Scientific Journal of Riga Technical University
Environmental and Climate Technologies
DOI: 10.2478/v10145-011-0021-3 *2011*
Volume 6

Assessment of Exergy for Renewable Energy Disposable in the Site of Building

Vygantas Zekas, Vytautas Martinaitis, *Department of Buildings Energetics, Vilnius Gediminas Technical University*

Abstract **– Future energy challenges to construct near zero energy buildings and to have a centralized network together with integrated distributed generation from local disposable renewable energy (LdRe) raises new goals of a complex approach to energy supply. In the context of the current scientific sector, a single comprehensive approach to the general LdRe is missing. Following the typical way, all buildings are planned or designed in light of the energy needs of the intended activities in the buildings and only after the determination of these activities are the points and forms of energy supply planned. This article presents another approach in the planning process – a building and its energy needs planning taking into account the LdRe. It also provides the universal system describing the quantity and quality of LdRe. This research includes LdRe flows' assessment, with the building, as LdRe energy user flows linking to the user only as a potential user of this energy. The exergy analysis method is used to determine the LdRe indicator. Actually determined main renewable energy (RE) flow' (solar, wind, soil and air) values are used for the calculations. Standard 1 ha land plot area and set volumes above the land surface and beneath it are analyzed. After determination of disposable RE flows exergy quantity of the exergy change in the period of half year, one typical month and day is depicted**.

Keywords **– distributed generation, exergy assessment, exergy in the site of building**

I. Introduction

Renewable energy (RE) integration into traditional power distribution networks is a well-known process. RE integration is taking place both in network energy distribution systems, as well as directly on the user side. This process is accompanied by the so-called - Distributed Generation (DG). Today, DG is increasingly found within the energy supply, distribution and use strategies at the national, regional and global levels while planning resource utilization or implementing various energy efficiency in buildings-related programs [1]. Usually DG is associated with the use of renewable energy.

Renewable energy, unlike fossil fuel energy can be disposable at any point on the planet that is without a distribution network. In each case, the combination of such RE amount and energy flows (wind, solar, air, soil, water, wave, biomass, etc.) will be different.

In each individual DG case normally the same engineering task is posed – to meet the energy needs of the user by locally disposable energy. Implementing energy use from the local renewable energy user's demand for energy, their nature and fluctuations are determined, as well as an equipment package is selected – accumulator (if needed), power transformers' equipment is installed (at a user-friendly site), as well as the usual case the user is connected to the electricity distribution network or installs a local solid fuel boiler (as a backup heat source).

Generally, this process can be described as – distributed generation from local disposable renewable energy (DgLdRe).

Unconventionally, thinking from the prospect of sustainable development, the other approach proposes to plan energy supply in the opposite manner – the building site, its conditions and energy parameters have to dictate what type of energy use is the most suitable in that area, as well as what building and with what parameters should be created. Such logic is closer to the idea of sustainable development, because, in this case, nature can not attempt to tilt toward the user but the user comes to nature and adapts to it with the purpose to best absorb the given benefit of nature' in the particular area. Obviously, there is a need to assess the exact location, the land plot suitable for the user and the energy parameters found within that land plot.

Land area use is a sustainable development indicator [2, 3]. This indicator is used to measure the activity on the land area and its impact on the environment through the alternatives of activities, which could have been achieved/created, if the area were not occupied by the analyzed activity. But the main usage of this assessment indicator is through biological processes exchange that is to what extent the analyzed activity influences the existing organic processes.

In terms of renewable energy, the use of land use is directly related to the land area and volumes over the land surface and beneath it, where there is a potential difference of forming energy-flows. Renewable energy of a various kind, quantity and quality can be found in each square meter (with the volume above the ground surface and beneath it). It is appropriate to use a locally disposable renewable energy (LdReI) indicator as an additional indicator of the value of one land user. The latter can be directly used both in environmental impact assessment methods, as well as in searching for optimal energy supply solutions from renewable energy.

The typical interpretation of the expression "locally disposable renewable energy", which is normally found in literature, is individual renewable energy sources parameters summary's aggregate numbers and maps depicting RE potential (by separate sources). As such, two projects can be mentioned – interactive maps of RE prepared by U.S. National Renewable Energy Laboratory (NREL) and the project "Sustainability Victoria" implemented in Victoria, one of the cities of Australia. Interactive maps where detailed breakdown of fundamental RE parameters are shown were prepared in "Sustainability Victoria" project. Aggregate parameters change over time, the possibility to cover one RE flows by another, and the more suitable RE flows and how they fit in with varying energy needs throughout the year in modern buildings are the questions, which, according to under the author's knowledge, are not widely discussed in literature. Moreover, such assessments cover larger than exact one building sites.

Cathryn Hamilton in her work [4] summarizes the key approach of RE potential identification which is used to determine the individual flows of RE. In determining the potential of RE, it is found that:

- *RE Resource Base* is understood as a theoretical existing quantity of RE;
- *RE Resource* is understood as that part of the overall RE potential, which can be absorbed under current economic circumstances applying modern technology or modified modern technology;
- *RE Reserve* is understood as that part of the potential, which is proved to be existent and can be effectively used under prevailing modern economic conditions.

Mishela Robba et al [5] identify these calculation stages a bit differently: RE Resource Base is referred to simply as energy potential; RE Resource – as theoretical energy potential which can be absorbed and RE Reserve – as absorbed energy.

In this assessment, a buildings' energy supply from LdRe, the RE Resource is analyzed which can be achieved for a typical user by modern equipment that is surface geothermal energy (heat energy absorbed from the soil by soil collectors), wind (wind kinetic energy is absorbed using small-scale wind power plants), air temperature potential (absorbed by air heat pumps) and solar energy (absorbed using solar collectors and solar phototubes). Energy quantity is determined taking into account their thermodynamic quality – exergy.

Presenting the concept of building's energy integration into nature, the case of land area is taken and only the physical origin of RE is assessed: that is solar radiation, wind kinetic energy and air and soil temperature potential. Biomass, to one typical energy consumer extent, is accepted as a non-renewable energy, due to the very biological process, given the limited land area.

The main energy flows, which should enter into the determination of LdRe are shown in Figure 1.

In literature, there are a few land use indicators (in terms of RE) and only of individual RE flows. Hon Loong Lam et al [6] analyze the regional land use in terms of biomass only. Energy land-use factor is determined. Methodology of how to plan the disposable potential of biomass on the regional level is presented. As a result, the energy land use factor sq. km/TJ/year in units is presented. Vladimir Strezov et al [3] in his article mentions individual land employment characteristics (determined by other researchers): wind energy 72 km^2/TWh, the use of solar power for electricity generation – 28-64 km^2/TWh (without a parallel land use), geothermal energy - 18-74 km^2/TWh.

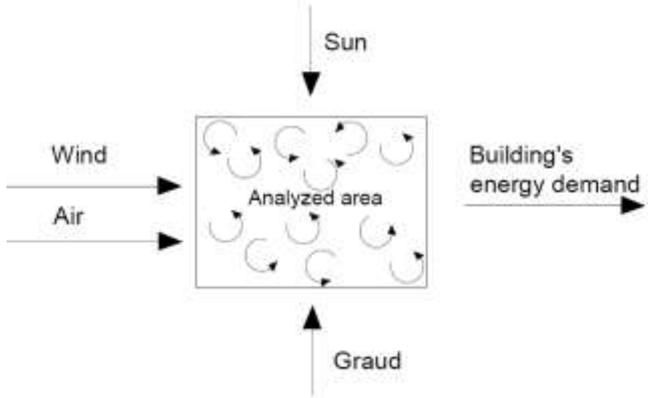


Fig. 1. Typical RE flows affecting elements' volume and area.

The available literature lacks detailed information which would bring together different RE flows locally disposable in the analyzed area that is within the defined area and volume over the analyzed land surface and beneath it.

II. RE FLOWS EXERGY ANALYSIS

Assessing sustainable development (part of this process is RE usage), the exergy model [7] is mentioned as one of the main forms of assessment. In this initial LdRe determination, the exergy assessment method is selected, the results of which can be used in later stages of the assessment of sustainable development. The selection of the exergy method is motivated by the fact that RE flows are of different physical nature (radiation, kinetic energy, heat) and the determination of only the energy quantity is not sufficient while the aim is to profit from exergy as a measure that can describe not only the quantitative importance of RE flow but also a qualitative advantage. Exergy method addressing the issue of buildings' energy supply is quite widely used by VGTU Buildings Energy Department specialists [8-11].

The key point why the exergy assessment method is still quite moderately applied not only for the analysis of equipment is reference environment objective parameters determination problem. Exergy as a possible work from the process is determined in respect of the reference point. The assessed system is in balance with the reference environment. Two reference environment systems are distinguished – full balance (the assessed system is in balance with its environment at its pressure, temperature and chemical composition) and simplified (the system is in balance at its pressure and temperature). In state of balance with reference environment the exergy of system is zero that is not possible to create work.

Supplying building with energy from RE the chemical transformation that is traditional in generators does not occur. Analyzing typical physical nature RE flows it is chosen in this analysis to use simplified environment of reference that is exergy quantity is determined according to environment of reference temperature and pressure. As the quantity of exergy directly depends on the assessed system and the difference in reference parameters, that is the potential, and thus it is very important to determine objective parameters of reference environment. The influence of reference environment parameters on the exergy analysis results of various energy systems is quite widely reviewed [12, 14]. Accomplished works conclude that exergy analysis results change only slightly due to various intensive environment parameters. Normally, pressure is considered to be constant, since most systems operate at such level above the ground, which is close to 1 atmosphere pressure. Usually, exergy analysis results are checked through a change in temperature – from 0 to 25 ^{0} C. Within such temperature limits, a conclusion is made that the energy systems' exergy analysis results vary only slightly. Since this assessment does not include the evaluation of energy systems (that is, only energy flows are evaluated), so a sensitivity analysis does not answer the question – what should be the reference environment for LdReI determination?

This question is analyzed [8, 11] and answered by the survey conducted by Adriana Angelotti at al [15]. All these works highlight that when exploring exergy systems that are close to reference environment parameters, these parameters are very important. Also [15] attention is drawn to two further important points of exergy analysis – air humidity and dynamic exergy assessment, namely that the air humidity and duration of selected values (annual average, monthly, daily, design parameters, etc.) have a significant impact on the final exergy analysis results.

In case of RE flows assessment, the building environment (in mentioned works taken as reference environment) becomes an analyzed system, the parameters of which change constantly. In this case, another reference system is needed in regard to which the amount/quality of energy in the environment would be determined. According to the author's knowledge, the literature does not contain research that would depict a complex analysis of RE flows in terms of exergy and analyzing the selection of the required reference environment.

Assessing RE flows, the main target of flows is the microclimate created in the buildings and its parameters. Usually these parameters are designed and stable, so the assumption can be immediately made that in this study case the dynamic exergy analysis is inappropriate, and that the main reference environment parameters are room temperature T_0 and atmospheric pressure P_0 and as an additional parameter characterizing reference environment – the design humidity of the room ω_{0th} The design parameters of microclimate in different areas (mainland coast, the different climatic zones, etc.) vary, hence the exergy potential of relevant RE flows' will be different, although their original settings look identical in accordance to the RE benefits. It should be noted that this research addresses the energy flows and their potential in regard of reference environment only. Application of specific energy generators for building's useful energy creation is not analyzed here. In this research, the exergy potential demonstrates the possibility to access the useful work and the extent to which this possibility can be implemented is not analyzed.

III. Methodology of RE exergy flows analysis

First, it should be noted that the assessment of exergy for RE disposable in the site of a building is accomplished under the measurements conducted in this work.

Objective – to determine complex physical origin RE flows potential in specific geometric random measurements area (Fig. 2) and to express it by overall exergy amount, reflecting changes in RE flow dynamics and common patterns. Solar radiation energy exergy, wind kinetic energy (equal to exergy), air and soil thermal exergy are assessed.

Meteorological data is collected using climatological data identification station installed at the Vilnius Gediminas Technical University. The analyzed data is collected within the period of six months from 1 January 2011 till 28 June 2011.

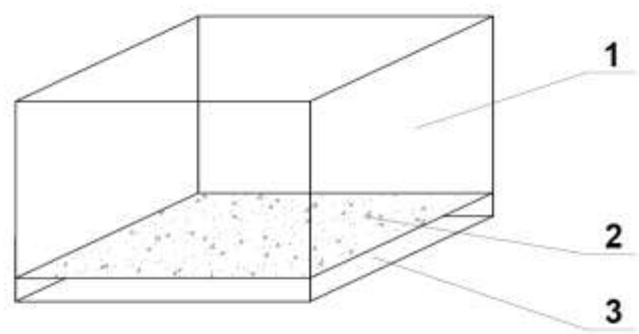


Fig. 2. Assessed RE flows area: 1 – air volume above the land surface (100x100x50 m); 2 – land area (100x100 m); 3 – soil layer beneath land surface (100x100x5 m).

The aggregated flows' exergy is determined:

$$Ex_{L,T} = Ex_{sol} + Ex_{wind} + Ex_{air} + Ex_{geo} \quad (1)$$

Where $Ex_{L,T}$ – locally disposable aggregated theoretical RE exergy; Ex_{sol} – solar radiation exergy, Ex_{wind} – wind flow exergy, Ex_{air} – air flow exergy and Ex_{geo} – geothermal exergy.

LdReI is determined as the aggregated exergy quantity for one square meter of site of the building, W/m^2.

A. Solar radiation exergy

Solar energy is the driving force supporting the processes of land surface [16]. Atmosphere surface reaches 1368.3 W/m^2 [16] energy, or 1270 W/m^2 [17] exergy quantity.

According to the review of one of the newest RE potential assessment methods [5], solar radiation can be determined in three ways:

- on the basis of local physical measurements;
- using satellite data;
- combination of both methods.

In the scope of this analysis, the fist method is used – that is the method of local solar radiation physical measurements.

DOI: 10.2478/v10145-011-0021-3 *2011*
Volume 6

The equations presented in Petela work [18] and Winter CJ book [20] are used in the solar radiation exergy analysis. They are also found in subsequent studies [17, 19].

Solar radiation exergy Ex_{sol} is determined:

$$Ex_{sol} = A_{land} I \psi_{sol} \tag{2}$$

where A_{land} denotes land surface area m^2 (used in calculations 10000 m^2 area), I denotes total solar radiation on a horizontal surface, measured in W/m^2 ψ_{sol} means relative solar radiation energy potential determined:

$$\psi_{sol} = \left[1 - \frac{4}{3} \cdot \frac{T_0}{T_{sol}} (1 - 0{,}28 lnf)\right] \tag{3}$$

where T_0 denotes reference environment temperature, K (used 293,15 K, 20 ^{0}C) and T_{sol} – radiating surface (sun) temperature, K. According to Szargut calculations [16] this temperature is 5807 K, f- dilatation factor – 1.3 x10^{-5}.

Assessing the theoretical exergy quantity of solar radiation per specific area, the possible shadow area and shading duration per day should be assessed as well. At this stage of the assessment these factors are not assessed, as there are no shadows at the meteorological measurement station zone which assumes that solar radiation reaches the earth surface without any obstacles.

It is important to note that the sun given exergy amount during the cold season can be considered to be positive, while during the warm season – negative, that is the relevant amount of exergy during the warm season to be diverted from the building or with the help of generators to be converted into the building's useful form of energy – cool.

B. Wind exergy

Wind is considered as a dynamic movement of air flow. Moving air flow has a kinetic energy which in physical terms is equal to flow exergy and has the same mathematical expression of kinetic energy [21]:

$$\psi_{wind} = \frac{1}{2} V_{wind}^2 \tag{4}$$

where V_{wind} is wind speed m/s. In order to determine the quantity of flow exergy crossing the air, it is necessary to determine the air rate, which is determined:

$$\dot{m}_{air} = \rho A V_{wind} \tag{5}$$

where ρ is air density, kg/m^3, in calculations used 1,225 kg/m^3 and A – area, which is crossed by air flow, in calculations used 5000 m^2 and it is perpendicular to the ground surface.

Wind exergy quantity is determined:

$$Ex_{wind} = \dot{m}_{air} \psi_{wind} \tag{6}$$

Due to turbulent wind as air flow nature, the potential of wind directly depends on terrain roughness and adjacent barriers, and, in order to evaluate locally disposable wind exergy quantity, the wind flow researches lasting for a number of years are required. At the same time, it is stated [5] that even having one-year wind flow measurement data the air potential can be assessed in 5-15 percent accuracy (depending on the long-term average wind speed variations). In order to know the dynamics of wind flows, along with other LdRe flows, the wind flows are measured in the half-year period.

C. Air exergy

Air flow exergy can be determined by using the equation presented by Wepfer [22] which is also used in other studies [21, 23]:

$$\psi_{air} = C_{p,a}\left(T_{air} - T_0 - T_0 \ln\left(\frac{T_{air}}{T_o}\right)\right) + R_a T_0 \ln\left(\frac{P_{air}}{P_o}\right) \tag{7}$$

where $C_{p,a}$ denotes specific heat of air, kJ/kgK ((in calculations used 1.004 kJ/kgK). Gas constant R_a in calculations used 0.287 kJ/kgK. T_0 and P_0 is the reference environment temperature, K and pressure Pa (in calculations used respectively 293.15 K, 20 ^{0}C and 101.325 kPa)

Air exergy quantity is determined:

$$Ex_{air} = \dot{m}_{air} \psi_{air} \tag{8}$$

Air flow rate is taken from wind exergy quantity determination calculations. Air flow is analyzed as an integral part of wind flow which has thermal potential. The assessed area (which is reached by air flow) contains no structures or objects that would change the amount of inflowing air flow.

D. Geothermal exergy

Surface geothermal energy is a stable, steady and easily predictable source of energy. Its main characteristic is slow recovery due to that this kind of RE is considered to be partly non-renewable. According to [22], geothermal energy flow is 30 -50 mW/m^2 in the eastern part of Lithuania and is constant during the entire year (without assessing the surface soil layer, which is affected by air temperature fluctuations and sun).

Assessing geothermal energy in terms of exergy, the thermal energy exergy is evaluated, which is determined under [23] further multiplying the right member by the analyzed area A m^2:

$$Ex_{geo} = \left(1 - \frac{T_0}{T_{soil}}\right) Q_{geo} A \tag{9}$$

where Q_{Geo} energy flow reaching the earth's surface (in calculations used 30-50 mW/m ^{2} energy flow), T_{soil} - soil temperature, in calculations shall be used equal to 5 ^{0}C.

Although, in this case, the heat flow without the help of energy generators would be directed from the building to the ground, the exergy amount can be considered to be positive,

DOI: 10.2478/v10145-011-0021-3
2011
Volume 6

that is indicating the possibility to get useful energy with the help of energy generator during the cold season or to get direct benefit with the loss of the relevant amount of heat during the warm season.

IV. Results of RE exergy analysis

All calculations are performed using accumulated detailed (one-minute interval) climatological data of the half-year period. The overall half-year change of LdRe exergy quantity is shown in Figure 3.

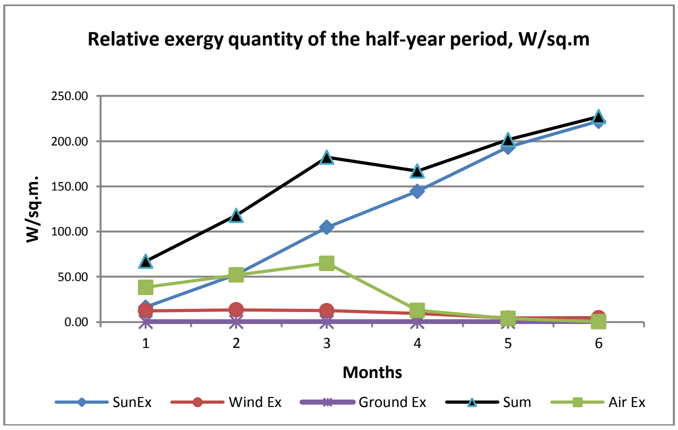


Fig. 3. LdRe-flows changes during the analyzed period.

As shown in the diagram in Figure 3, the dominant exergy quantity in the winter time is of the air flow, while during the summer – the sun is considered as the main source of exergy for the area. Aggregated exergy quantity (at the analyzed area) mainly repeats the linear increase in the solar exergy quantity. Another important characteristic of the area – there is an exergy source selection possibility during the cold period, while during the warm period the only source is the sun. Comparing geothermal heat energy exergy flow is insignificant and its long-term consumption in larger quantities is not possible. Incidental use of larger quantities would require a break to regenerate the source or sources must be supplemented by example excess solar energy.

LdRe flows exergy dynamic in May is shown in Figure 4.

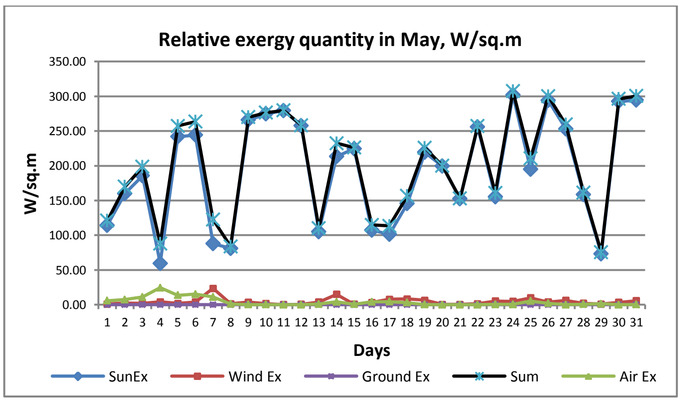
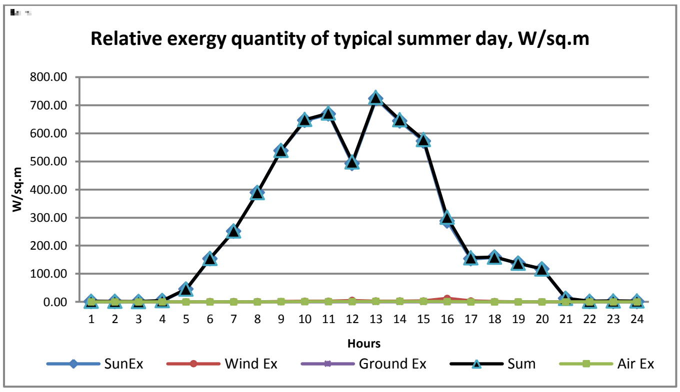


Fig. 4. LdRe-flows change during analyzed period.

Figure 4 calculation results show that the main exergy source (in one month) is the sun. Wind only slightly complements aggregated quantity of exergy.

Exergy flows dynamic of a typical day – a windy early spring day (4 February) and a sunny summer day (10 June) are shown in Figures 5 and 6.

As it can be seen from the daily exergy change diagrams of the summer period, no exergy flow reaches the analyzed area during the third part of the day. Exergy flow climax is inconvenient in terms of time when during the typical work day at home is minimum energy demand (10.00- 15.00 h).



Fig, 5. RE exergy dynamics of typical summer period day.

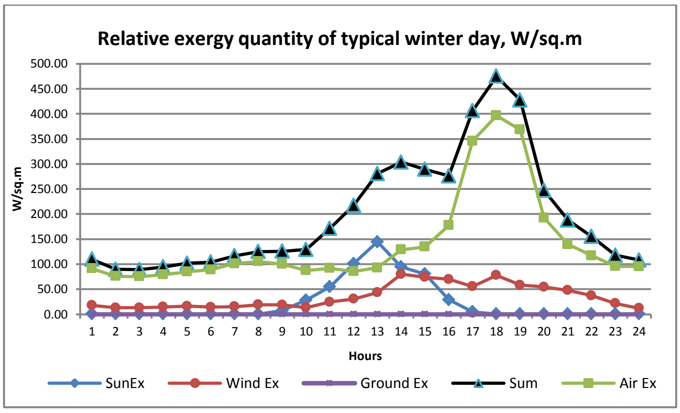


Fig. 6. RE exergy dynamics of typical winter period day.

Such a flow is more suitable to accumulate. Air, wind and geothermal energy are useless RE energy flows in terms of exergy during the summer period.

During the winter period, when the wind exergy is more likely and solar exergy quantity is rather small, it is clear that the main energy source is wind (air) and its exergy in the second half of the day. Solar energy contribution is minimal, but air flow exergy is quite significant, comprising 60-70 % of LdRe exergy.

LdReI is expressed as an average exergy quantity per square meter of one particular building site area during the selected time period (annual, summer, winter, etc.). Under the implemented initial study and climatological data gathered in the half-year period, it can be stated that the LdReI of the analyzed area is 160.57 W/sq.m of exergy flow. Dividing the analyzed period into cold/heating (January-

DOI: 10.2478/v10145-011-0021-3 2011
Volume 6

April) and warm (May-June), the result, respectively is 133.63 W/sq.m and 214.45 W/sq.m of exergy flow.

V. Conclusions

Assessment of distributed generation from locally disposable renewable energy at a building site is presented in this study. The suggestion was to use a locally disposable renewable energy indicator as one of the value indicators of the earth and also one case exergy flows change is shown. A few points can be presented as important conclusions of the exergy analysis:

- Reference environment is essential for exergy analysis the parameters of which have not yet been resolved in scientific literature which why the selection of objective parameters is still very relevant.
- Exergy analysis shows the distribution of LdRe exergy flows, that is in certain cases the main exergy source is definitely the sun;
- Exergy potential is in all RE kinds during the winter period. The dominant are solar and air. This shows that some power generators' combination is possible;
- Geothermal energy flow is insignificant so in order to use larger amounts of energy it is necessary to think about the abstinence period, or supplement of source with excess solar energy. Otherwise, the source will be cooled and after a while it becomes inefficient to use.
- LdReI is – 160.57 W/sq.m.

Planning the building supply from locally disposable renewable energy, it is important to know flow changes of local nature. On the basis of the total locally disposable exergy quantity, the task for building designers can be formed, that is a task for engineering systems combination selection and systems power distribution systems and accumulators selection. In this way, the building can be optimally supplied with energy from the locally disposable energy sources and sustainable development concept would be implemented more rationally.

References

1. **Manfren, M., Caputo, P., Costa, G.** Paradigm shift in urban energy systems through distributed generation: methods and models. *Applied Energy,* 2011, vol. 88, p. 1032-1048.
2. **Evans, A., Strezov, V., J. Evans, T.** Assessment of sustainability indicators for renewable energy technologies. *Renewable and Sustainable Energy Reviews,* 2009, vol. 13, p. 1082-1088.
3. **Wagendorp, T., Gulinck, H., Coppin, P., Muys, B.** Land use impact evaluation in life cycle assessment based on ecosystem thermodynamics. *Energy,* 2006, vol. 31, p. 112-125.
4. **Hamilton, C.** *Renewaable energy resource assessment methods and methodologies for assessesment at LGA scale - A strudy of the city of Plaiford.* Centre for Design, RMIT University ond University of South Australia, 2008. 55 p.
5. **Angelis-Dimakis, A., Biberacher, M., Dominguez, J., Fiorese, G., Gadocha, S., Gnansounou, E., Guariso, G., Kartalidis, A., Panichelli, L., Pinedo, I., Robba, M.** Methods and tools to evaluate the availability of renewable energy sources. *Renewable and Sustainable Energy Reviews,* 2011, vol. 15, p. 1182-1200.
6. **Loon Lam, H., Sabev Varbanov, P., Jaromir Klemeš, J.** Regional renewable energy and resource planning. *Applied Energy,* 2011, vol. 88, p. 545-550.
7. **Gasparatos, A., El-Haram, M., Horner, M.** A critical review of reductionist approaches for assessing the progress towards sustainability. *Environmental Impact Assessment Review,* 2008, vol. 28, p. 286-311.
8. **Martinaitis, V.** *Thermodynamical analysis model of building life cycle*. Vilnius Gediminas Technical University, 2001, 172 p.
9. **Biekša, D., Martinaitis, V.,, A. Šakmanas, V.** An estimation of exergy consumption patterns of energy-intensive building service systems // *Journal of civil engineering and management*. Vilnius: Technika, 2006, t. 12, Nr. 1, p. 37-42.
10. **Biekša, D.** *Assessments of building service systems process integration applying exergy criterion*, Ph. D. Thesis, Department of Heating and Ventilation, Vilnius Gediminas Technical University, 2008.
11. **Martinaitis, V., Biekša, D., Misevičiūtė,** V. Degree-days for the exergy analysis of buildings // *Energy and Buildings, Elsevier Science,* N42, 2010, p.1063-1069.
12. **A. Rosen, M., Dincer, I.** Effect of varying dead-state properties on energy and exergy analyses of thermal systems. *International Journal of Thermal Sciences,* 2004, vol. 43, p.121-133.
13. **Ozgener, L., Hepbasli, A., Dincer, I.** Effect of reference state on the performance of energy and exergy evaluation of geothermal district heating systems: Balcova example. *Building and Environment,* 2006, vol. 41, p.699-709.
14. **Utlu, Z., Hepbasli, A.** Parametrical investigation of the effect of dead (reference) state on energy and exergy utilization efficienvies of residential-commercial sectors: A review and an application. *Renewable and sustainable energy reviews,* 2007, vol. 11, p.603-634.
15. **Torio, H., Angelotti, A., Schmidt, D.** Exergy analysis of renewable energy-based climatisation systems for building: A critical view. *Energy and Buildings.* 2009, vol. 41, p.243-271.
16. **Szargut, J.** Anthropogenic and natural exergy losses (exergy balance of the Earth's surface ant atmosphere). *Energy,* 2003, vol. 28, p. 1047-1054.
17. **Hermann, W.** Quantifying global exergy resources. *Energy,* 2006, vol. 31, p. 1685-1702.
18. **Petela, R.** Exergy of undiluted thermal radiation. *Solar Energy,* 2003, vol. 74, p. 469-488.
19. **Alta, D., Ertekin, C., Evrendilek, F.** Quantifying spatio-temporal dynamics of solar radiation exergy over Turkey. *Renewable Energy,* 2010, vol. 35, p. 2821-2828.
20. **Winter CJ et al.** Solar power plants. New York: Springer; 1991.
21. **Baskut, O., Ozgener, O., Ozgener, L.** Effects of meteorological variables on exergetic efficiency of wind turbine power plants. *Renewable and Sustainable Energy Reviews,* 2010, vol. 14, p. 3237-3241.
22. **Wepfer, W., Gaggioli, R., Obert, E.** Proper evaluation of available energy for HVAC. ASHRAE Trans 1979;85(1):214-30.
23. **Hepbasli, A., Alsuhaibani, Z.** Eergetic and exergoeconomic aspects of wind energy systems in achieving sustainable development. *Renewable and Sustainable Energy Reviews,* 2011, vol. 15, p. 2810-2825.
24. **E. Glassley, W.** *Geothermal Energy. Renewable Energy and the Environmental.*New Mexico State University, 2010, 289 p.
25. **Hepbasli, A.** A key review on exergetic analysis and assessment of renewable energy resources for sustainable future. *Renewable and Sustainable Energy Reviews,* 2008, vol. 12, p. 593-661.

Vygantas Zekas, graduate of Vilnius Gediminas Technical University, Department of Buildings Enginerics. He has Industry Engineering (2005) and Energy Engineering (2009) degrees.
Graduate Vygantas Zekas has been part of academic staff of Department of Building's Enginerics, of Faculty of Environmental Engineering, Vilnius Gediminas technical University since 2010. The main research areas are renewable energy resources and building audit.

DOI: 10.2478/v10145-011-0021-3

Address: Saulėtekio al. 11, LT-10223, Vilnius, Lithuania
Phone: +370 69919249
E-mail: vygantas.zekas@vgtu.lt

Vytautas Martinaitis, Professor, dr. habil. of VGTU, Building Energetics (until 2009.09 Heating and Ventilation) dep. Prof. Vytautas Martinaitis has been part of academic staff of this department since 1974 in Kaunas Technology University and since 1989 - in VGTU, in 1992-1996 dean of Environmental Engineering Faculty, since 2002 head of Building Energetics dep. of VGTU. The main research area is energy efficiency of sustainable housing: thermodynamic, exergy and life cycle analysis. He has participated in local and international projects related to energy efficiency. He is author of more than 110 publications. He has Civil Engineer Diploma (1972) and two steps doctoral degree diploma. PhD thesis "Research and development of turboprop gas burner for greenhouse microclimate system" was defended in Polytechnic Institute of Byelorussia (1982). Doctor Habilitus Thesis "Thermodynamical analysis model of building life cycle" was defended in Kaunas Energy Institute (2000).
E-mail: vytautas.martinaitis@vgtu.lt

Vygantas Žėkas, Vytautas Martinaitis. Eksergijas izmantošanas atjaunojamajai enerģijai novērtējums ēkās.
Enerģētikas jaunais mērķis ir veidot ēkas ar enerģijas patēriņu tuvu nullei, kā arī veidot centralizētas enerģijas apgādes sistēmas kopā ar integrētiem tīkliem ar ģenerācijas sadalītāju no vietējās atjaunojamās enerģijas. Mūsdienās literatūrā pietrūkst metodes, kas ļauj kompleksi analizēt atjaunojamās enerģijas potenciālu konkrētā vietā. Parasti visas ēkas tiek plānotas un projektētas pēc enerģētiskām vajadzībām, kas balstās uz paredzēto izmantošanas jomu, un tikai pēc tam tiek izvelēts enerģijas veids, kas spēs segt vajadzības un pieslēgšanās vietu. Šajā rakstā tiek piedāvāts cits ēku projektēšanas un būvēšanas princips. Tas nozīmē, ka ēka un tās enerģijas vajadzības tiek plānotas, balstoties uz konkrētajā vietā pieejamiem atjaunojamiem resursiem. Tiek piedāvāta universāla metode atjaunojamās enerģijas kvalitātes un apjoma noteikšanai. Lai noteiktu atjaunojamās enerģijas apjomu, tiek izmantota eksergijas analīzes metode. Aprēķinos tiek ņemtas faktiskās pusgada vērtības no galvenajām atjaunojamās enerģijas plūsmām (saule, vējš, grunts un gaiss). Tiek aplūkots tipisks 1 ha zemes un noteikti apjomi virs un zem zemes virsmas. Nosakot atjaunojamās enerģijas plūsmas, tiek parādītas to izmaiņas pusgada periodā. Aprēķinu pamatrezultāti: pētītā objekta gadījumā par galveno eksergijas avotu kalpo saule. Vasaras periodā saule ir vienīgais eksergijas avots. Aukstas ziemas laikā ir iespējams izvelēties starp vēja (kopā ar gaisu) eksergiju vai nelielo saules eksergijas daudzumu. Konkrētajā gadījumā uzstādītais atjaunojamās enerģijas daudzums ir 190,22 W/m^2.