influenced by activities that are under the control of the university, paying attention to the activities that can directly and indirectly affect and damage the environment.
• Monitoring, measuring and regularly reviewing the development of the environmental protection level. To reserve resources to ensure continuous improvement and analysis of progress.

• Compliance with environmental policy and requirements. Observe the requirements established for the university by law and authorities, and develop environmental activities in accordance with its obligations.
4. GREEN CAMPUS DESIGN

The Green Campus is one of the mechanisms for the transition to a green economy in the energy balance, which should ensure the sustainable development of Russia and the world community as a whole (Fig.4.1).

![Green Campus role in sustainable development and the transition to a green economy.](image)

The Green Campus is a comprehensive program consisting of technical, motivational, educational events designed to help companies to develop an internal environmental policy and to learn to take care of the University's resources. This program implementation will be integrated into the policy and the University culture by steps.

With the Green Campus program and facilities, it is possible to reduce the natural resources usage and contribute to the environment protection. The results of the Green Campus creation will help all those who wish to reduce energy consumption and resources for the maintenance of the educational institution. This means reducing harmful substances emissions into the atmosphere, primarily greenhouse gases, what are the main reason of the currently urgent problem of the global climate change.
4.1. Design procedure of wind power plant installation and barriers

The technical wind energy potential in the region is a part of the overall wind potential energy, which could be used at the modern equipment development level and compliance with environmental standards. The region technical potential is the sum of the technical potentials of the zones that create it. Based on the impact analysis of the wind power plants on the environment and humans, some environmental requirements for their location and appropriate alienation of the area are considered. It is important to take into account all the factors that will influence the further wind installations development.

The wind energy potential requires a sufficient technological level of wind power plants, expressed by the maximum achievable power depending on the wind speed, as well as the accommodation conditions for the maximum efficient use (Minina A., 2009)

One of the technical potential key parameters of the zone is the territory area of Saint Petersburg, that is suitable for the development and a wind station installation. $St$ is equal to the value of $q$ from the total area $S$ remaining after subtracting the areas of parks, campus, agricultural land, industrial and water management areas, boiler house and cultural facilities.

$$St = q \cdot S \quad (4.1)$$

Values $q$ are specific to a certain region, and in the present work the following positions are accepted for the Polytechnic campus and related to the Saint Petersburg region:

- Average wind speed in Saint Petersburg 2.0 m/s at a height of more than 10 m
- Operation coefficient of the windmill installed capacity with a capacity of more than 100 kW Order 18 - 20%
- The most efficient is the wind energy processing by means of wind power plants of high power (from 100 to 1500 kW).
The windmills location for maximum wind flow usage, as a rule, depends on the location on the site. Since in this thesis the possibility of installing mills without the harm to the campus image and ecology is considered, but for scientific purposes, the location cannot be calculated exactly, since the campus is too small. However, the installation of a wind generator must fulfil all the standards and requirements. Therefore, based on the studies made, it is accepted to place units at the distance of 10 to 15 diameters of windmills (Lavado M., 2015)

The windmill design differs with highly technological effectiveness, therefore, modern technologies and developments are used to create wind power stations, as well as the achievements of many industries. Such an approach can be considered as an example for the development of alternative energy types in the near future.

![Wind Speed Distribution](image.png)

*Figure 4.2 Wind speed distribution depends on the urban and rural areas.*

Due to the specific requirements for the windmill, the project at the Saint Petersburg Polytechnic University cannot be implemented even with the consideration of conditions as follows (Fig. 4.2):
• High vibration of the windmill. Because of the high-rise buildings around the Polytechnic University, the velocity vector changes and the installation of the wind turbine cannot be as efficient as the installation on the Saimaa Lake shore in LUT. However, in order to increase the height of the windmill externally, the wind turbine installation on the university building roof can be considered. Such a design is installed on the building roof and as a result of its operation it can destroy the structure with an increased vibration level and to deteriorate learning conditions, laboratory tests and educational process.

• High noise level. Wind farms create a high noise level, especially in the residential areas with one or two-story houses. Since a large plant comprises several windmills, windmill cannot be installed in the Polytechnic University, as it will be economically unprofitable, as well as it will destroy the living conditions of the citizens in Saint Petersburg.

• Destruction possibility due to strong wind. The potential destruction threat of the windmill creates an additional threat to the city residential areas, since such a facility weighs more than 100 tons. Its fall from a great height will be catastrophic for the urban population, as well as for the architectural ensemble. Also, such a design heaviness is not provided for the installation on the roofs of historical buildings, that are already forced to undergo additional loads during the winter due to the snow cover.

• Vacant areas deficiency in the city. The wind turbine requires a large space, that is not available in a modern city due to the high development density. Urban space can be used for urban greening purposes instead.

In general, when comparing these two alternative energy types, the cities energy supply by the conversion of solar energy into electrical energy seems more promising. Therefore, in this master's thesis consider two promising projects with solar energy (roof solar power plant and carport power plant) are considered, that can be developed and implemented at the Polytechnic University, as well as fit into the development strategy.
4.2 The Scientific and Research building.

The design of the solar panel installation on the roof of the Scientific and Research Center of the Polytechnic University will be considered as the example of LUT’s Green Campus, where examples of the certain installation angle usage, efficiency, and maintenance are given. The panels location on the SRB’s roof, as well as the degradation with which the solar panels are exposed over time, and finally the losses that the PV system may have are considered.

When the building was constructed, many factors were taken into account - the climate of the region in which construction is planned, the freezing depth of the soil, the groundwater level and snow load, since all this factors will affect the foundation (Fig.4.3). Next, the soil type on which the building and the location is erected - on a slope or in a lowland - was determined. The specific constructive elements weight - as a rule, we are talking about ceilings, walls and roof - also affects the choice of the foundation type. The specific weight will help to determine the load the building roof can withstand for further solar panels installation.
Figure 4.3. Flat roof view of the Scientific and Research Building.

General information about facility:

Year of construction: 2014

Number of floors: 3, basement, add-in mezzanine

The purpose of the building: non-residential

Exploitation: as Scientific and Research Building

Total area: 23419,5 m²

The structural features description of the building and sanitary and electrical engineering devices are given in the Appendix 1.
4.2.1 Environmentally sustainable solutions for SRB

In the master thesis solutions that allow to reduce energy consumption are considered in the terms of cost, predicted savings effect, payback period, and environmental impact.

Figure 4.4. Sustainable solutions indication of in Scientific and Research Building.

Solar panels on the roof will generate energy for the campus needs, among which is the lighting at night. The parking will provide charging of electric vehicles and develop the university parking structure.

Another project (Fig.4.4), the implementation of which is possible on the research building roof is a green roof. The green roof acts as an element of a storm sewage system, cleaning, filtering and containing rainwater during heavy rains. In addition, the green plantations are also an additional thermal insulation, that reduce heat input through the roof. The rainwater usage for flushing in the toilet bowls and for the green plantations watering reduces the
annual water consumption. To reduce the water consumption in the building, rainwater is accumulated and used. However, because of the urban legislative restrictions, the rainwater usage for toilets flushing is only for office premises, that is why it is possible to implement this solution in the student campus.

Efficient window structures and glass let in more rays of the visible spectrum, while reflecting up to 70% of thermal energy and reducing the load for lighting and air conduction systems. The usage of efficient equipment and devices in the building water supply system makes it possible to reduce water consumption.

![Figure 4.5. Indication of sustainable solutions inside the Scientific and Research Building.](image)

Implementation of sustainable solutions inside the SRB in the following steps (Fig. 4.5):

Each workplace has the individual management: ventilation and air-conditioning system (air flow on the floor air distributor), opening windows system to organize the natural ventilation and the sun blinding system on windows.

Light sensors. The lighting system is dimmable, equipped with the presence and motion sensors. Light sensors and automation system allow to maximize the natural lighting usage and to reduce the electricity consumption for artificial lighting by 40% per year (Melen P., 2013).
Building materials and structure affect the microclimate of a room. At summer nights, a material is cooled by natural airing of premises, and during the daytime – effectively absorb heat. Space-planning solutions (premises orientation with respect to the facade, rooms height, window structures height) taken into account to maximize the natural light usage. The color scale of the finishing materials was also selected taking into account the need for the maximum reflection of daylight.

The system of displacement ventilation with floor-mounted individually adjustable air distributors at each workplace ensures a comfortable stay of the personnel in the office premises.

### 4.3 Flat roof solar power plant

Despite the fact that the renewable energy sources are free, equipment, solar panels in particular, is the most expensive component of the project, as it depends on the type, manufacturer, efficiency and service. Considering the panels size could be varied on the roof, during the design of the parking project the panels must be of a certain size, what considerably increases their cost. If the goal is to optimize the carport solar power plant while not changing its dimensions, solar panels of better efficiency, and most likely more expensive, should be taken into consideration. The result will be a higher price system, though a more profitable final price per watt.

To estimate roughly the project cost, the mentioned requirements for the panels installed on the roof should be taken into account:

- Ability to withstand a mechanical load of up to 6000 Pa due to the threat of collapse during a snowy winter
- Long-term warranty on the panel, at least 10 years
- 25 years of performance warranty. Productivity will decrease every year, what will affect the payback period, though after 25 years the panel should be in the working order
- Easily replaceable inverter and the panels must be connected with different connections
- Easy approach should be provided to maintain the panels
- Safety must be respected and access to the roof of a certain number of people

In order to get an idea of the approximated total price per installed watt, the following equation (4.2) can be used for both flat roof and carport.

\[
Total \text{ Price}_{flat\ roof} = PanelPr_{flat\ roof} + \frac{Pr_{others}}{PanelP_{flat\ roof}} \quad (4.2)
\]

where \(PanelPr_{flat\ roof}\) – panel price [€/W], \(Pr_{others}\) – total costs minus panel price [€],

\(PanelP_{flat\ roof}\) – panel power [W]

In order to maximize the solar collector efficiency, the orientation and the inclination angle of the collector are very important. To absorb the maximum amount of solar energy, the solar collector plane should always be perpendicular to the sun's rays. The support’s angle is chosen by the Solar Advisor Model and optimal angle for Saint Petersburg is 41°. The azimuth angle is also important and when it is possible, 180° should be chosen (System Advisor Model, 2017)

Moreover, dependence on the solar cell inclination can be observed in the azimuthal inclination, (Fig. 4.6) where it is shown how the slope angle depends on the coordinates.
For the supports installation it is recommended to use aluminum supports; the recommended distance is 2.8 m between rows of panels. The distance between the rails should be the same all the time, since it depends on the panel length.

Figure. 4.6 Azimuthal inclination (Solar Soul, 2012).

Figure. 4.7 Flat roof supports and dimensions (Schletter, 2013)
For the efficient performance, the panels should be limited from possible shadow sources. On the roof of the research building the main sources of shadows are ventilation pipes, roof windows and walls (Fig.4.7).

Since the design was not originally part of the project, there are no additional supports on the roof, to which the panels could be attached. Consequently, the supports of the supporting system should be loaded with cargo, so that in case of sudden gusts of wind and other weather phenomena the structure is stable.

In general, the solar collector orientation depends on the option of installing solar collectors, the collector installation is done on the building roof, so it is very important at the design stage to consider the possibility of optimal collectors installation.

### 4.3.2 Weight on the roof

The choice of a flat roof of the building was justified by the following advantages: reduced price; simplified installation, easy maintenance, and the possibility of obtaining additional useful space, where a roof solar plant could be located. The main element of the flat roof is a solid base, made in several layers. Moreover, in Saint Petersburg there is a danger of high snow loads, so for the roof a combined roofing on reinforced concrete slabs of two layers of roofing material was selected.
Roofs are limited in space and often represent problems of placement, shading and waterproofing. On the one hand, if the existing roofing system is more than a few years old, it may require the replacement as a part of the PV installation. On the other hand, if the roof system is new, the PV system upgrade may deprive the roof guarantee. The structure itself may not be adequate to support additional loads.

At this point in the designing phase (Fig. 4.8), the total roof weight has to be considered, since additional weight to the racks consequently increases the roof weight that has its limit. Whether or not the solar plant is going to be covered by snow during the winter, the snow load has to be taken into account in the weight calculations.

Weight from wind, extra cable length and their protection casing and protection mats are left apart in these calculations.
\[ m_{after}' = m_{support}'' + \frac{m_{panel} + m_{ballast}}{A} \]  \hspace{1cm} (4.3)

where \( m_{support}'' \) - Support density area [kg/m\(^2\)]

\( m_{panel} \) - Panel weight [kg]

\( m_{ballast} \) - Ballast weight [kg]

A - Installation area per panel [m\(^2\)]

Considering the amount of packed snow has not being reached in the last two winters the solar plant has being operative, which so far, means less maintenance costs.

### 4.4 Carport solar power plant

Carports are an ideal solution for businesses who would like to invest in a solar PV system but do not have appropriate roof spaces. Carports also have the additional benefit that the car park can still be used for its intended purpose whilst simultaneously providing a good return on an otherwise unproductive space. Carports can be designed to fit existing spaces and can be configured in a variety of ways. It could also be installed in a range of heights so that companies with a fleet of small and medium vans can use the carpark benefit (Lavado M., 2015)

The optimal solution for productive work will be determined by finding the location, the impact on the chosen site and the interval between the machines. Large parking lots can include a port system that will cover two rows of cars, where larger panels can be used, which reduces the project cost.
Figure 4.9 Area for the carport solar power plant near the SRB.

The parking area with solar panels near the research building will be an indicator of the energy efficiency and one of the Green Campus symbols. The parking covers the area of approximately 1400 m$^2$ (Fig. 4.9).

The parking system of the SRB should provide a number of advantages when used:

- Simple materials usage for the parking design to reduce its cost, payback period and make a smooth shift for easy parking.
- Ability to use a wide range of types and models of solar panels
- Aluminum fasteners ensure durability and long interruptions between periodic maintenance
- Gutters to collect rainwater, which could be used in other systems.
- Additional charging points for electric vehicles built into the structure.
One of the drawbacks of the renewable energy, namely the solar generation drawbacks, is the station's occupation of vast areas that can be used for agricultural purposes, home construction and parks. Not all roofs are well suited to accommodate a PV array. Therefore PV-careers, awnings and shadow structures are an attractive option for system integrators and potential customers.

For several years, the entrance for vehicles to the territory of the Polytechnic University takes place on the basis of a system of passes and is limited to students, stimulating travel on public transport and the bike parking usage, that are constructed more and more every year. However, the parking near the SRB is necessary to park the motor transport of the management and the rector's staff. The list of the requirements for the carport solar power plant is as follows (SP 113.13330, 2012):

- According to the typical parking places in Russia the area for a single car should be no less than 2.0 m x 5.0 m and no more than 2.8 m x 5.5 m.
- The construction could be modular with only bolt connections without the need for welding on site.
- The minimum height or clearance of the carport has to be, for example, 3 meters to make sure the snow work vehicles can clear the area during winter.
- In one slot (the area between the support structures) there will be 2 cars to save space and reduce the panels cost.

Each of these carport units has 10 vertical support structures separated one from the other by a 5 meters parking gap for 2 cars. The total length of the carport system (3 carport units) is approximately 200 meters and this has the capacity for 48 cars.
The structure of the 15° system carport is made out of aluminum and is completely modular, meaning that there is no need for welding, and, thus, the installation time is saved. Because of the close location of the research corps, the parking floor will be in the shadow of the building, so the slope will face the SRB in the direction indicated by the arrow B in the Figure 4.10. This structure is used as a solar panel support and as such the panel inclination is of major importance, though in this case panel inclination is not subject to additional weights, a larger angle would have made the carport look awkward and lose functionality.
5. GREEN CAMPUS STRATEGY

In the leading countries, Green Campuses is the key to the environmental programs development and the renewable energy projects implementation. It is extremely important that the main project-forming and active participants of such Green Campuses are students, undergraduates, young scientists whose creative potential will help to develop new technologies and abandon the fossil crowd.

The Polytechnic University has every chance to become the first university in Russia with all the attributes of the Green Campus. To achieve this goal, you need to achieve the following:

- Physical attributes. The green energy objects, energy efficiency equipment and sustainable physical environment: buildings, laboratories, facilities, technology and infrastructure.
- Living laboratory. Development and demonstration of the sustainability solutions, researches and teaching from Green Campus objects and future development for enterprises.
- Culture. The university's Green Campus means a society where all employees and students practice sustainable behavior in their daily live, make decisions considering the consequences for the environment and follow the rules of a sustainable lifestyle. Sustainability and the resource usage efficiency should be introduced and be gradually realized in the organization of the SPbPU, and also sustainable solutions should be traced in the university management.

In each area, the university must take a number of actions to achieve the Green Campus standards. For this purpose, in a master's thesis the SPbPU environment management program was developed [Appendix 1].
5.1 Algorithm of actions for the SPbPU

The Green Campus on the territory of the Polytechnic University will allow to solve a whole complex of tasks of three directions:

- Economic – saves resources, reduces energy consumption, renewable energy facilities provide additional output.
- Ecological – reduces emissions of harmful substances into the atmosphere and improves the waste processing.
- Social – strengthens the reputation and image of the university, educates people in the principles of the environment concern.

![Diagram of resource conservation principles](image)

*Figure 5.1. Basic principles for conserving resources in the Green Campus.*
The economic and environmental benefits of the "green office" are the reduction of unnecessary costs and careful attitude to resources. The most popular component is the paper usage reduction – from printing on "revolutions" to electronic document management – and putting waste paper. (Fig. 5.1) For example, one ton of waste paper saves 17 trees (Gevorkian P., 2011). In addition, recycled paper costs less than fresh sheets of wood.

Furthermore, to increase the efficiency, the movement of green campuses should now turn to managing organizational changes and base its strategies on a more thoughtful understanding of the way universities really function. Such an approach will allow people to understand the unlimited possibilities for increasing innovative transformations and adopting the system approaches for controlling the "ship" and directing it to the right goal. New higher levels of governance and decision making matrix should be developed to ensure efficient interaction between faculties, departments and research centers in the same campus that has embarked on the course of sustainability in its development. The model of interest acceptance, responsibility and control is needed that would unite the pro-rectors, personnel departments, teaching staff and other units in higher education institutions into the one vision and goal.

The Green Campus is a project in which there are no limits and everyone can find their own mission in it, to translate their ideas into life and realize the potential. The Green Campus platform to begin to act, the basic steps are required to be implemented:

- Establishing a Green Campus Committee with students and staff;
- Undertaking the environmental review;
- Implementing the action plan;
- Monitoring and evaluating actions carried out;
- Linking the program to curriculum work;
- Informing and involving the campus and wider community;
- Developing the green charter.
To optimize the energy usage, the Smart Grid system should be implemented. Continuous network measurements provide detailed information about the use of electricity, i.e. when and where electricity is used. The measurements results are used in the energy efficiency plans. If necessary, the load of the intelligent grid could be controlled. The idea of the Smart Grid is to equalize peak loads by shifting the load to the network or, for example, turning off the heating of one house for one hour during a peak load.

Smart grids are very important when using renewable energy, since the generation is uneven and the battery is used for the energy storage. This will allow batteries usage to equalize the peak loads. The batteries are charged during the off-hours, and during the peak loads they supply electricity to the network.

Small decentralized energy production units, such as small wind and solar power stations, could be connected to an intelligent network. The smart grid is more secure than conventional networks and is more resistant to different weather conditions.

5.2 Introduction of renewable energy facilities at the regional level

The Green Campus includes not only as the sustainable development area for students, but also as an interactive platform for future projects and the renewable energy integration at the regional level of Russia. It is very important, both for regional authorities and for business people, to have the interactive renewable energy objects to illustrate its capabilities and show all opportunities for their implementation. The one of such projects could be the manual solar tracker in the Polytechnical University’s park and its on-line system for research and monitoring the energy production (Fig.5.2).
Each person could conduct to research and monitor the efficiency of manual solar panel in Saint Petersburg, inspect the changes on the special web-page. (LUT Green Campus, 2017) The idea is to observe the changes in the panel's efficiency at different times of the day, under different weather conditions, with shadows and other external influences on it. The information policy of the university all projects should be implemented, as well as excursions to laboratories and promotion of students scientific works about sustainable development.

After the experimental facilities in the Green Campus territory, renewable energy, energy of the future, will be gradually introduced into the energy balance of the Russian regions. Algorithm of actions at the regional level for the implementation of objects operating on the basis of the RES (Federal Law № 35-FZ, 2007):

1. Substantiation of the subjects needs in the Russian Federation in electric and thermal energy, as well as needs in fuel, the satisfaction of which is possible due to the RES usage (potential need): Drawing up a list of settlements by the RES subjects not connected to the general consumption networks and points using imported fuel for heating, cooking hot water and food; drawing up a list of Russian regions subjects with unsustainable power supply or restrictions on connection to public networks (connection failures), and clarification and analysis of existing developments (programs) for the use of the renewable energy sources.
2. Definition (clarification) of the available RES in Russian subjects by sources. Solar and wind energy, small hydropower, biomass energy, low-potential heat, peat.

3. Drawing up a list of existing plants using the RES and peat in the Russian subjects, indicating the technical and economic characteristics and determining the volume of their production of electrical and thermal energy, fuel.

4. Drawing up a list of equipment and technologies based on the RES, the usage of which is possible in the region (domestic and foreign production).

5. Defining the program objectives (defining the validity period; determining the share for the time interval; determining the volume, capacity; reducing the level of expenditure, the number of jobs created).

6. Drawing up the list of objects constructed under the program.

7. Elaboration of proposals on legislative and normative support of the program and the production stimulation of electric and thermal energy, fuel.
CONCLUSION

Even though there is no doubt about the amount of solar radiation arriving to our planet and its possibilities still, for a northern town as Saint Petersburg, the society is skeptical. The goal of this work was to show the existing prospects of renewable energy and the number of development opportunities. In addition, another aim was to document and propose the Green Campus model at the SPbPU, so that other students and people can make their own conclusions about this kind of projects in Russia.

The study was based on the existing LUT Green Campus, where for several years renewable energy facilities have been functioning successfully and promoting the RES researches.

The renewable energy sources introduction makes it possible to increase the energy security of the regions in Russia and to increase the self-sustainment ratio. Despite the fact that Russia possesses huge resources of wind, geothermal energy, solar energy, biomass energy, hydropower resources, at present renewable energy sources (except for large hydropower facilities) are not commonly used in the country.

There is still a number of economic and technical problems that hamper the large-scale development and dissemination of renewable energy technologies. To overcome these problems, the further progress is needed in costs reduction through training, scaling up activities, creation of flexible investment conditions, integration of renewable energy technologies into existing energy systems, building up researches and development. The Saint Petersburg Polytechnic University is ideal for these purposes.

The Green Campus is a comprehensive program consisting of technical, motivational, educational events designed to help companies to develop an internal environmental policy and to learn to take care of the University's resources. This program implementation will be integrated into the policy and the University culture by steps.
The Green Campus includes not only as the sustainable development area for students, but also as an interactive platform for future projects and the renewable energy integration at the regional level of Russia. It is very important, both for regional authorities and for business people, to have the interactive renewable energy objects to illustrate its capabilities and show all opportunities for their implementation.

This thesis is the beginning of the global project that can become truly successful in Russia. The Polytechnic University already occupies the leading position in the development of new technologies, whereas the Green Campus can give a promotion for the development of even larger profiles and educational programs. As a master degree student I am going to continue my research and take part in the Green Campus realization during the PhD studies.
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### Appendix 1.

<table>
<thead>
<tr>
<th>Name of structural elements</th>
<th>Description of structural elements</th>
<th>Technical condition (sludge, cracks, rot, etc.)</th>
<th>Specific weight of structural elements</th>
<th>Physical deterioration, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foundation</td>
<td>Modular reinforced concrete</td>
<td>Without visible defects</td>
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<td>0</td>
</tr>
<tr>
<td>Walls and exterior finish</td>
<td>Reinforced concrete columns, monolithic reinforced concrete carriers, aerated concrete blocks with insulation and finishing with ceramic granite tiles</td>
<td>Individual cracks and potholes</td>
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<td>5</td>
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<td>Partition</td>
<td>Monolithic, aerated concrete blocks</td>
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<td>6</td>
<td>0</td>
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<td>beams</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attic</td>
<td>On reinforced concrete beams, monolithic reinforced concrete slab</td>
<td>Without visible defects</td>
<td>10</td>
<td>0</td>
</tr>
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<td>Basement ceiling</td>
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<td>Description of structural elements</td>
<td>Technical condition (sludge, cracks, rot, etc.)</td>
<td>Specific weight of structural elements</td>
<td>Physical deterioration, %</td>
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<tr>
<td>Interior trim</td>
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<tr>
<td></td>
<td>Suspended ceilings, plaster, painting with water-dispersed paints</td>
<td>Without visible defects</td>
<td></td>
<td></td>
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<tr>
<td>Sanitary and electrical devices</td>
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<tr>
<td>Water supply</td>
<td>From the city’s central network</td>
<td></td>
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<tr>
<td>Sewerage</td>
<td>The discharge to the city network</td>
<td></td>
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</tr>
<tr>
<td>How water supply</td>
<td>Centralized</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Bathrooms</td>
<td>Shower rooms</td>
<td></td>
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<tr>
<td>Lighting</td>
<td>Open wiring</td>
<td></td>
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<tr>
<td>Ventilation</td>
<td></td>
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<tr>
<td>Elevator</td>
<td>4 pc. for passengers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 pc. for technical purpose</td>
<td></td>
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</tr>
<tr>
<td>Alarm</td>
<td>Fire safety, security</td>
<td></td>
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<tr>
<td>Gas supply</td>
<td></td>
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<tr>
<td>Other services</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Double-span overhead cranes</td>
<td>Without visible defects</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Stairs and entrances</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Porch, prefabricated reinforced concrete stairs, ramp</td>
<td>Without visible defects</td>
<td>7</td>
<td>0</td>
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<td>100.0</td>
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</tbody>
</table>
### ENERGY

**Reducing energy consumption**
- Reduction the total energy consumption of the university by at least 5% through management and renewal of energy consumption
- Reduction of non-energy-efficient equipment
- Installation of light sensors and water consumption sensors, as well as optimization of energy consumption at night
- Reduction the energy consumption and optimization the main campus lighting
- Coverage of electricity costs from the general grid in accordance with actual consumption
- Optimization of the boiler room in the Polytech
- Energy facilities Maintenance on campus

**Increasing the utilization of renewable energy sources**
- Investigation in solar energy and wind energy projects as Green Campus
- Partial coverage of used energy by renewable sources on campus
- Development of new technologies and improvement of existing ones for renewable energy
- Efficient free parking spaces usage and carport solar plant installation
- Increase the renewable energy share in the overall energy balance
NATURAL RESOURCES AND WASTE

**Minimising the amount of waste generated in SPbPU's operations**

- Invest in sorting garbage and install assembly chambers on campus
- Develop biomass optimization from food production on the campus
- Make the university a point of hazardous waste collection with proper disposal (batteries, batteries, light bulbs and other household hazardous waste)
- Develop a recycling and waste management system and make sure that the SPbPU staff and stakeholders on the campus follow the sorting instructions for waste
- Carry out garbage collection for students and city residents

**Reducing water consumption**

- Reduction of total water use at the university
- Renovation, examination and increase of the water efficiency research
- Optimization the water consumption
NATURAL RESOURCES AND WASTE

<table>
<thead>
<tr>
<th>Life cycle management of hazardous waste</th>
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</thead>
<tbody>
<tr>
<td>• Storage of proper disposal and hazardous waste</td>
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<tr>
<td>• Packaging and hazardous waste labeling</td>
</tr>
<tr>
<td>• Organization and training of students in handling hazardous waste</td>
</tr>
<tr>
<td>• Safety improvement for student and staff of University</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Increasing environmentally friendly procurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Preference for more energy-efficient equipment</td>
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<tr>
<td>• Procurement of green labels</td>
</tr>
<tr>
<td>• Standardization of developments to all environmental and green standards</td>
</tr>
<tr>
<td>• Legal and accounting control services for environmentally friendly procurement</td>
</tr>
</tbody>
</table>
### SCIENTIFIC RESOURCES AND ACADEMIC EDUCATION

#### Research and educational process
- SPbPU students and staff conduct and publish high-level research that improves the environment state
- International relations improvement, experience exchange with other “green” universities
- Introduction of courses and educational programs related to the environmental protection theme and renewable energy
- Study of renewable energy at real objects in the university laboratories
- Students' stimulation in studying ways of Russian transition to renewable energy

#### Academic experts and decision-makers with expertise in sustainable development
- Orientation of all students with environmental problems
- Organization of activities related to environmental protection
- Information environment for students and teachers about problems and achievements
- The general collation of both students and institutions in the successful projects development
- Participation of foreign professors and foreign experience usage
TRANSPORTATION

Decrease the environmental impact of transportation around Campus and reduce traffic jams in Saint Petersburg

- Create a more favorable structure of movement within the campus between the buildings
- Electric and solar cars development as a Polytech project
- Public transport popularization
- Promotion of healthy lifestyles and bicycles usage by young people
- Increase the paid parking spaces for students and staff

The using of parking areas around campus

- Development of carport solar plant near the Scientific and Research Building
- Research and popularization of projects for public parking near shopping centers, airports, public parking lots in Saint Petersburg in general, as well as throughout Russia
- Cooperation with the largest oil companies to improve fuel quality, environmentally friendly petrol development
- Development of biofuel based on woodworking companies
### IMPACT OF ENVIRONMENTAL MANAGEMENT SYSTEM

**Expanding the impact of the environmental management system**

- Interest in the use of technology in other units of the Polytechnic - tasks will be expanded depending on the organization and objectives.
- Companies interest in the development and scientific research of new renewable energy technologies based on the Polytechnic University and the willingness to cooperate.
- Increase of international relations and access to the international level with its own green campuses.
  
  The carbon footprint from SPbPU can be as indicator of progress for Paris agreements as over the world decarbonisation until 2100.
- Carbon intensity index will be selected for the university's investment portfolios.

**The sustainable development**

- Sustainable development and improvement an efficiency of equipment in the field of renewable energy.
- Modern view positioning of the energy future.
- Presenting effective technologies and involving students in development and modernization.
- Area for new research and the new training courses creation on the basis of the Institute of Energy and Transport Systems.