What does a **building performance** mean? Earlier designers just partly thought about its meaning or didn't think about it at all. Nowadays it is more and more common to consider ecology because it touches upon all parts of human life and activities, which includes such a huge field as **design and building**.

Regulatory frameworks set up types of materials which are used in building: heat insulation's requirements, windows' characteristics and other indices of new buildings and also existed buildings while its reconstruction. It vividly shows the way of solving problems connected with greenhouse gases' outburst as buildings with high level of energy use contribute to such outbursts. Building opportunities will become higher if they are added with other operational standards. In the «Advanced Buildings Benchmark^{TM}» publication the New Buildings Institute, Inc. requires to show both calculated and de facto data of energy use, as it is used in Russia and Kazakhstan. In spite of the fact that regulations, aimed to provide energy efficiency, exist in many countries, in a few of them they are carried. Usable Buildings Trust considers Australia, The USA and Great Britain to be the countries which give these regulations up less than others.

According to Loren Berkly's National Laboratory (California) all the buildings consume approximately a third of all energy output in the world. It is used to heating, conditioning, lighting, water supply, and other systems of building life cycle. In 2005 a consulted company "Ecofys" made a research according to which the potential economy of building energy use in the world is 50%. It means that with the help of effective strategy of building performance it is possible to decrease energy use almost on 17% which is more than two thirds of gross energy use in European Union in 2005.

The building energy use is growing very fast as a growing living standard in developing countries. "It is necessary to launch building standards and its tough control where a building up is up-tempo" says Silvia Rezessy, the energy efficiency advisor in Renewable Energy and Energy Efficiency Partnership (REEEP). Launching of such factors is the most perspective for emerging countries.

Scale 1. Building up in 2002-2005 yrs. In Russia, K/m2

Building type	**2002**	**2003**	**2004**	**2005**
Apartments	19 566	21 092	24 854	26 038
One famuly	14 210	15 174	16 145	17 571
Total:	33 776	36 266	40 999	43 609

In Russia a building up is taking into consideration new energy efficiency standards which are proven in 2001. It is very used in Moscow where 20% of buildings are built according to the new standards. As a result of economic growth in Russia which is 6,4%, the growth of building up during 5 years is forecasted. It is planned to build 250 mln m2 of dwelling.

Next to Moscow there 49 regions in Russia and for the last three years many energy efficiency standards in building were adopted. But it is difficult to follow the standards when a country is developing very fast. So the REEEP and the Institute for advanced studies (IMT) are working together to work out improved methodology of energy efficiency standards.

Using this method the governments of 53 regions in Russia adopted energy efficiency standards by 2006. This direction is absolutely new for Russia. Energy efficiency should become the key factor on such stages as designing, building up, survey and sailing new buildings.

But there is a question “Why is ecological dwelling or other building performance so expensive?” The answer is simple. Expensive is only to build but during its life cycle it will be compensated what is proven with the Green Building Studio.

The aim of the project is to find out how the scope-planning and design constructions depends on the energy efficiency based on the calculation of the whole building life cycle by the example of a cultural and business complex.

Astana was chosen as a place of designing. This city is open to courageous architectural solutions. Astana is a new and young city so it can be compared with a new technologies test’s field. Surrounded building up doesn’t affect on the design project because of low-rise buildings of the main part of the city. There are many vacant places to make new buildings and complexes what was one more reason to chose the city for the project.

Project goals:

- To reveal how a building form, its space orientation, climate (wind, temperature, humidity) affect building performance, general and specific (heating, ventilation, conditioning, lighting);

- To reveal the way how window placing (percentage-wise) affect building performance (heating, ventilation, conditioning, lightning);

- To show the impact of design features (the glass material – a glass unit formula, a material of enclosing parts, inside partition, floor panel and a covering material);

- To reveal the impact of the chosen heating, ventilation and conditioning system (HVAC).

The main goal of the project is to find the maximum balance of building performance and its aesthetic appeal.

For the purposes of the project the complex analysis was made. It consists of four stages of high building forming (fig.1). The analysis was made under the principle of improving aesthetical appeal together with increasing building performance.

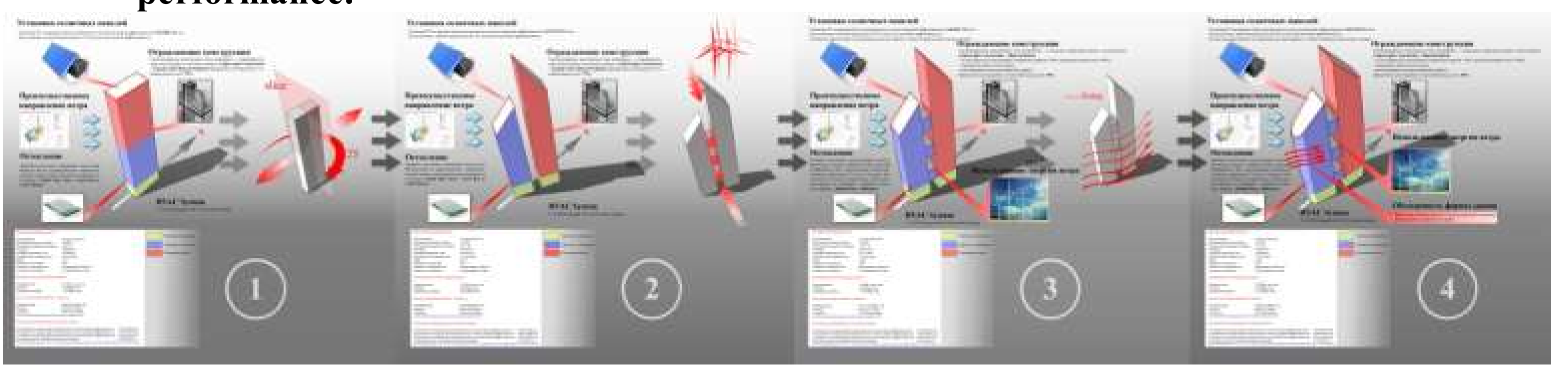

Figure 1. Analysis of building forming depending on factors affecting building performance.

The subject of analysis is a multi-purpose business building with the following functions:

- Residential (hotel space)
- Business (office space)
- Trade (retail space)

Building height is 40 storeys. The inspiration for this project came from such a natural phenomenon as the stone in desert (fig. 2) was formed by wind, sun and rain. With time it seems to adjust the environment:

Рисунок 2. The influence of natural factors on the stone in desert.

According to this example we made the analysis of high building forming depending on natural factors' influence as a result of which the most supportive environments which affect increasing building performance were found.

Energy efficiency analysis:

<u>The subject #1(fig. 3):</u>

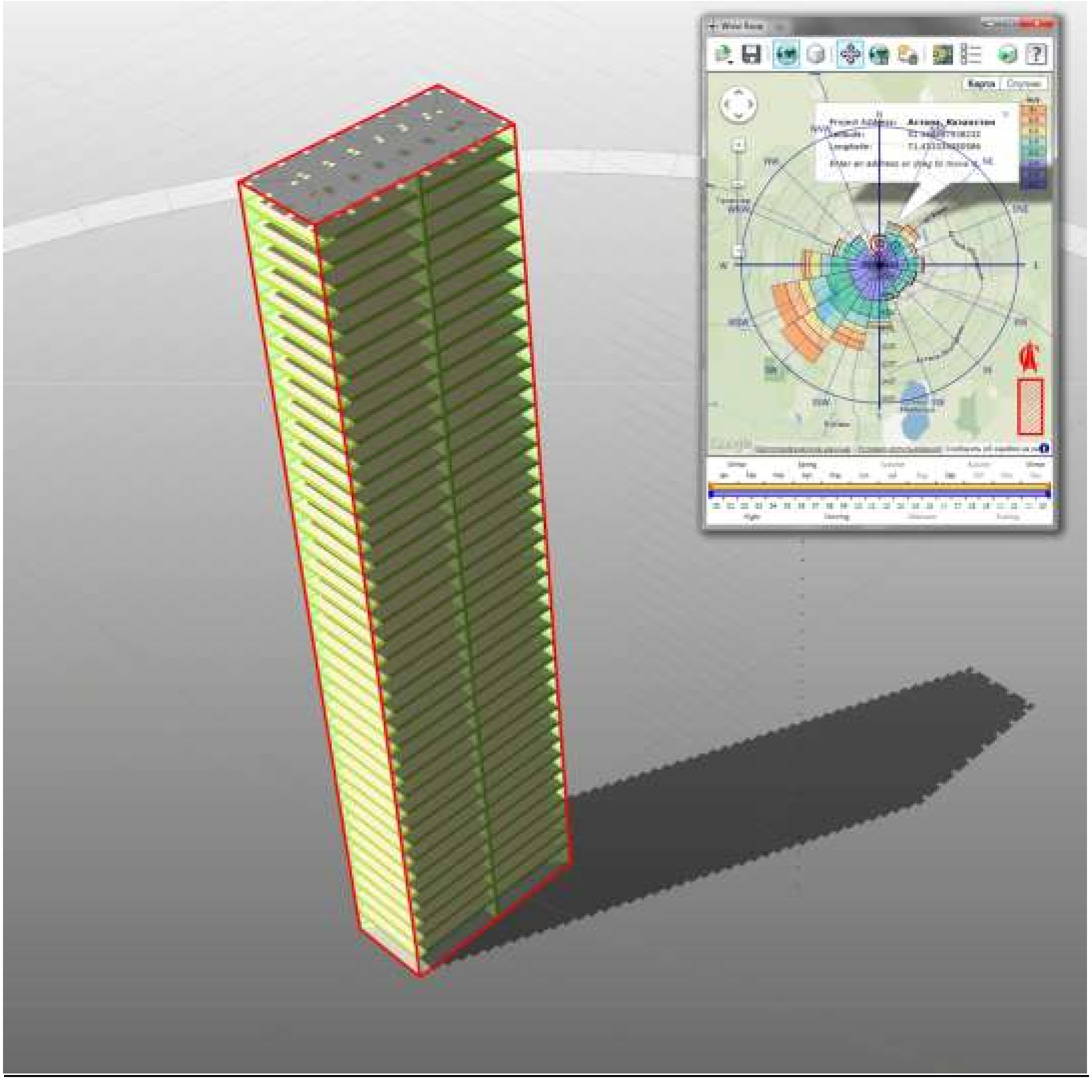

Figure 3. The subject's form #1.

The first form is a rectangular volume sized 15x33 and 40-storeys. The optimized wideness of the building allows to place any types premises with its depth of no more than 6 m, which is recommended by SP23-102-2003 as a normal premises' depth. It also allows to separate space for private offices with 2/3 ratio and open spaces.

The subject's data:

- Geographic location: Astana, Kazakhstan. Exposure is meridional.
- Purpose of use: cultural and business complex which includes retail spaces (first 4 floors), office spaces (18 storeys) and hotel space (18 storeys).

Visionary design:

- **Outside wall**: translucent structures like stained glass used in cold climate. (**Lightweight Construction – Typical Cold Climate Insulation**) Percentage-wise from the main wall area is 75%.

- **Interior walls**: partition of non-translucent materials like brick, plasterboard, tongue-and-groove boards (**High Mass Construction – No Insulation**).
- Outside walls of underground parking: non-translucent constructions with low level of heat conductivity used in cold climate (**High Mass Construction – Typical Cold Climate Insulation)**.
- **Roof material**: high level of heat insulation, dark roof (**High Insulation - Dark Roof).**
- **Covering material**: laminated plastic/ceramic-granite (**Lightweight Construction – No Insulation)**
- **Slab panel's material**: high-strength constructions with low level of heat insulation, cold climate (**High Mass Construction – Cold Climate Slab Insulation**).
- **Glazing**: triple glass unit, translucent glass like Phoenix Clear, capacities – hot/cold climate, low-emission coating with 6 items (**Triple Pane Clear - LowE Hot or Cold Climate).**
- **Average height of window sill is 750 mm**
- **Heating, ventilation and conditioning system**: (HVAC) - 11.3 EER Packaged VAV, 84.4% boiler heating
- **Floor space**: 19800 sq.m.
- **Square of enclosure structure**: 13536 sq.m.

The following calculations were held according to building performance:

- Analysis of how solar energy affects heating, ventilation and lighting depending on climate peculiarities, building form and its orientation.

- Analysis of how wind affects heating systems (during cold period of a year) and building constructions.

- Analysis of forming – how building form affects energy cost, connected with wind and sun influence.

- Climate analysis (temperature difference, cold and warm year periods, humidity etc.)

1. Solar radiation analysis (Fig. 4):

- Exposure is meridional
- Measure date is July 22
- Window area is 75%

Analysis showed that the maximum solar heat is taken by roof covering – 0.5 kWh/m2, where solar batteries could be placed. In this situation we can receive 362,386 kWh/year of alternative energy according to maximum effectiveness. East wall will get 0,35 kWh/m2, south – 0,38 kWh/m2, west – 0,4 kWh/m2, what will negatively affect **conditioning and ventilation** during summer.

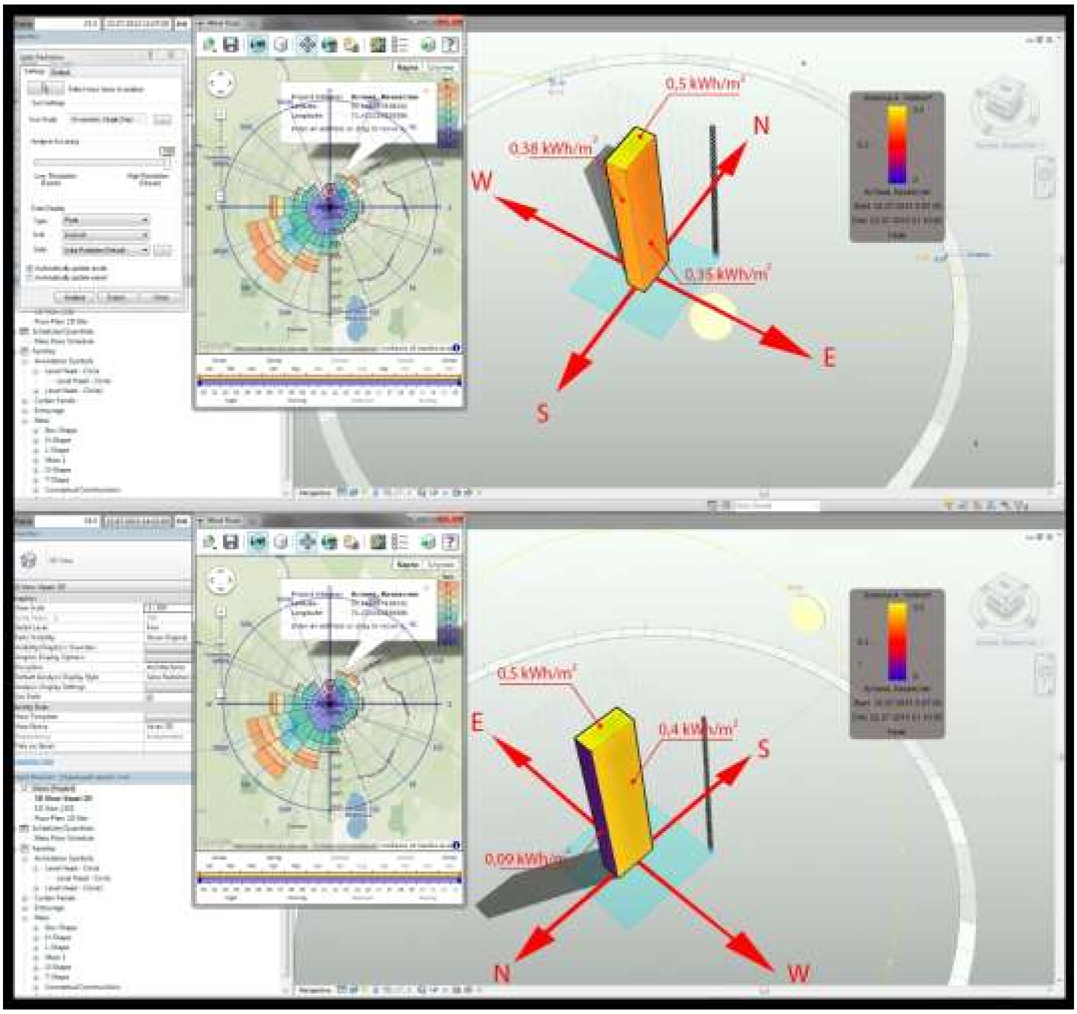

Figure 4. Solar radiation analysis.

The highest level of energy uses on conditioning of this building since March till October (fig. 5) and makes up approximately **4600000 mJ per year** what is almost the third part of general conditioning expenses. The rise of expenses also connects with building exposure. The rest part of energy is used on conditioning heat from lamps, temporary equipment and other equipment what makes up almost 45% from all the expenses.

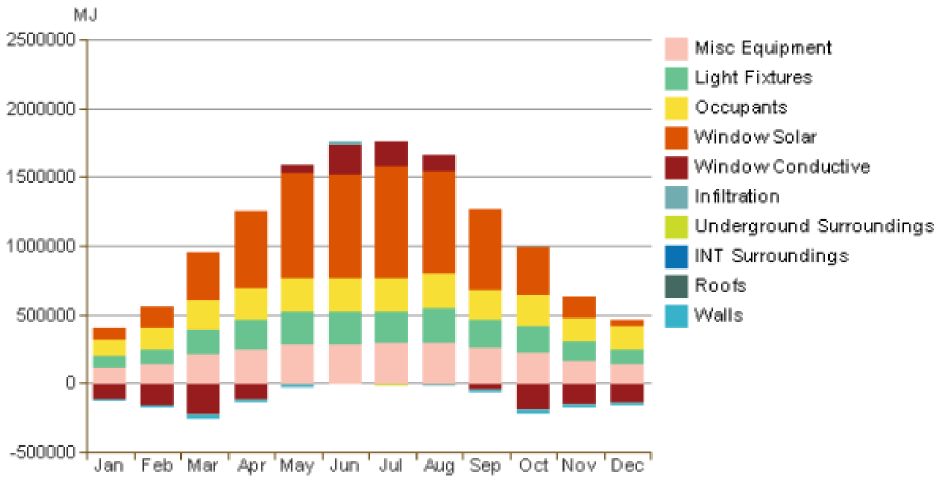

Figure 5. Annual data - conditioning (mJ per month). How external factors affect conditioning energy use.

- The scheme reflects how different equipment and building systems affect conditioning. It shows how heat gets into building (through glazing mostly) and what exactly provides with additional building cooling.

You can see that during summer period heat goes through window opening. The same situation with cold during winter period.

2. A huge area of window opening (75% from the whole envelope) is directly-proportional to increasing expenses connected to building **heating** during cold year periods (fig. 6).

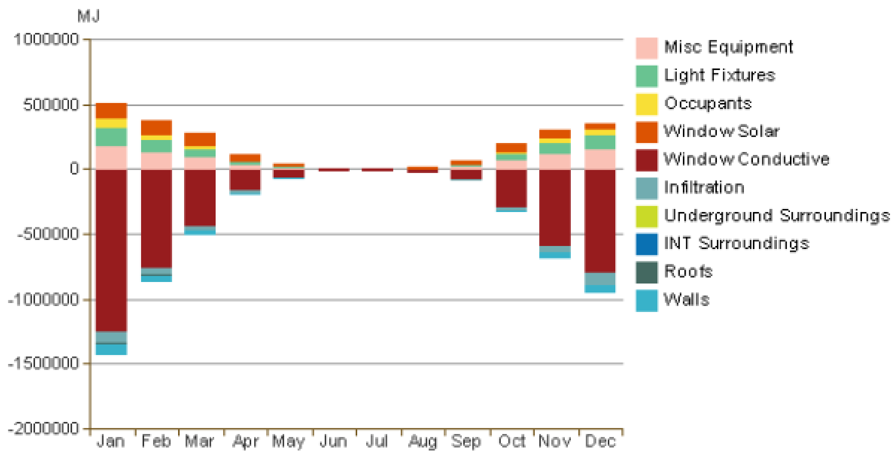

Figure 6. Annual data: heating (mJ per month). The influence of external factors on heating energy use.

The scheme reflects how different equipment and building systems affect heating. It shows how the heat goes out (through glazing mostly). The graph shows that most energy goes out through window opening which is connected to climate peculiarities: during winter period since October till March it used approximately **5100000** mJ, which is 95% from the whole heating expenses.

The analysis points out that mostly energy use on conditioning and heating is connected to the **area of widow opening**, **material, the construction of a glass pack** and **building exposure**.

3. Building exposure (Fig. 7) connected with wind patterns magnificently affect both heating and building construct. Analysis shows that two sides of the building are under wind (Fig. 8), which rises energy loss during cold year periods. There are vertical flows of air mass because of rectangular volume of the building form, what affects design capability – curve and twisting.

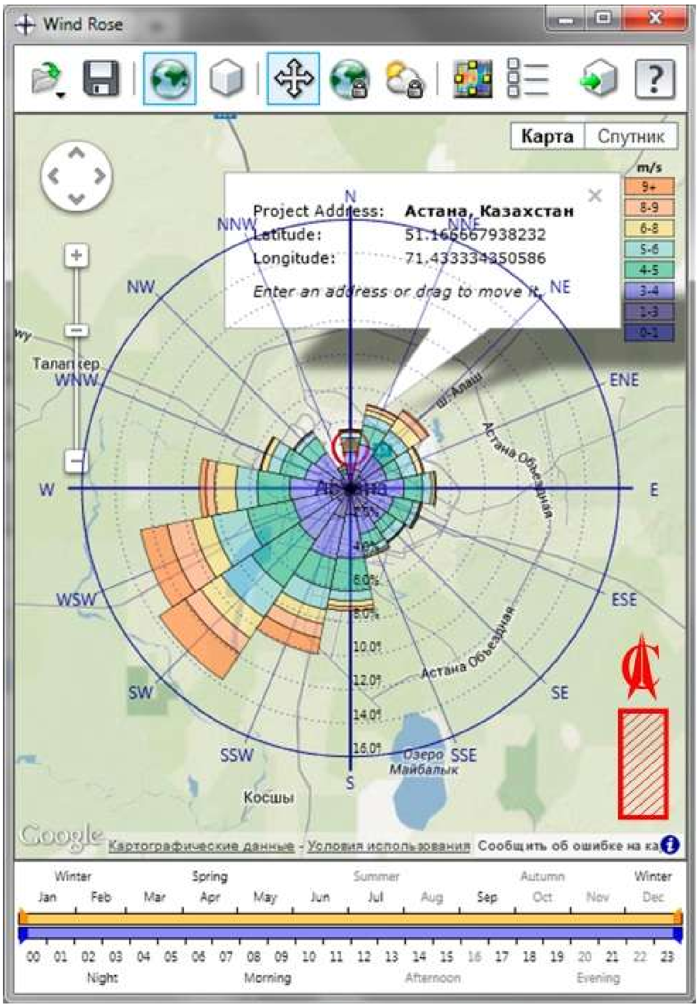

Figure 7. Building exposure concerning wind patterns.

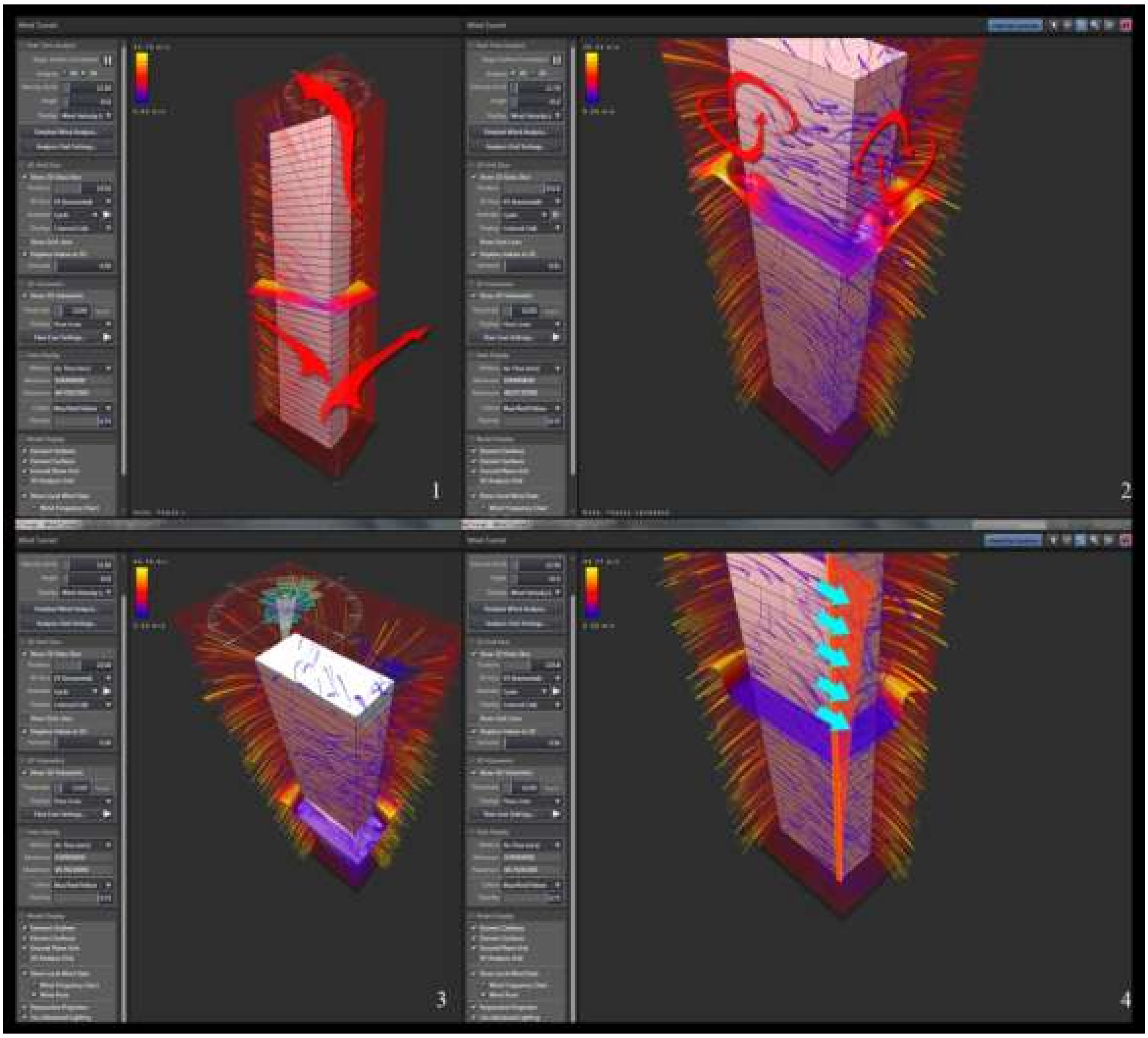

Figure 8. Wind effect analysis.

This slide shows the interaction between wind effect and building considering that average wind speed in Astana is 12 meters per second. It mostly has a south-west direction and meridional exposure. On the first and second pictures you can see that most of envelope will relate to wind effect that is negative for the following:

Building framings – extra load – extra curve and twisting.

Heating. Increasing energy use during heating season.

Solving:

- Reduction of glazing area;
- Changing of building exposure;
- Streamlined forming.

4. The most fuel use (fig. 9) (heating energy) is during the coldest months (January) and reaches the point of **4500000 mJ.**

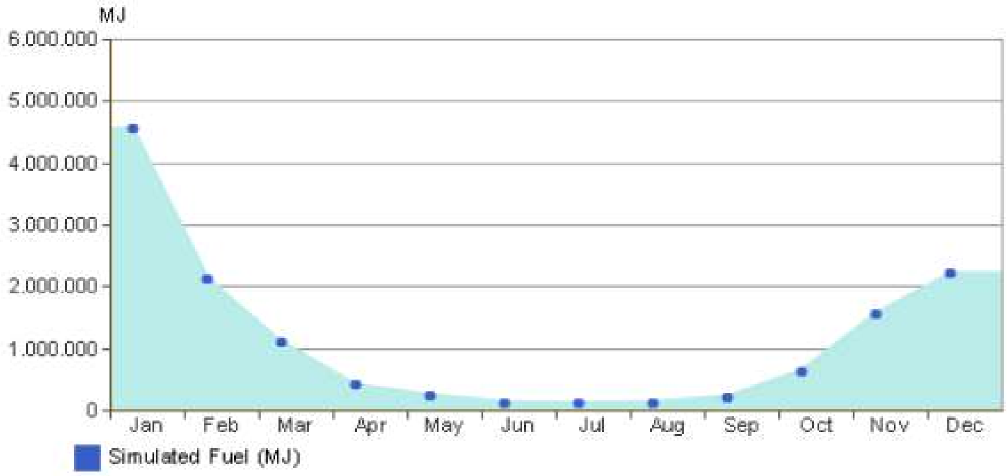

Figure 9. Monthly fuel use

According to the graph the highest level of fuel use is on January, which is the coldest. The lowest level of fuel use is in summer. In Autumn and Spring the use increases (till the winter period) and decreases (till the summer period).

5. The highest level of energy use (conditioning energy) is in the hottest month June and reaches **1300 kWh** (fig. 10).

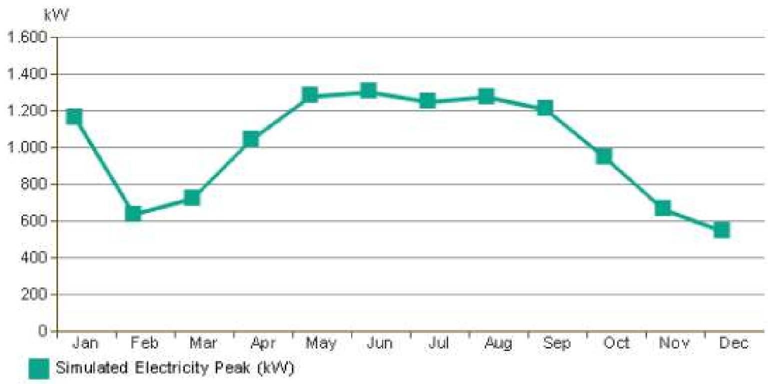

Figure 10. Peak points of electricity use.

High level of electricity use on peak points is connected with high energy use to conditioning and ventilation during these months.

The usage of alternative energy sources: max 362,386 kWh per year can be compensated by means of placing solar cell panels on the roof.

Continuing the point we can use adjacent territory or near standing buildings' roofs to place solar cell panels.

6. **Annual CO_2 emissions** (fig. 11) is approximately 2000 metric tons per year. It is connected to general energy use to building life support and as the graph shows the emissions could be partly compensated with alternative energy sources that make approximately 200 metric tons per year.

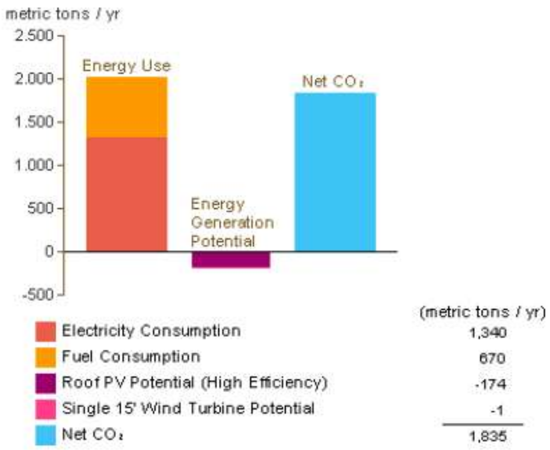

Figure 11. Annual CO_2 emissions

- Generated energy is energy which produced by alternative energy sources, allowing to decrease CO_2 emissions.
- Usable energy is fuel and electricity use.

7. Climate analysis of the project area shows:

- The coldest months are since November till February
- The hottest months are since May till September
- The most humidity is since November till March
- The lowest humidity is during summer months
- Primary wind direction is S-W
- Average wind speed is 12,75 meters per second

As a result of all the calculations the following building life cycle's expenses were determined:

- The usage cycle of energy and value

Life Cycle Electricity Use:	83,665,770 kWh
Life Cycle Fuel Use:	403,405,515 MJ
Life Cycle Energy Cost	$1,807,103

*30-year life and 6.1% discount rate for costs

These results will be compared with the following forms.

The aim is to reduce building life cycle's expenses in the end on 25%

<u>The subject #2:</u>

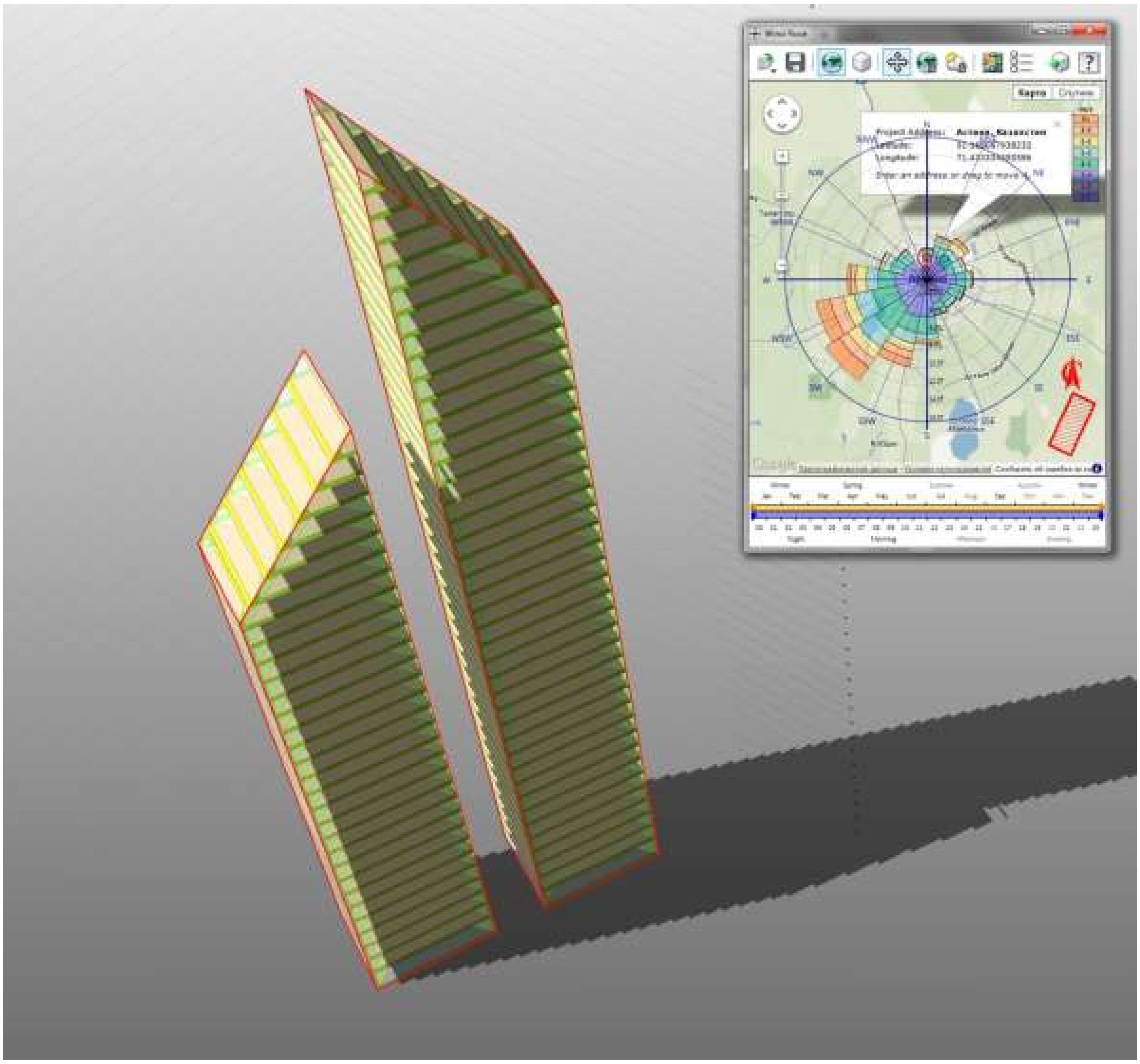

Figure 12. Building form #2.

This form was revealed as a result of huge forming analysis. The main aim on this stage is to compare energy efficiency between building #2 and #1 considering the same building data but different forms. The volume is intermediate between the start and final concept. The volume is separeted on two parts, each of which is cut off. Plan measures of each part are 15*19 with 30 and 40 storeys accordinly. Effective building widness allows to place any type placement with the depth no more than 6 m what is reccomended by SP 23-102-2003 as a normal premises' depth. It also allows to separate space for private offices with 2/3 ratio and open spaces.

Main changes in form #2:

1. **Exposure change on 25° according to S-W axis clockwise (this is made with the aim to reduce wind loads and hide a part of the building from incoming solar beam and as a result to affect energy use to heating and ventilation).**

2. **Changes connected to space-planning decisions (the aim is to reach the initial project plan and add daylight to center placed rooms, to reduce wind loads, to increase roof where we can place solar batteries).**

The subject's data:

- **Geographic location:** Astana, Kazakhstan. Exposure is meridional.
- **Purpose of use**: cultural and business complex which includes retail spaces (first 4 floors), office spaces (26 storeys) and hotel space (36 storeys).

Visionary design:

- **Outside wall**: translucent structures like stained glass used in cold climate. (**Lightweight Construction – Typical Cold Climate Insulation**) Percentage-wise from the main wall area is 75%.
- **Interior walls**: partition of non-translucent materials like brick, plasterboard, tongue-and-groove boards (**High Mass Construction – No Insulation**).
- **Outside walls of underground parking**: non-translucent constructions with low level of heat conductivity used in cold climate (**High Mass Construction – Typical Cold Climate Insulation)**.
- **Roof material**: high level of heat insulation, dark roof (**High Insulation - Dark Roof**).
- **Covering material**: laminated plastic/ceramic-granite (**Lightweight Construction – No Insulation**)
- **Slab panel's material**: high-strength constructions with low level of heat insulation, cold climate (**High Mass Construction – Cold Climate Slab Insulation**).
- **Glazing**: triple glass unit, translucent glass like Phoenix Clear, capacities – hot/cold climate, low-emission coating with 6 items (**Triple Pane Clear - LowE Hot or Cold Climate**).
- **Average height of window sill is 750 mm**
- **Heating, ventilation and conditioning system: (HVAC) - 11.3 EER Packaged VAV, 84.4% boiler heating**
- **Floor space**: 18765 sq.m.
- **Square of enclosure structure**: 16537 sq.m.

The following calculations were held according to building performance:

- Analysis of how solar energy affects heating, ventilation and lighting depending on climate peculiarities, building form and its orientation.

- Analysis of how wind affects heating systems (during cold period of a year) and building constructions.

- Analysis of forming – how building form affects energy cost, connected with wind and sun influence.
- Climate analysis (temperature difference, cold and warm year periods, humidity etc.)

Analysis are held with due regard to design peculiarity, materials, forming, exposure, climate, functions and alternative energy sources.

1. Solar radiation analysis

The result of the second plan's analysis:

The square of envelope is reduced because of exposure changes and as a result the intensity of sunlight influence was cut (fig. 13).

- Exposure was changed on 25˚clockwise according to N-S axis
- Measure date is July 22
- Window area is 75%

Analysis showed that the maximum solar heat is taken by roof covering – 0.6 kWh/m2, because of roof cut where solar batteries could be placed. In this situation we can receive 312,975 kWh/year of alternative energy according to maximum effectiveness. East wall will get 0,3 kWh/m2, south – 0,35 kWh/m2, west – 0,3 kWh/m2, what will positively affect **conditioning and ventilation** during summer.

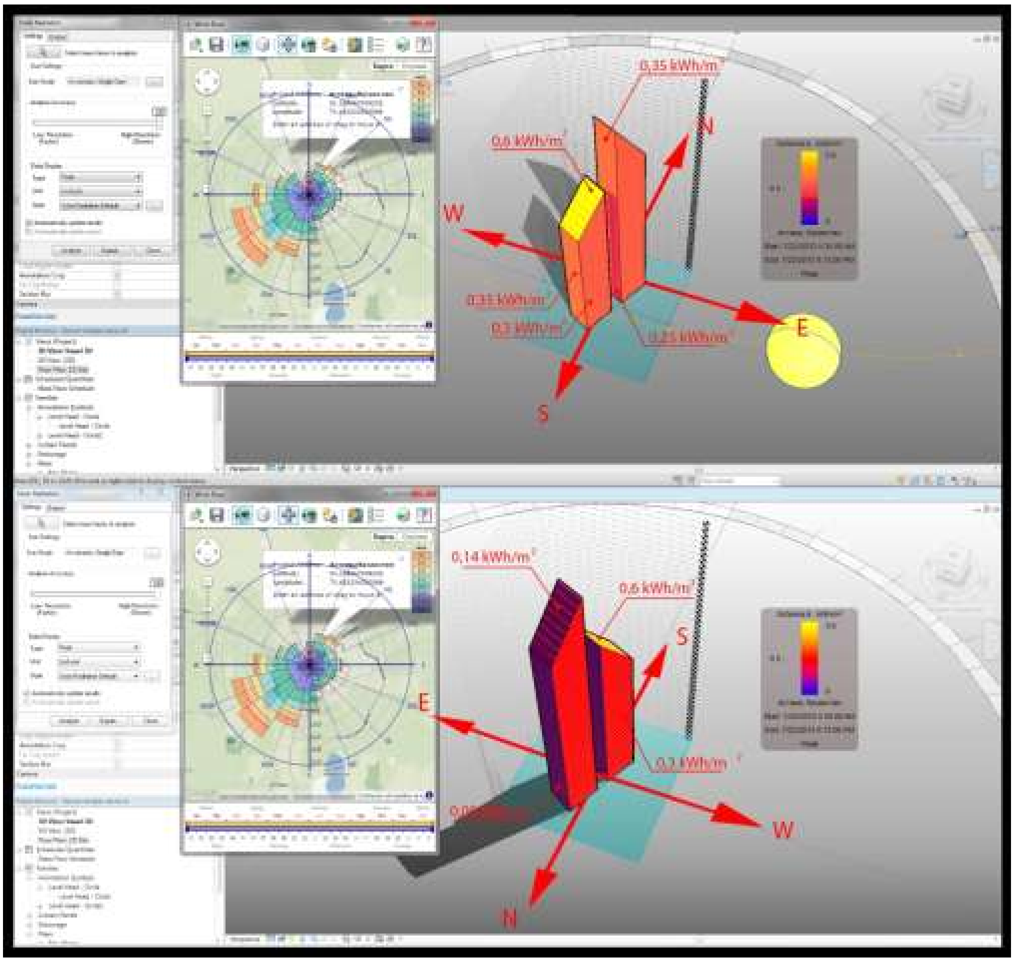

Figure 13. Solar radiation analysis.

The building takes approximately 0,35 kWh/m^2 in average. On this stage the changes didn't affect cooling system's expenses because of envelope increasing. It means that general glass opening also didn't change (fig 14).

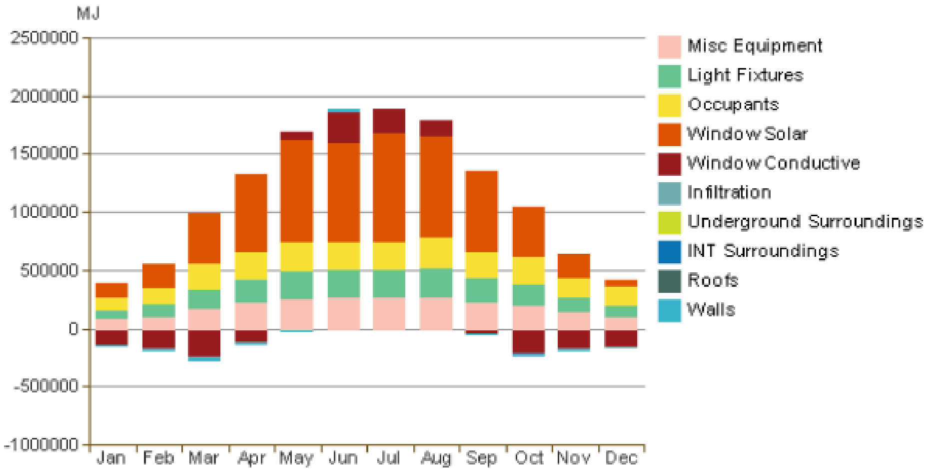

Figure 14. Annual data - conditioning (mJ per month). How external factors affect conditioning energy use.

The scheme shows that the max level of conditioning energy use is in summer period when the level of daylight is maximum.

Possible variants of reducing conditioning and ventilation expenses:

- To reduce glazing

- To change building exposure

- To choose glass pack's formula (for example to use glass made by AGC - Stopray Neo 60/40 – the high level of light transmission (LT=60%), solo fair 40%, ug-value - 1.1W/m².K).

- To choose another conditioning system. (For now the most effective system of conditioning and heating is taken)

2. A huge area of window opening (75% from the whole envelope) is directly-proportional to increasing expenses connected to building **heating** during cold year periods. In this case the window area was increased because of form change and as a result heating expenses increased (fig. 15):

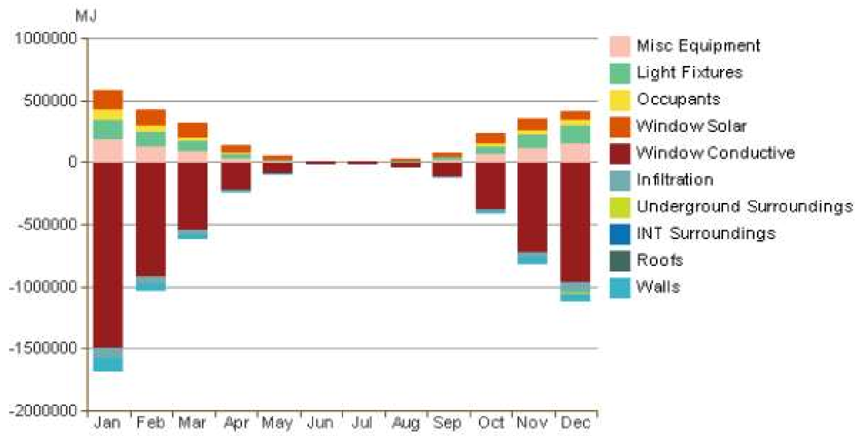

Figure 15. Annual data: heating (mJ per month). The influence of external factors on heating energy use.

In the graph you can see that in winter there is the max heating energy use while the heat goes out (through window area mostly). It is connected to climate peculiarities: during winter period since October till March it used approximately **5400000** mJ, which is 97% from the whole heating expenses.

The analysis points out that mostly energy use on conditioning and heating is connected to the **area of widow opening**, **material, the construction of a glass pack** and **building exposure**.

The opportunities to reduce heat loss are the following:

- Cutting the glazing
- Choosing a glass pack formula
- Choosing another heating system

In comparison with the first form heat loss is more because of more building envelope which means more glazing. In this case it is profitable to reduce glazing (-15/20%). It will positively influence on conditioning and will need to increase a little lighting, as placements' depth is max 6m.

3. **Building exposure** (Fig. 16) connected with wind patterns magnificently affects both heating and building construct**.** Analysis shows that only one side of the building is under wind what is connected with exposure changes according N-S axis.

There are vertical flows of air mass because of rectangular volume of the building form (fig. 17), what affects design capability – curve and twisting.

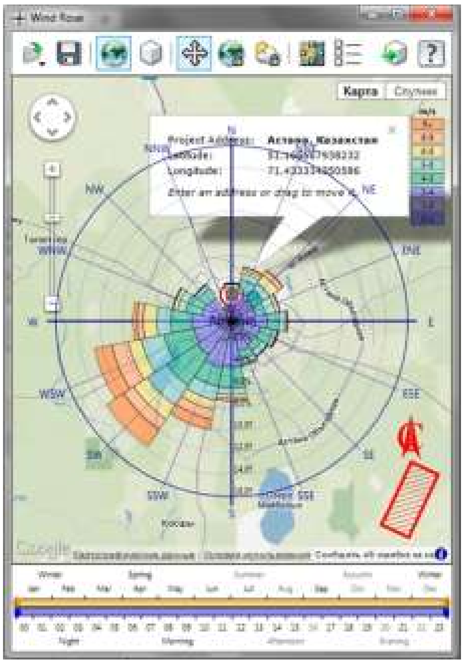

Figure 16. Building exposure concerning wind patterns.

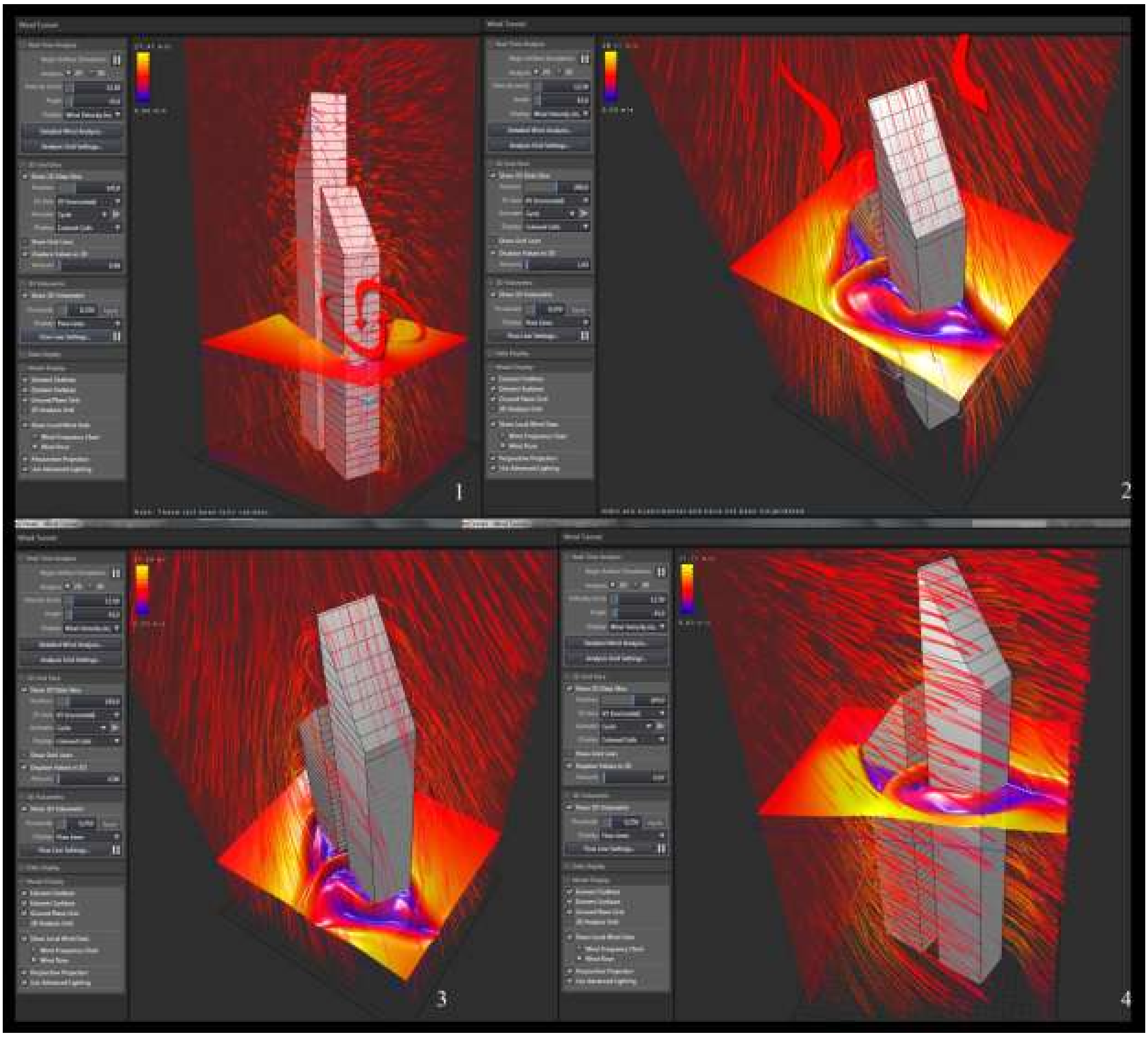

Figure 17. Wind effect analysis.

This slide shows the interaction between wind effect and building considering that average wind speed in Astana is 12 meters per second. It mostly has a south-west direction and meridional exposure.

Changes in the initial project:

1. Building exposure was turned on 25˚what helped to reduce wind effect.
2.The form was cut what makes a building more streamlined.

4. The most fuel use (fig. 18) (heating energy) is during the coldest months (January) and reaches the point of **5500000 mJ**. The increasing of this number is directly connected with increasing of envelope and exceeds the previous number (Form #1) on **1000000 mJ**:

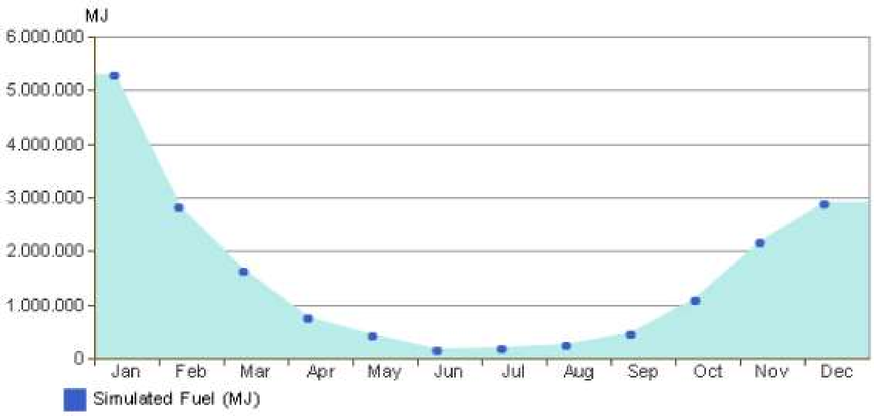

Figure 18. Monthly fuel use

The highest level of energy use (conditioning energy) is in the hottest month June and reaches **1370 kWh** (fig. 19):

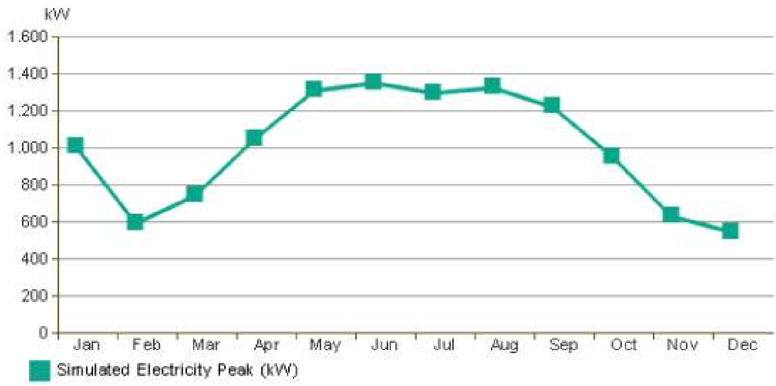

Figure 19. Peak points of electricity use.

High level of electricity use on peak points is connected with high energy use to conditioning and ventilation during these months.

5. **The usage of alternative energy sources:** max 312,975 kWh/year can be compensated by means of placing solar cell panels on the roof.

6. **Annual CO_2 emissions** (fig. 21) is approximately 2100 metric tons per year. It is connected to general energy use to building life support and as the graph shows the emissions could be partly compensated with alternative energy sources that make approximately 150 metric tons per year. The number of alternative energy can be increased by increasing the number of solar cell panels and setting up wind turbines.

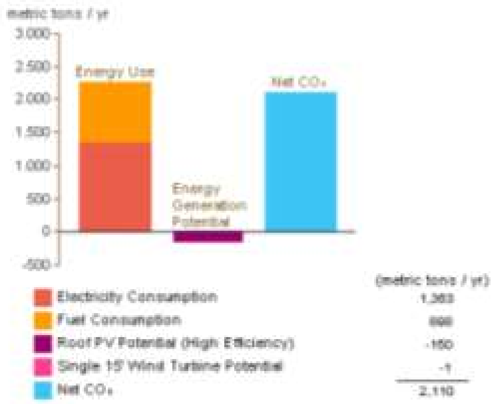

Figure 20. Annual CO_2 emissions

- **Generated energy** is energy which produced by alternative energy sources, allowing to decrease CO_2 emissions.
- **Usable energy** is fuel and electricity use.

The number of energy use increased and CO_2 emissions increased also. The number of alternative energy decreased because of cutting the roof square.

7. Climate analysis of the project area shows:

- The coldest months are since November till February
- The hottest months are since May till September
- The most humidity is since November till March
- The lowest humidity is during summer months
- Primary wind direction is S-W
- Average wind speed is 12,75 meters per second

As a result of all the calculations the following building life cycle's expenses were determined:

Life Cycle Electricity Use:	85,072,050 kWh
Life Cycle Fuel Use:	540,553,820 MJ
Life Cycle Energy Cost:	$1,942,739

*30-year life and 6.1% discount rate for costs

Comparing this variant and the first one we can see **increasing energy use** on the amount of **142 thousand c.u.** And as a conclusion it is not enough to change only the building form. To get more energy efficiency the measures connected with design concept and materials should be made.

According to analysis the following decisions were made to increase building performance:

- To cut the square of window opening
- To change glass quality
- To increase heat insulation
- To change inside envelope's quality
- To use wind turbines as an extra source of energy

- To add cantilever storeys between separated buildings

The subject #3:

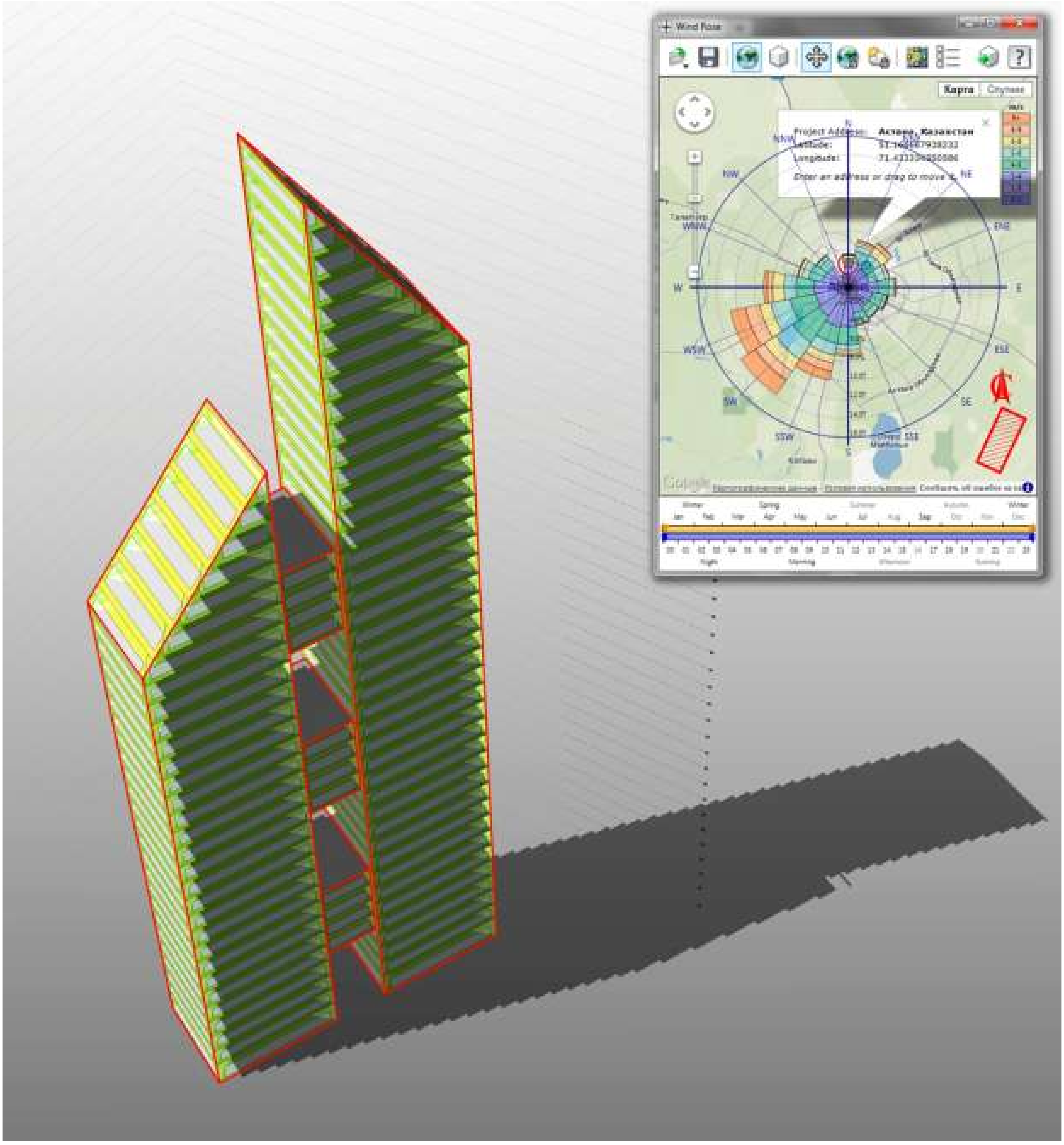

Figure 21. Building form #3.

This form was revealed as a result of huge forming analysis and energy effeciency (EE) analysis. The main aim on this stage is to increase EE, cut life cycle expenses by changing the following points: glazzing, glass pack formula, materials, usage of extra alternative energy sources (wind and increasing roof). There are cantilevered storeys between main buildings inside of which will be the zone of recration (conservatory) and offices. The roof is used to set up solar cell panels. The space between buildings it is supposed to be used by wind tribunes. Plan measures are the same. Effective building widness allows to place any type placement with the depth no more than 6 m what is reccomended by SP 23-102-2003 as a normal premises' depth. It also allows to separate space for private offices with 2/3 ratio and open spaces.

Main changes in form #2:

1. **Decreasing the square of window opening**
2. **Changing glass formula**
3. **Increasing heat insulation**
4. **Changing inside envelope's quality**
5. **Using wind tribunes as an extra energy source**
6. **Adding cantilevered storeys between buildings**

The subject's data:

- **Geographic location:** Astana, Kazakhstan. Exposure is meridional.
- **Purpose of use**: cultural and business complex which includes retail spaces (first 4 floors), office spaces (26 storeys) and hotel space (36 storeys). Cantilevered storeys – office spaces and the zone of recreation.

Visionary design:

- **Outside wall:** translucent structures like stained glass with high insulation. **(Lightweight Construction – High Insulation)** Percentage-wise from the main wall area is 50%.
- **Interior walls:** partition of translucent materials like glass (**Lightweight Construction – No Insulation**).
- **Outside walls of underground parking:** non-translucent constructions with high level of heat insulation (**High Mass Construction – High Insulation**).
- **Roof material:** high level of heat insulation, dark roof (**High Insulation - Dark Roof**).
- **Covering material: Lightweight Construction – High Insulation**
- **Slab panel's material:** high-strength constructions with low level of heat insulation, cold climate (**High Mass Construction – Cold Climate Slab Insulation**).
- **Glazing:** double glass unit. The solar reflection glass. (**Double Pane – Reflective**)
- **Average height of window sill is 750 mm**
- **Heating, ventilation and conditioning system**: (HVAC) - 11.3 EER Packaged VAV, 84.4% boiler heating
- **Floor space: 20013** sq.m.
- **Square of enclosure structure: 16117** sq.m.

The following calculations were held according to building performance:

- Analysis of how solar energy affects heating, ventilation and lighting depending on climate peculiarities, building form and its orientation.

- Analysis of how wind affects heating systems (during cold period of a year) and building constructions.

- Analysis of forming – how building form affects energy cost, connected with wind and sun influence.

- Climate analysis (temperature difference, cold and warm year periods, humidity etc.)

Analysis are held with due regard to design peculiarity, materials, forming, exposure, climate, functions and alternative energy sources.

The result of the third plan's analysis:

1. **Solar radiation analysis (fig. 22)**

- Exposure was changed on 25˚clockwise according to N-S axis
- Measure date is July 22
- Window area is 50%

Analysis showed that the maximum solar heat is taken by roof covering – 0.6 kWh/m2, because of roof cut where solar batteries could be placed. In this situation we can receive 644,481 kWh/year of alternative energy according to maximum effectiveness. East wall will get 0,3 kWh/m2, south – 0,4 kWh/m2, west – 0,3 kWh/m2. Because of increased roof square it is possible to place extra solar cell panels.

The influence of solar on the building is **-0,35** kWh/m2, the same as in the second plan.

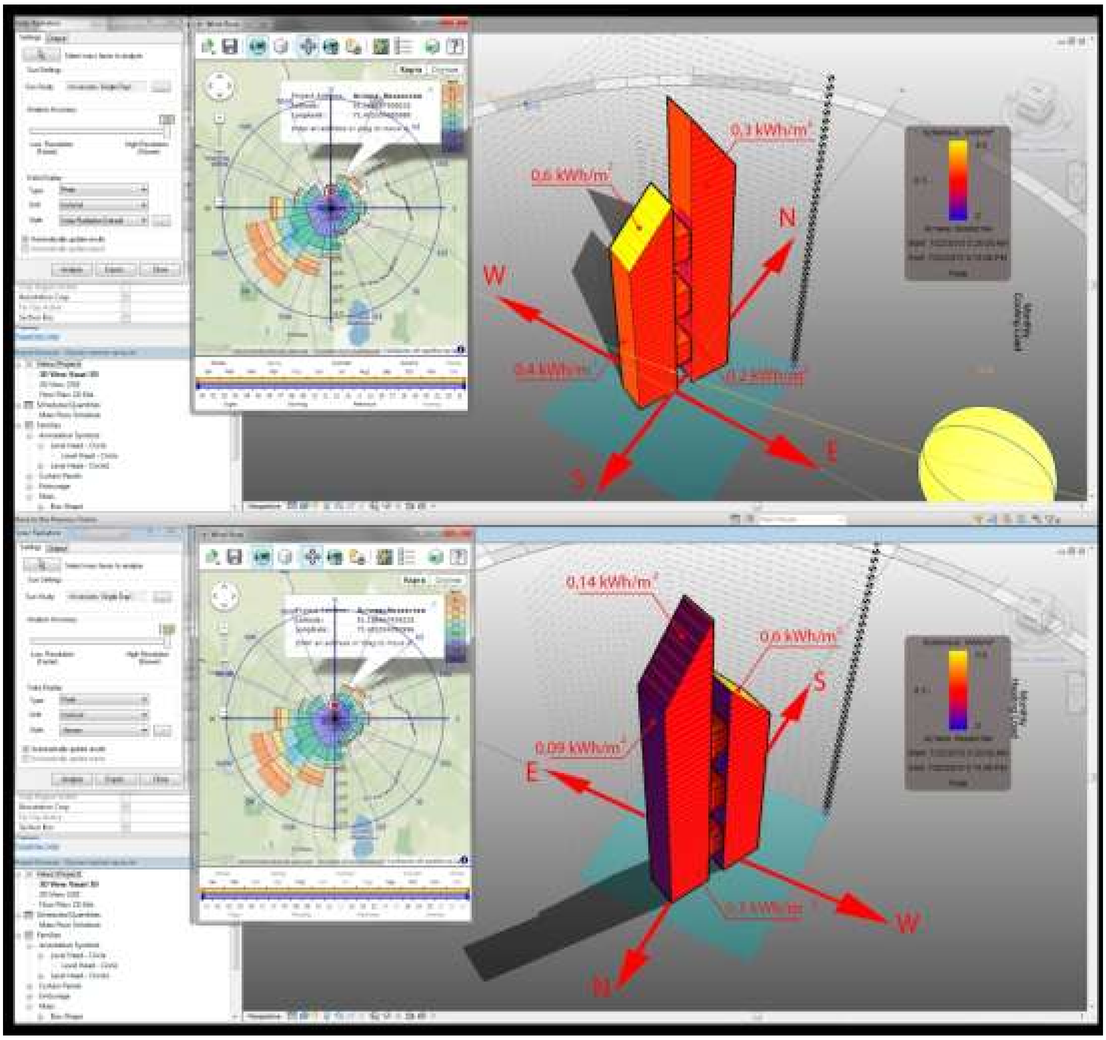

Figure 22. Solar radiation analysis

Because of the decrease of window area the glass pack formula has changed. The solar reflection increased and conditioning expenses decreased. In this case the solar is **900000 mJ**, what significantly differs from the previous numbers and allows us to save a huge amount of energy (fig. 22).

The following measures were made in this plan:

- Decreasing of window area (from 0,75 to 0,5)
- Choosing the glass pack formula

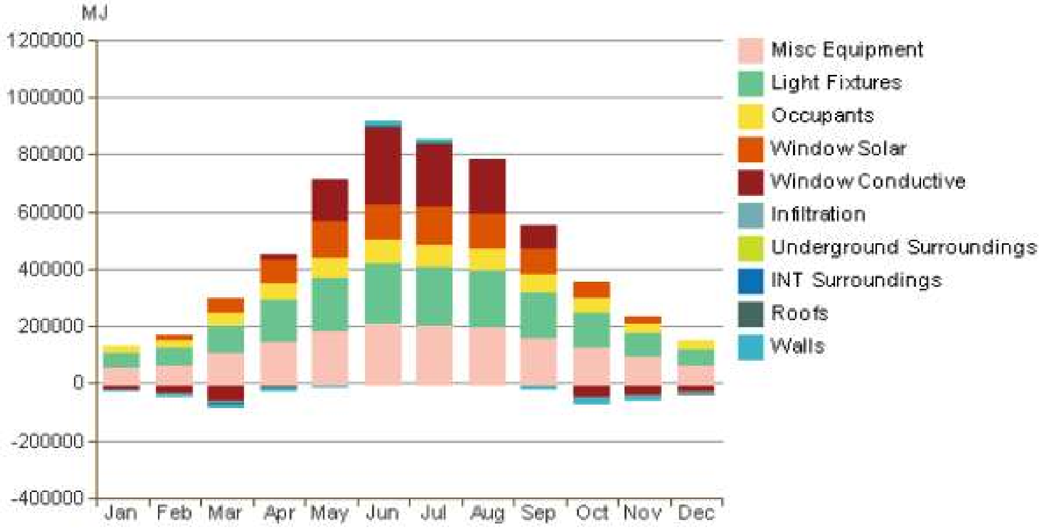

Figure 22. Annual data: conditioning (mJ per month). The influence of external factors on conditioning energy use

Functional equipment didn't change so the energy loss on different equipment conditioning was not taken into consideration.

2. Heat loss increased a few and it is connected with the change of glass pack (fig. 23). So an extra double glass pack is needed in the second and third positions.

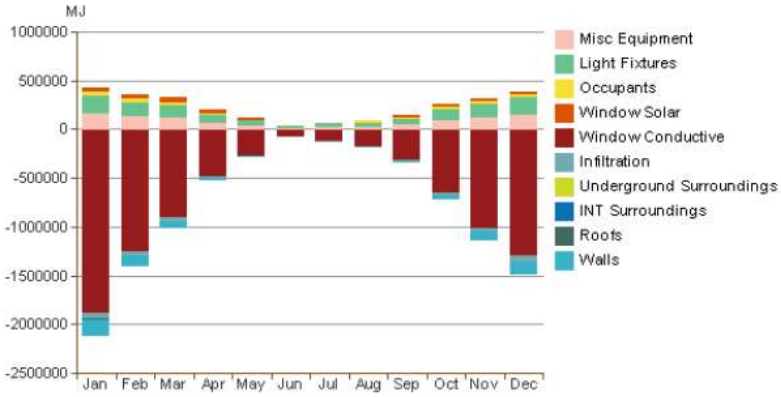

Figure 23. Annual data: heating (mJ per month). The influence of external factors on heating energy use

In the graph you can see that in winter there is the max heating energy use while the heat goes out (through window area mostly). In comparison with the second plan heat loss almost didn't change because new glazing provides a high level of solar reflection, what helped to cut conditioning expenses. In addition to this glass pack is double what didn't give a chance to cut general heat expenses.

3. **Building exposure** (Fig. 24) connected with wind patterns magnificently affects both heating and building construct. In this case the influence of wind patterns is decreased by means of reducing window area (fig. 25).

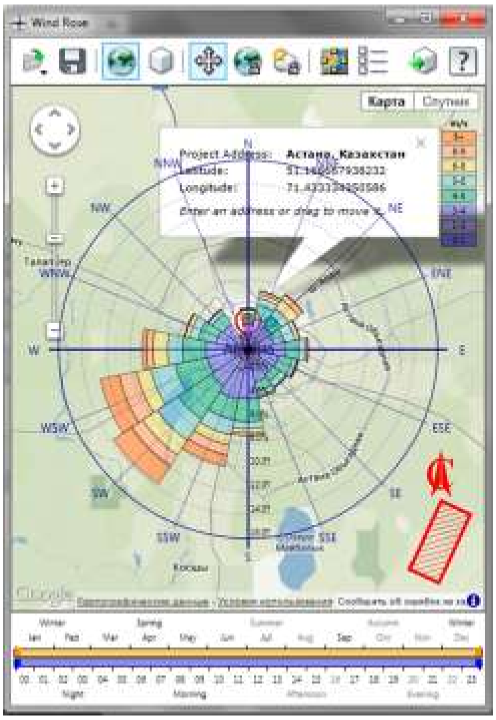

Figure 24. Building exposure concerning wind patterns.

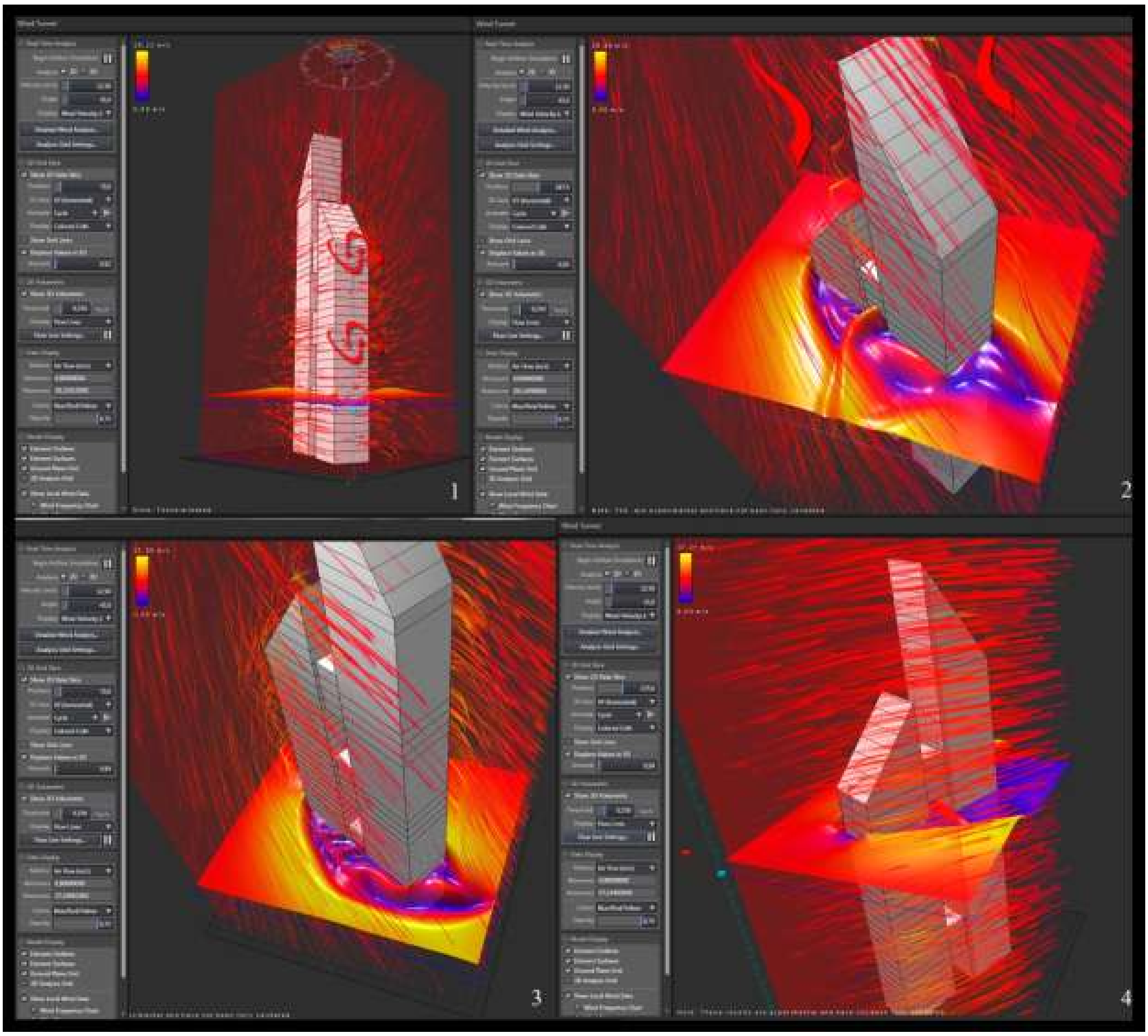

Figure 25. Wind effect analysis.

This slide shows the interaction between wind effect and building considering that average wind speed in Astana is 12 meters per second. It mostly has a south-west direction and meridional exposure.

Changes:

1. Cantilevered storeys are added which combine 2 buildings. The construction became tougher. Wind tribunes are placed between cantilevered storeys.

2. Window area is decreased that became a reason of saving heat energy during cold year period.

4. **The most fuel use** (fig. 26) (heating energy) is during the coldest months (January) and reaches the point of **3200000 mJ** which is significantly lower than **5150000 mJ** according to the second plan.

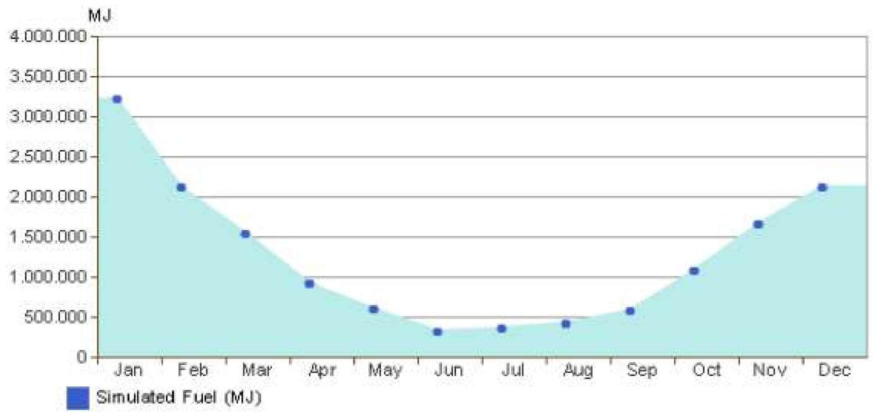

Figure 26. Monthly fuel use

5. **The highest level of energy use** (conditioning energy) is in the hottest month June and reaches 730 **kWh (fig. 27) that is less than 1370 kWh** in the second plan.

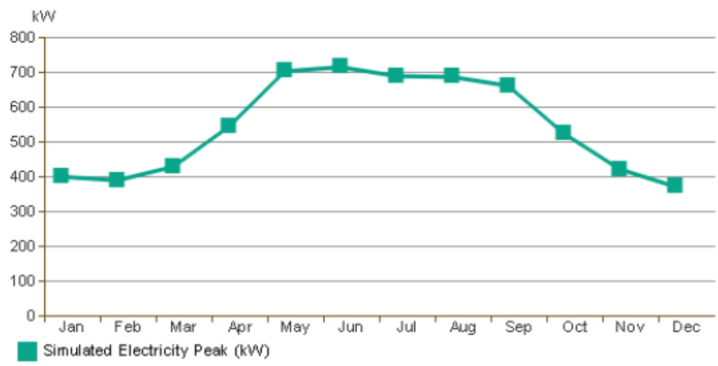

Figure 26. Peak points of electricity use.

High level of electricity use on peak points is connected with high energy use to conditioning and ventilation during these months. In comparison with the previous plan energy expenses are cut and it will significantly affect building's life cycle.

6. **The usage of alternative energy sources (fig. 27):** max **644,481 kWh/year** can be compensated by means of placing solar cell panels on the roof. It doubles the second plan data. First of all it is connected with extra place on cantilevered storeys' roof. Annual CO_2 emissions are approximately 1450 metric tons per year which is lower than previous result of 2100 metrical tons per year. It makes the project more profitable and **ecological**.

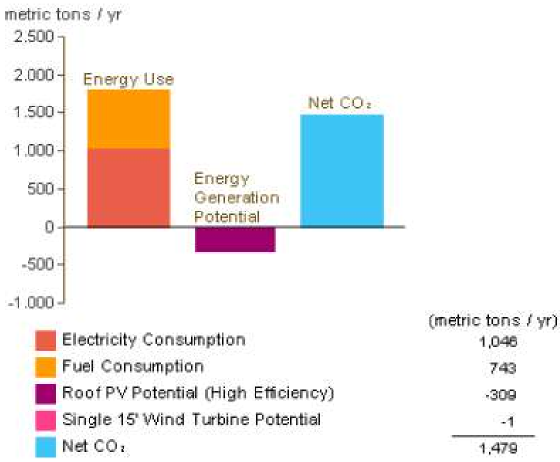

Figure 27. Annual CO_2 emissions

- **Generated energy** is energy which produced by alternative energy sources, allowing to decrease CO_2 emissions.
- **Usable energy** is fuel and electricity use.

7. **Climate analysis of the project area shows:**
   - The coldest months are since November till February
   - The hottest months are since May till September
   - The most humidity is since November till March
   - The lowest humidity is during summer months
   - Primary wind direction is S-W
   - Average wind speed is 12,75 meters per second

As a result of all the calculations the following building life cycle's expenses were determined:

Life Cycle Electricity Use:	65,321,160 kWh
Life Cycle Fuel Use:	447,233,117 MJ
Life Cycle Energy Cost	$1,517,680

*30-year life and 6.1% discount rate for costs

The analysis #3 shows how energy efficiency can be changed due to changing design peculiarities. **In comparison with the second plan efficiency growth is 30%!**

The subject #4:

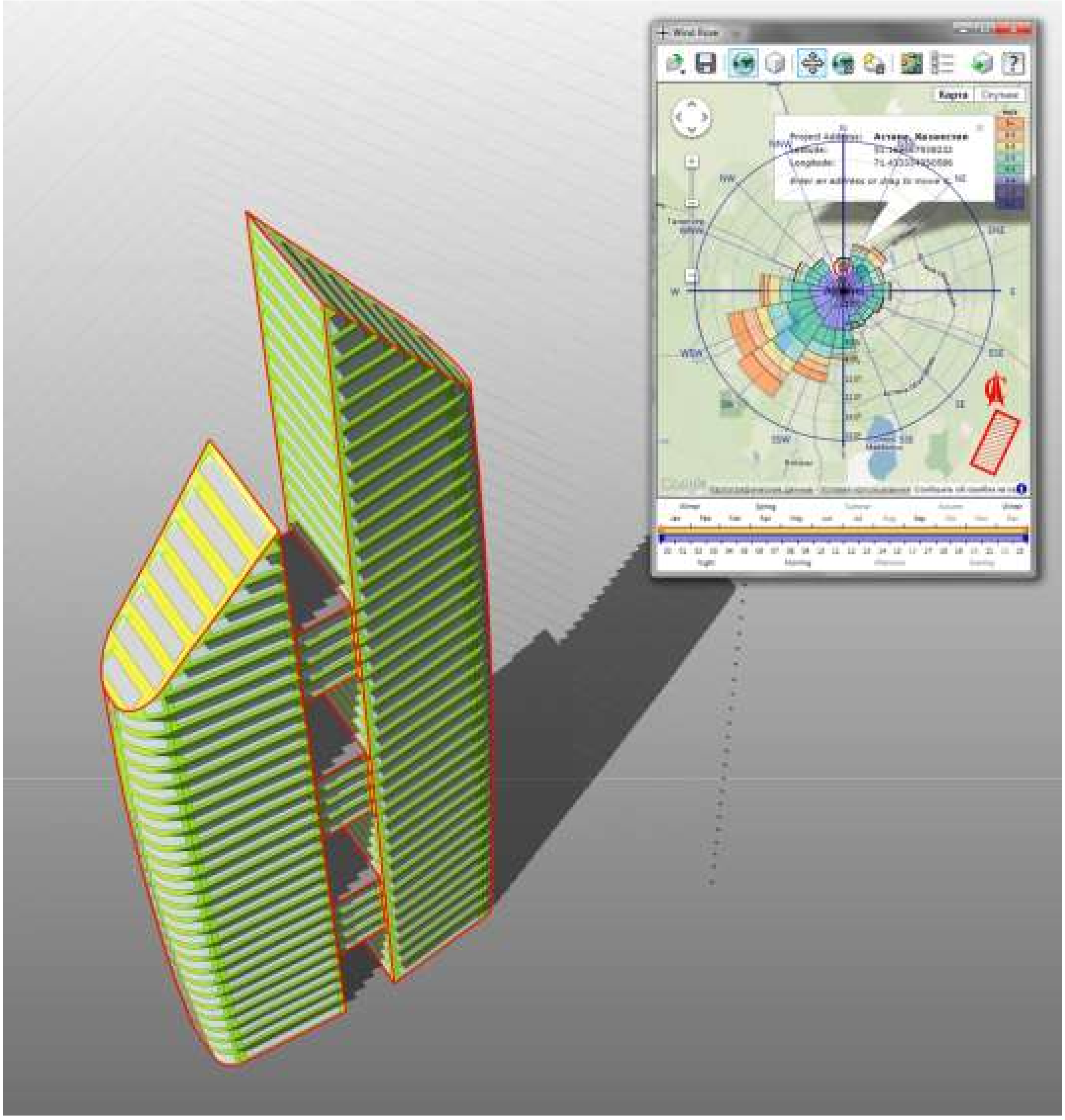

Figure 28. Building form #4

This form was revealed as a result of huge forming analysis and energy effeciency (EE) analysis. The main aim on this stage is to increase EE, cut life cycle expenses by changing building form (its streamline) to reduce wind effect. The space between buildings is supposed to be used for wind tribunes. This form is a final according to aesthetic point of view and max energy effictive according to analysis. The measures doesn't change.

Main changes in form #4:

1. **Making more streamlined form to reduce wind effect. This is a very important factor because of multi-storey building. More storeys more wind effect. Taking into consideration the project place (Astana city) it is necessary to point out that the city is situated in the steppe and the wind has the most speed and windflow. We tried to change the building form and its exposure to reduce wind effect as maximum as it could be but according to aesthetic requirments of the project.**

The subject's data:

- **Geographic location:** Astana, Kazakhstan. Exposure is meridional.
- **Purpose of use**: cultural and business complex which includes retail spaces (first 4 floors), office spaces (26 storeys) and hotel space (36 storeys). Cantilevered storeys – office spaces and the zone of recreation.

Visionary design:

- **Outside wall:** translucent structures like stained glass with high insulation. **(Lightweight Construction – High Insulation)** Percentage-wise from the main wall area is 50%.
- **Interior walls:** partition of translucent materials like glass (**Lightweight Construction – No Insulation**).
- **Outside walls of underground parking:** non-translucent constructions with high level of heat insulation (**High Mass Construction – High Insulation**).
- **Roof material:** high level of heat insulation, dark roof (**High Insulation - Dark Roof**).
- **Covering material: Lightweight Construction – High Insulation**
- **Slab panel's material:** high-strength constructions with low level of heat insulation, cold climate (**High Mass Construction – Cold Climate Slab Insulation**).
- **Glazing:** double glass unit. The solar reflection glass. (**Double Pane – Reflective**)
- **Average height of window sill is 750 mm**
- **Heating, ventilation and conditioning system**: (HVAC) - 11.3 EER Packaged VAV, 84.4% boiler heating
- **Floor space: 18346** sq.m.
- **Square of enclosure structure: 15236** sq.m.

The following calculations were held according to building performance:

- Analysis of how solar energy affects heating, ventilation and lighting depending on climate peculiarities, building form and its orientation.

- Analysis of how wind affects heating systems (during cold period of a year) and building constructions.

- Analysis of forming – how building form affects energy cost, connected with wind and sun influence.

- Climate analysis (temperature difference, cold and warm year periods, humidity etc.)

Analysis are held with due regard to design peculiarity, materials, forming, exposure, climate, functions and alternative energy sources.

The result of the third plan's analysis:

2. Solar radiation analysis (fig. 29)

- Exposure was changed on 25˚clockwise according to N-S axis
- Measure date is July 22
- Window area is 50%

Analysis shows that sunlight influence has changed. It is approximately **0,30 kWh/m²** what is good for conditioning during summertime.

Analysis showed that the maximum solar heat is taken by roof covering – 0.6 kWh/m2, because of roof cut where solar batteries could be placed. In this situation we can receive 445,345 kWh/year of alternative energy according to maximum effectiveness. East wall will get 0,3 kWh/m2, south – 0,4 kWh/m2, west – 0,3 and 0,25 kWh/m2. In comparison with the subject #3 the building form became more streamlined.

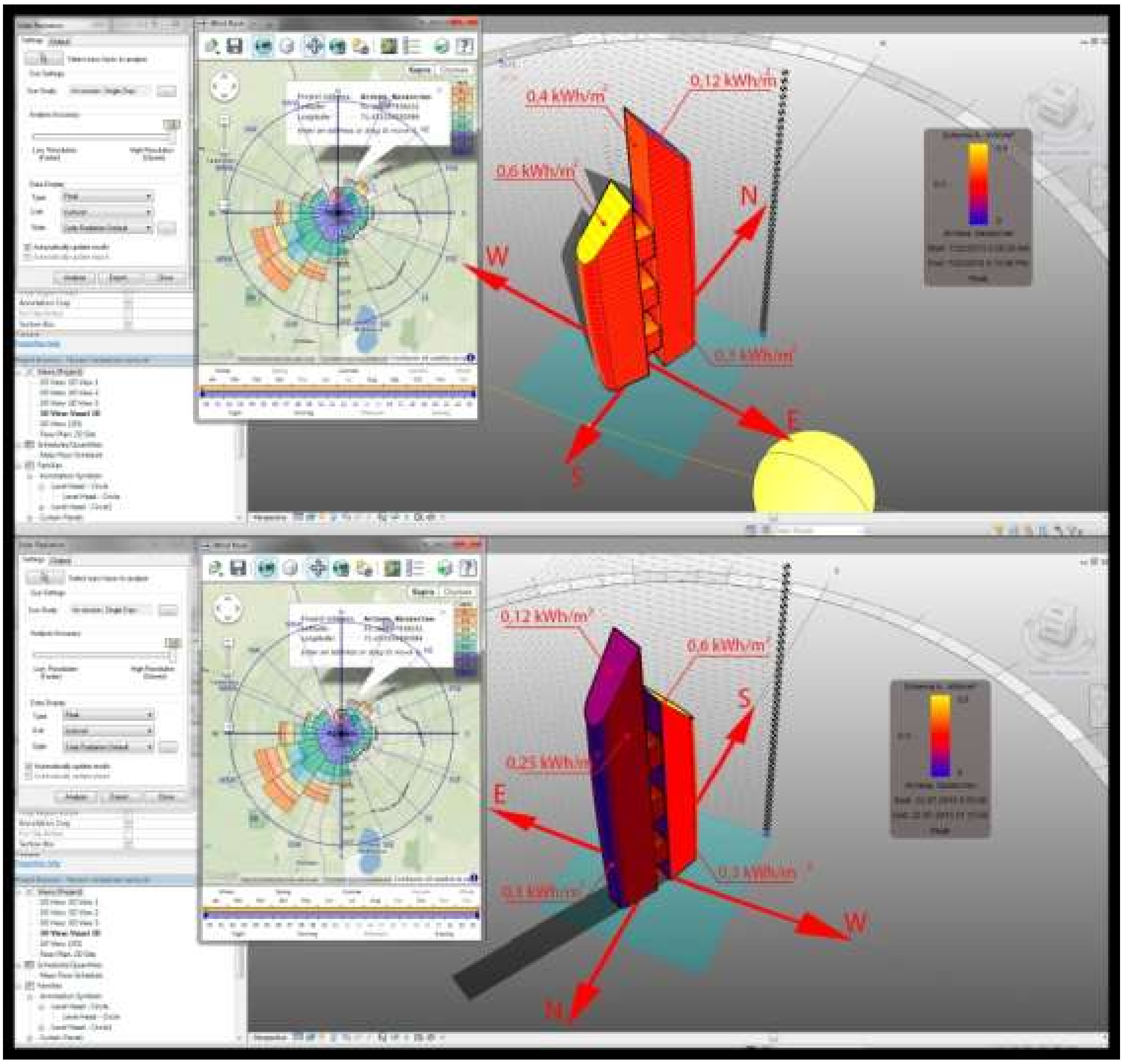

Figure 29. Solar radiation analysis

The maximum energy is used on conditioning during summertime when the most solar energy goes through window area. In comparison with the subject #3 there are a few changes because changes were made only in building form.

As the subject #3's energy efficiency is good so the subject #4 is directed to improve aesthetic view.

- **The number of heat**, affecting conditioning (fig. 30) during the summertime is reduced from **910000 mJ** to **820000 mJ.**
- **The number of cold** coming through window area and walls during wintertime increased from **70000МДж** to **120000МДж.** It will positively affect conditioning**.**

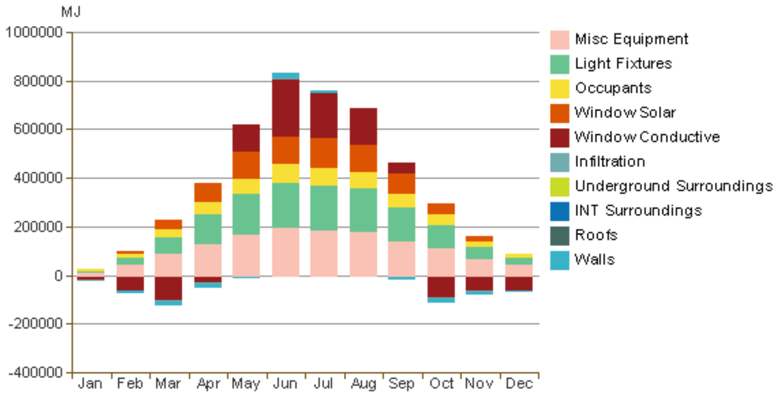

Figure 30. Annual data: conditioning (mJ per month). The influence of external factors on conditioning energy use

The graph shows that the maximum energy loss goes to conditioning during summertime when solar energy goes through window area.

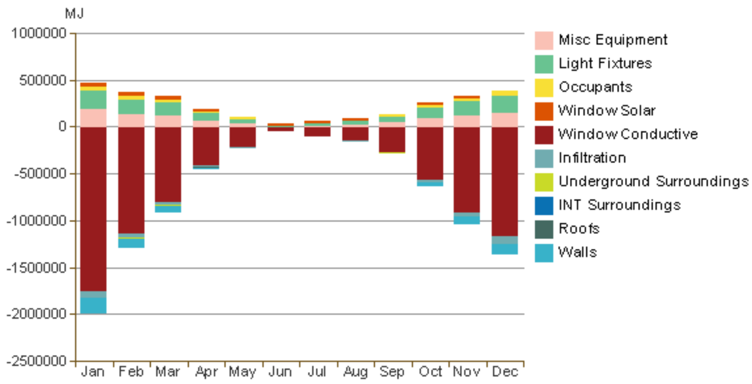

Figure 31. Annual data: heating (mJ per month). The influence of external factors on heating energy use

In the graph (fig. 23) you can see that in winter there is the max heating energy use while the heat goes out (through window area mostly). In comparison with the third plan heat loss almost didn't change and energy loss reduced from **2100000 to 2000000 mJ.** What is the reason of decreasing the building due to streamlining. Also because of streamlining wind effect reduced. Energy saving and working out by alternative sources increased from **490000 mJ** to **500000 mJ.**

According to this analysis we can see that conditioning and heating energy loss is connected to window area, material, glass pack constructor and building exposure in most cases.

1. **Building exposure** connected with wind patterns magnificently affects both heating and building construct. In this case the influence of wind patterns is decreased by means of streamlining.

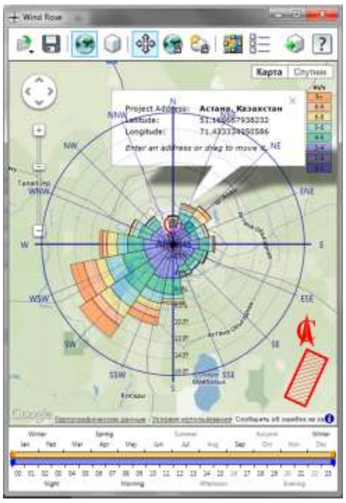

Figure 32. Building exposure concerning wind patterns.

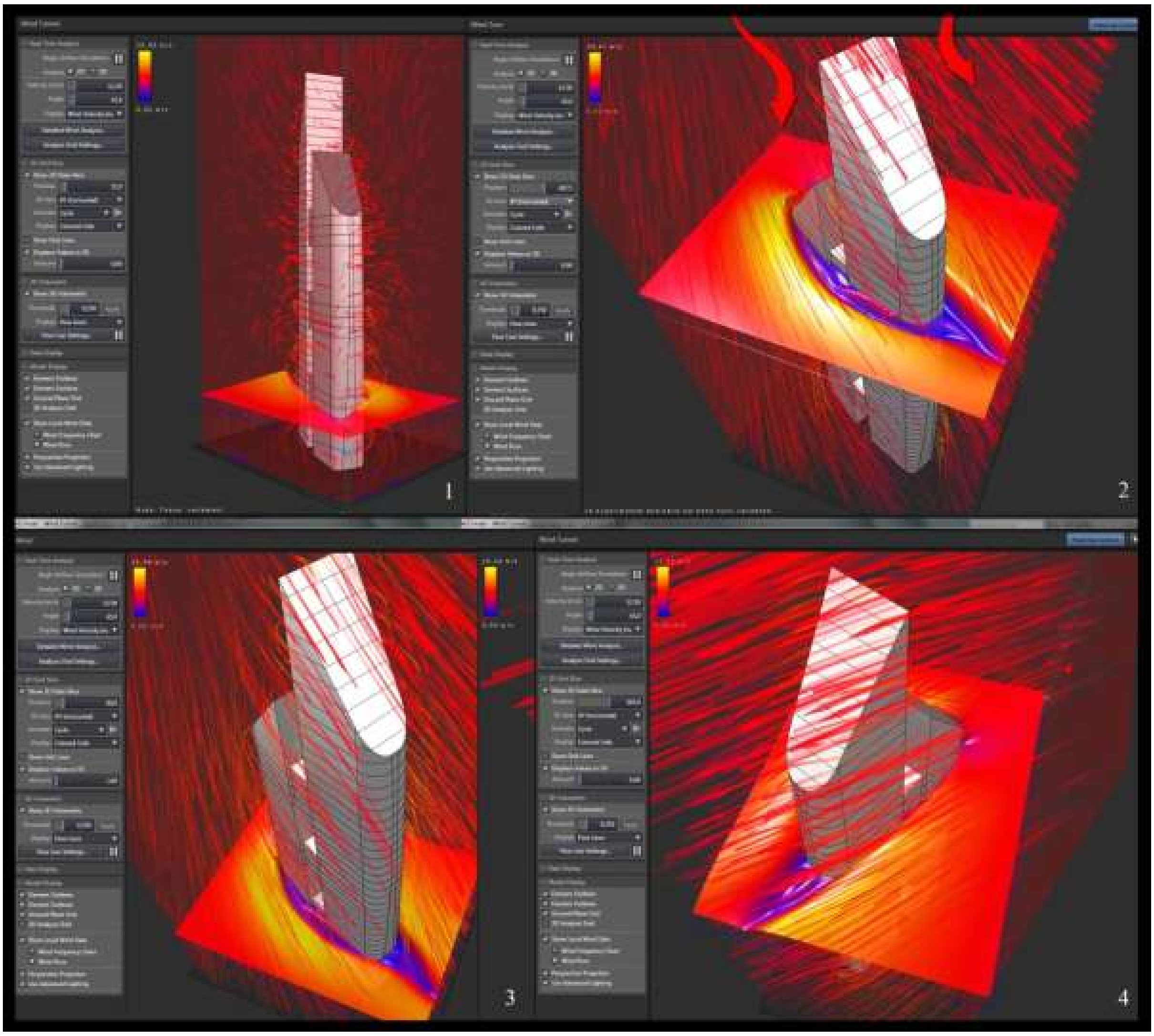

Figure 33. Wind effect analysis.

This slide shows the interaction between wind effect and building considering that average wind speed in Astana is 12 meters per second. It mostly has a south-west direction and meridional exposure.

Changes:

1. The building has streamlined form what allows wind to slide along the building. It will also cut heat loss. The streamlined form will reduce wind effect as a whole.

8. **The most fuel use** (fig. 34) (heating energy) is during the coldest months (January) and reaches the point of **3200000 mJ** which is the same as significantly lower than **5150000 mJ** according to the third plan.

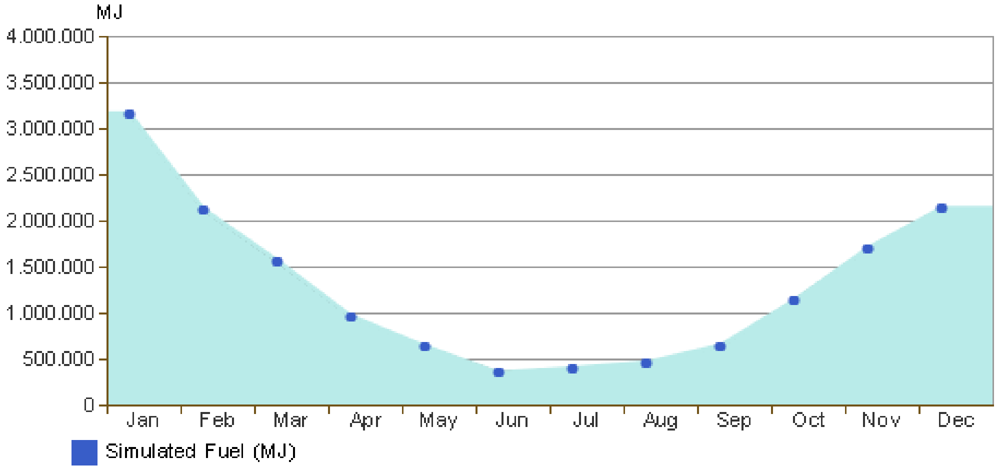

Figure 34. Monthly fuel use

2. **The highest level of energy use** (conditioning energy) is in the hottest month June and reaches 650 **kWh (fig. 35) that is less than 730 kWh** in the third plan.

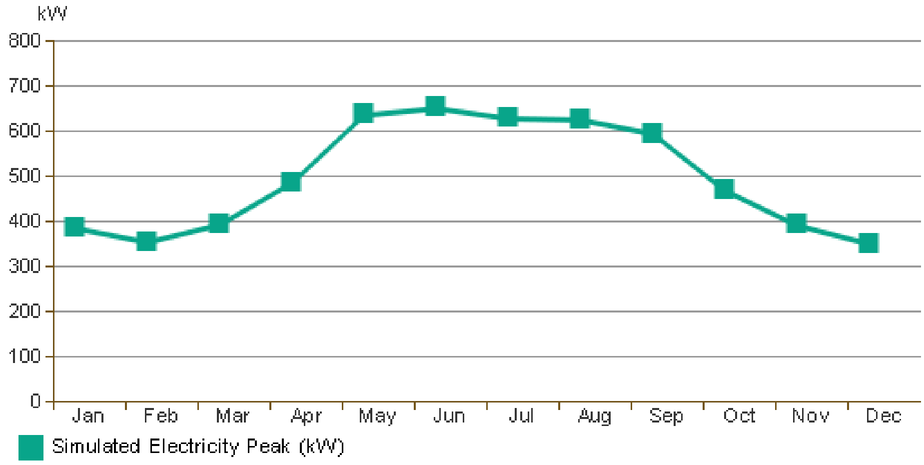

Figure 35. Peak points of electricity use.

High level of electricity use on peak points is connected with high energy use to conditioning and ventilation during these months. The reduction of loss is during winter period.

3. **The usage of alternative energy sources**: max **445,345 kWh kWh/year** can be compensated by means of placing solar cell panels on the roof. It is less than in the third plan **644,481 kWh**. It is connected with cutting the square of roof and as we can see according to the previous energy efficiency analysis this one is the most profitable.

4. **Annual CO_2 emissions** are approximately 1400 metric tons per year which is lower than previous result of 1450 metrical tons per year.

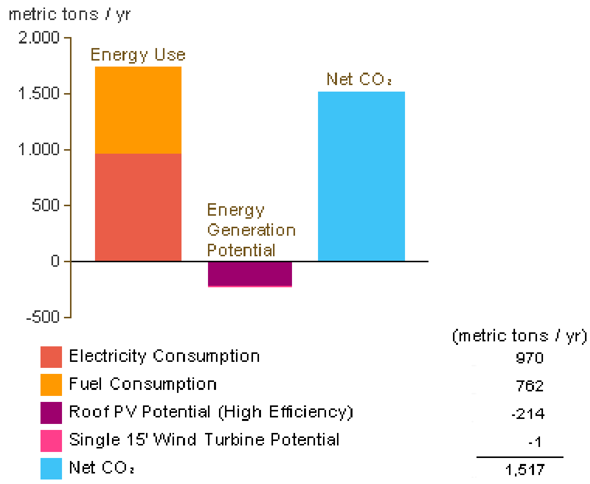

Figure 36. Annual CO_2 emissions

- **Generated energy** is energy which produced by alternative energy sources, allowing to decrease CO_2 emissions.
- **Usable energy** is fuel and electricity use.

5. **Climate analysis of the project area shows:**

- The coldest months are since November till February
- The hottest months are since May till September
- The most humidity is since November till March
- The lowest humidity is during summer months
- Primary wind direction is S-W
- Average wind speed is 12,75 meters per second

As a result of all the calculations the following building life cycle's expenses were determined:

Life Cycle Electricity Use:	60,583,110 kWh
Life Cycle Fuel Use:	458,634,617 MJ
Life Cycle Energy Cost:	$1,442,994

*30-year life and 6.1% discount rate for costs

In this project the only one type of conditioning and ventilation system was used as the most energy effective for this building.

As a result of done project we can conclude that when you project something you can't disregard such things as the building performance, energy loss, ecological damage during the life cycle of its building. Especially, when you can build it both good-looking and profitable. This project shows how you can increase building performance by simple changes in scope-planning and design constructions. This is the fact that it is possible to project building which provides itself.

Energy efficiency analysis shows how energy efficiency factors change when you change scope-planning and design constructions. Also I would like to point out that there are many variations in fact and everything depends on an architect. He takes all the responsibility of future ecology.

Figure 37. General view

Figure 38. General view