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THEORETICAL ECO-SPACE MODEL FOR APPLICATION IN REVITALISATION OF RURAL AREAS

The subject matter of the paper is the presentation of the results of the "Promotion of sustainable development of rural areas through the promotion of use of renewable energy sources" research and educational programme. It discusses synthetically the scope and methodology of ecological building design, together with guidelines for environmental protection design. An original theoretical model of ecologically friendly space is described in order to present contemporary methods, technologies and tools used for generating energy from renewable sources. Charts and models showing the possibilities of applying modern systems of generation, storage and distribution of energy from wind, sun, water, earth and biomass in the context of an urban and architectural space of a theoretical rural area are discussed in detail.

Keywords: ecological urban planning, renewable energy sources, revitalisation of rural areas

1. INTRODUCTION

In order to understand the scale of the problem, the significance of economic ecologism programmes and the need for energy-saving solutions in all types of human activities, it is worth quoting basic demographic data compared to the global energy consumption. Particular attention should be paid to the strategic sectors, which are construction and food production, focused mainly on rural areas. In 1950 as much as 70% of the world population lived in rural areas. Currently (2019) it is 25.4%, or about 1.95 billion out of the world's population of 7.71 billion. In Europe, in 2000, 71% of the population lived in cities (515 million out of

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726 million), in 2010 – 72.8% (535 million out of 735 million) and now, in 2019, 74.6% (554 million out of 743 million) people live in cities. According to the UN's demographic forecasts, the world's population will exceed 10 billion already in 2056; at the same time, Europe's population will fall below 709 million and the urban population will increase to 82.1 % (581 million from 708 million).

In the world, about 40% of energy is consumed in the construction sector, which at the same time produces 1 billion tonnes of waste per year. A large part of the energy is used for the use of buildings, including heating of buildings and maintaining climate comfort (cold and heat), while the remaining consumption consists mainly of the production of building materials, their storage and transport, as well as workmanship. At the same time, rural structures contribute to 25% of the planet's pollution.

2. ENERGY POLICY PROBLEMS

Construction has a direct and indirect impact on the environment. The indirect impact results from the use of mineral deposits, forests and water, development of construction technologies and utilisation of used objects. The direct impact is the impact of the building on the environment in which it operates. This is visible primarily in the territorial expansion of subsequent objects in open areas, but also in the production of waste, pollutants and sewage, oxygen consumption, exhaust emissions and others.

Tab. 1. Impact of construction on the environment, compiled by KB, 2015

Issue	Share	Effect
Use of minerals	Construction technology 40% stone, gravel, sand 40% steel, 20% others	Landscape devastation, poisonous emissions from mines and steelworks; air, water and soil pollution
Use of wood	25% of construction works	Reduction of forest area, disturbance of air and water circulation, steppe formation
Use of energy	40% of resources	Local pollution, acid rain, global warming
Use of water	16% of resources	Environmental pollution, wastewater, disturbance of fauna and flora ecosystems
Internal climate	30% of buildings – poor air quality	Increase in the incidence of diseases and allergies

The European Union's energy policy is implementing the "3 × 20" programme until 2020, in which the member states have committed themselves to reducing their greenhouse gas emissions by 20%, reducing the share of renewable energy in EU-wide consumption by 20% and reducing total energy consumption by 20%. According to those EU commitments, by 2020 renewable energy sources (RES) should account for 15% of gross final energy consumption.

Fulfilment of the above-mentioned obligations in the implementation of RES technologies is difficult due to numerous issues which can be generally classified as follows:

1. Information – no reliable information about costs, benefits and actual environmental impact.
2. Education – lack of sufficient education, training programmes and promotional campaigns.
3. Nature protection – lack of methods to avoid conflicts in the natural environment and lack of recognition of RES influence on the environment.
4. Institutions – no advisory institutions, no RES leaders in municipalities, no energy strategies for municipalities and regions.
5. Organisation – lack of collective actions and social participation programs, lack of transparency and actions.

2.1. General principles and guidelines for green building design

Theoretical studies and own designing experience of recent years allowed the author to formulate several general principles of green building design, taking as the priority the harmonious coexistence of human beings and their environment.

1. The decision on the location of the investment must take into account analyses of landscape, terrain and properties as well as the utility of local resources and infrastructure.
2. The consumption of natural resources, energy production and waste disposal should be decentralised, and the size of the investment should be adapted to the possibilities of acquiring energy and water acquisition and disposing of waste without harming the environment.
3. The method and type of the construction development should leave as much of the environment as possible intact.
4. Specific types of buildings should be diversified and well adapted to the site conditions in order to minimise earthworks and transportation of mass construction materials, which significantly increase the cost of such operations.
5. Building bodies should be simple and compact, so that the surface of the external partitions through which heat is lost can be reduced to the necessary minimum.

6. Most of the glazed surfaces should be located on the south side of the building. If it is necessary to use windows in northern façades, then the dimensions of windows should be minimized.
7. In order to generate solar energy, buildings should be equipped with glass porches or large glazing on the south side.
8. Through the use of glass partitions and sealing of all joints and contact points, uncontrolled ventilation of buildings should be eliminated, and ventilation systems should be designed to prevent direct escape of warm air outside the building.
9. Heat generating equipment and facilities (including installations) should be located centrally inside the building.
10. Regardless of the location of the energy and water consumption meters, energy-saving devices with built-in regulators and control systems should be used.
11. In the selection of building materials, the aim should be to save energy on a continuous basis (i.e. from the production to the construction stage) and to use local production capacities; it is advisable to use technologies that do not require the use of energy-intensive equipment.
12. If heavy materials are used, they should always be used to accumulate energy for heating purposes, which means that they should be placed on the inside of the building in the building's envelope, and covered by light materials.
13. Only materials that are not harmful to health, and in particular not allergenic, should be permitted.
14. The so-called "reusable" construction technologies, materials and tools should be used.
15. In order to avoid additional work, reduce waste and prolong the life of buildings, it is necessary to use good quality materials and to enforce a high level of performance according to correct construction designs.

The above-mentioned postulates are in line with the subsequent guidelines, concerning environmental protection and obtaining and maintaining the quality and comfort of the living space:

1. Preservation and care of the existing greenery and design of new high intensity green systems with the largest possible biologically active area.
2. Leaving humus from the earthworks on the premises.
3. Storage of solar and photovoltaic energy.
4. Use of integrated energy systems.
5. Location of houses in the east-west orientation; exposition of gardens and glazing to the south, together with energy uptake.
6. Use of natural, healthy building materials; cultivation of local traditions.

7. Shaping private spaces, zoning and combining functions.
8. Developing urban complexes in green areas over water, maintaining biodiversity and natural ventilation.
9. Developing spaces on a human scale, making them safe and durable, taking into account the aesthetic form and colours of the surrounding public space.
10. Modern systems for building construction and operation, dosing, saving and measuring energy.
11. Waste treatment and disposal systems, waste segregation.
12. Water storage and use on the property; local sources of media and sewage disposal.

2.2. Theoretical eco-space model

In order to meet the social and agricultural expectations and in line with the general trends in the implementation of environmental protection and RES promotion programmes, an original theoretical eco-space model was created to present modern methods, technologies and tools for the production of energy from renewable sources[1]. As a result of the research carried out on the subject as well as studies and analyses conducted, an educational set was made, consisting of a model, a set of display boards with a 3D visualisation and a multimedia show, presenting sources of energy from wind, sun, water, earth and biomass, in the context of urban and architectural space of a theoretical rural area.

[1] The eco-space model was developed in 2014 as part of the implementation of the programme co-financed by the Voivodeship Fund for Environmental Protection and Water Management in Poznań under the title of "Promotion of sustainable development of rural areas through the promotion of renewable energy sources", as part of the expansion of the WCIE teaching and training base in Sielinek. The programme was implemented in cooperation with the Ordering Party: Wielkopolski Ośrodek Doradztwa Rolniczego w Poznaniu [Greater Poland Agriculture Advisory Centre in Poznań], ul. Sieradzka 29 with the Contractor: Borowski-Architekci, architect Krzysztof Borowski, PhD, Eng., associate professor, Sokółki 12B, Kazimierz Biskupi. The coordinator of the project was Mrs. Ewa Kwapich from WODR Poznań, with its seat in Koło, ul. Kolejowa 13. Krzysztof Borowski was the chief designer of the model and manager of the executive team; the team was composed of: Dymitr Nowak, Kamil Głowacki, Michał Gawron, Jerzy Hyjek, Andrzej Foltman. Chief Consultant: architect Roman Pilch, PhD, Eng. The model was developed in the studio of the Urban Planning Department of the Faculty of Architecture at the Poznań University of Technology. The model and the set of boards are presented on the permanent exhibition in the WODR "Sielinko" Exhibition and Training Centre in Sielinek near Opalenica.

The works on the model were preceded by the development of an urban and architectural concept for the development of the area, developed with exemplary facilities and installations for generating, accumulating and saving energy. A theoretical model of the area was developed that shows the whole range of RES systems. An integrated spatial and functional system with realistic features was designed with the following network layers:

- a hypsometric landscape base map,
- a layout of environmental elements – green areas and water,
- functional zones with different development methods – compact residential and service buildings, habitats, agricultural production,
- a set of compositional elements – axes, regions, areas, borders, etc.,
- conventional technical infrastructure and RES maintenance networks,
- communication system – roads, paths.

The model, developed on the basis of the author's urban and architectural concept of land use, was made according to the required specification and consists of six integrated parts, making it possible to demonstrate and use independently different energy sources and technologies of energy production and distribution. Each of the six parts is designed to function independently or as a set. That makes it possible to exhibit all sections together or each of them separately. The sections are mobile and as such may be exhibited at various exhibitions, fairs, etc. or the 6 sections may be put together into a homogenous model. Each section of the model has a size of 1×2 m, which, when put together, gives a total size of a 2×6 m model of an area of 12 m^2. The model is made of cardboard elements cut out by laser and glued by hand, on a solid wooden base, with height-adjustable legs, and a glass cover dome on a structure made of aluminium profiles. The aluminium dome system makes it possible to cover each section separately or the model as a whole. The model may be connected to the electricity to provide power supply to the included RES exhibits.

An integral part of the eco-space educational set is a set of 17 display boards (printed in colour, on a rigid base, in 100×70 cm format) and a multimedia presentation (55 slides in PowerPoint). The boards and presentation give a theoretical introduction to the issues of ecological urban planning and RES, the principles of designing ecological buildings following urban and architectural guidelines for designing in accordance with the principles of environmental protection and a design of eco-space management in 2D (a map) and 3D (visualisation in perspective). The key element of the boards is the presentation of 36 different possibilities of production, distribution and use of RES systems – 6 systems per each section: water, sun, wind/air, biomass, earth/geothermal and urban planning/architecture. Each section presents RES systems on a development plan, 3D visualisation and several dozen charts in total, showing details of the systems' functioning and their practical application.

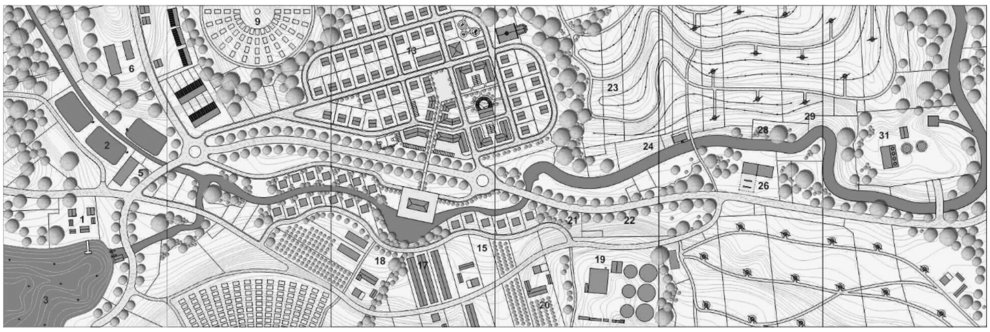


Fig. 1. An original theoretical eco-space model shown in order to present contemporary methods, technologies and tools for energy production from renewable sources, designed by KB, 2014

Fig. 2. Visualisation of the eco-space management plan, designed by KB, 2014

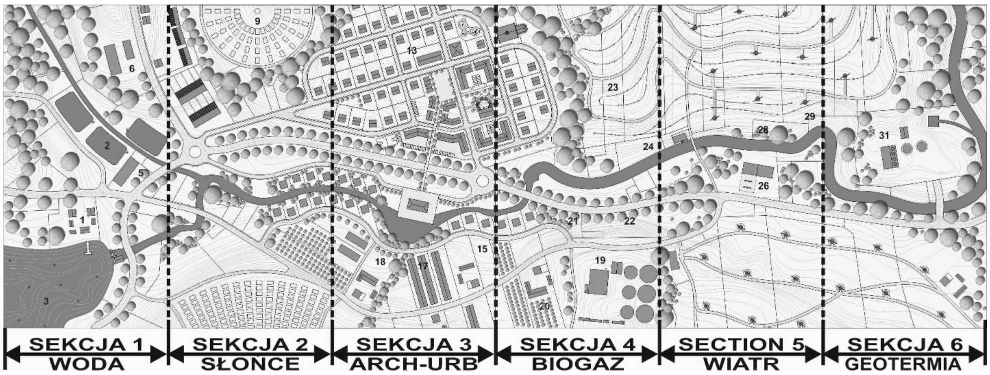
Fig. 3. The eco-space model, designed and implemented by KB, 2014

Fig. 4. Selected display boards of the eco-space model, the "Solar energy" set, designed by KB, 2014

Fig. 5. Selected display boards of the eco-space model, the “Solar energy” set, designed by KB, 2014

3. MODERN METHODS OF PRODUCING ENERGY FROM RENEWABLE SOURCES

In the eco-space model, 6 groups were distinguished, showing the possibilities of applying modern systems of production, storage and distribution of renewable energy. Each of the groups was presented in one of the 6 sections of the theoretical rural development plan. They were the following: water, sun, urban planning and architecture, biogas and biomass, wind and geothermal energy.



Water Sun Arch and urb Biogas Wind Geothermal

Fig. 6. Sections of the Eco-Space Development Plan, designed by KB, 2014

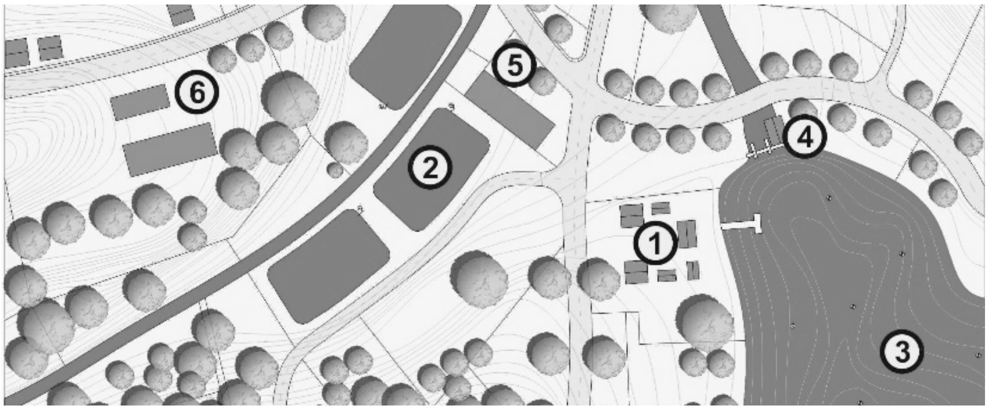


Fig. 7. Section 1 – WATER, designed by KB, 2014

1. A fishing and agrotourism farm using a small water turbine to produce electricity; the farm buildings use a photovoltaic (PV) installation; the CO installation is powered by the heat of lake water.
2. Fishponds with water-oxygenating windmills; subsoil heating system powered by groundwater heat.
3. Floating Windside rotors, producing electricity for the fishing farm; fountains are used for water oxygenation.
4. A hydroelectric power plant – of a flow-through or pumped-storage type; co-operating with the wind farm as an energy storage.
5. Pig pens, cowsheds – a ventilation heat recovery system used to feed water heating systems in carp ponds; heat recovery from slurry.
6. Sawmill – production of timber for construction purposes for the local market; sawmill waste used for the production of briquettes for CO furnaces.

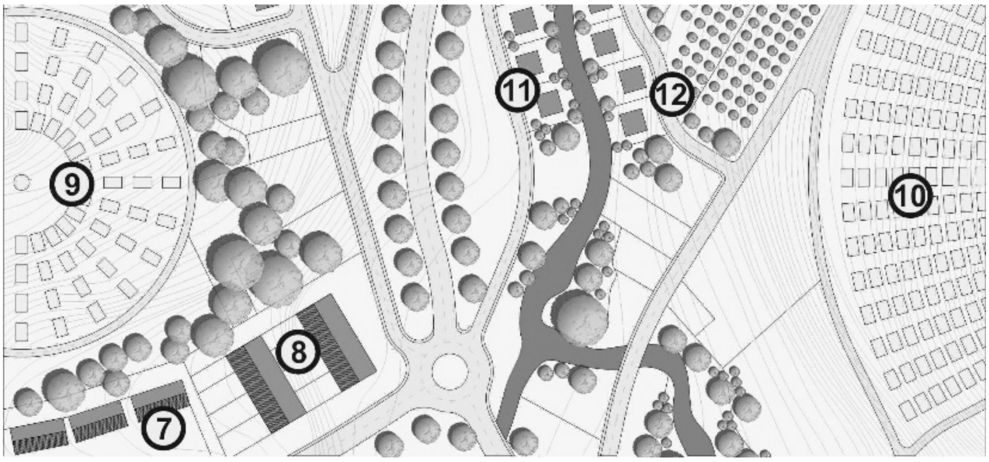


Fig. 8. Section 2 – Sun, designed by KB, 2014

7. Poultry farm using roof mounted photovoltaic panels to supply ventilation in the poultry houses.
8. Roof and above ground solar concentrators used for photovoltaic installations and for hot water production.
9. Solar power plant – a field of flat heliostats, a solar tower.
10. Solar farm – a field of photovoltaic panels; production of electricity for the national mains.
11. Residential buildings using photovoltaic roof panels to produce electricity for domestic use.
12. Residential buildings using an installation of flat-plate solar collectors for domestic water heating.

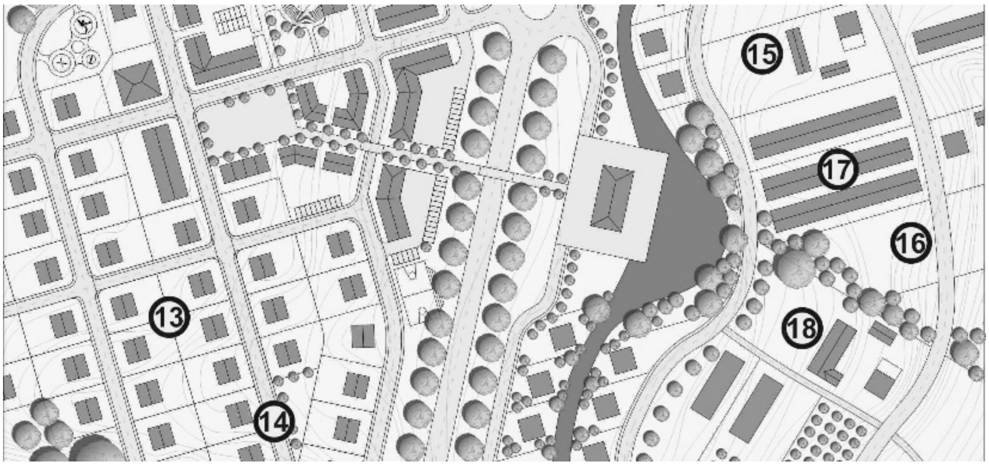


Fig. 9. Section 3 – ARCH-URB, designed by KB, 2014

13. Residential and public buildings with renewable energy installations: photovoltaic panels, solar collectors, heat pumps – domestic water and CO heating installations.
14. Street lighting and public information systems (bus stops, signs, boards) powered by solar installations.
15. A rural and municipal biomass heating plant.
16. A rural and municipal landfill with a sorting plant (raw material recovery) and a waste incineration plant – production of electricity and heat.
17. A horticultural farm – greenhouses powered by heat from a biomass oven, coolers for fruits/vegetables/flowers, powered by solar energy from photovoltaic panels.
18. A farmhouse – milk and beef production with heat recovery from milk cooling.

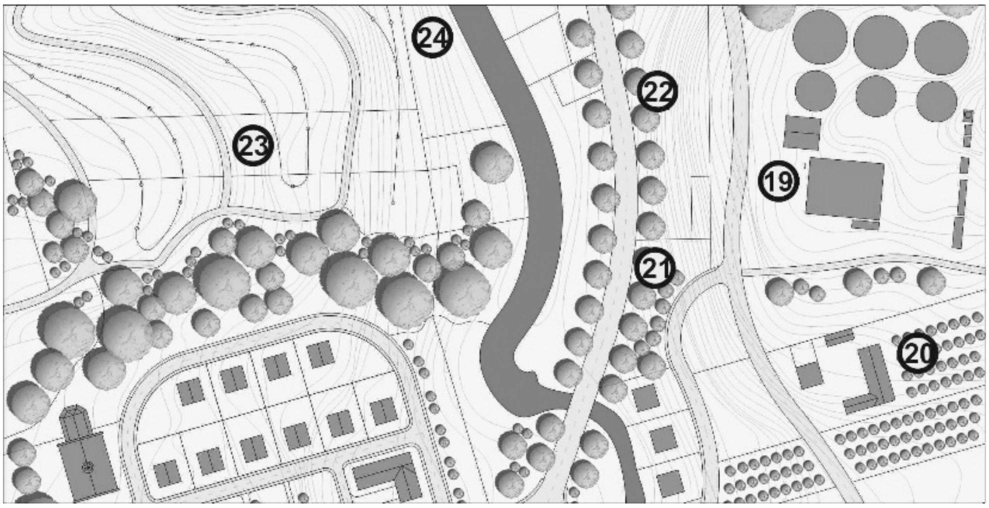


Fig. 10. Section 4 – BIOGAS, designed by KB, 2014

19. An agricultural biogas plant – use of gas to supply the gas network and the power grid, refuel vehicles as well as to produce heat for housing and production purposes.
20. A farm producing briquettes and pellets for furnaces and biomass for biofuel production. Energy crops: rapeseed, willow, poplar, cereal and rapeseed straw (sawmill waste).

21. Agricultural and food processing plants – e.g.: distillery, oil mill, fruit and vegetable processing plant, slaughterhouse, etc. using heat from biogas and supplying waste for biogas production.
22. Feed, fertilizer and biofuel production plants.
23. Field irrigation systems producing raw material for biogas plants.
24. A building with an installation pumping water from the river to irrigate the fields.

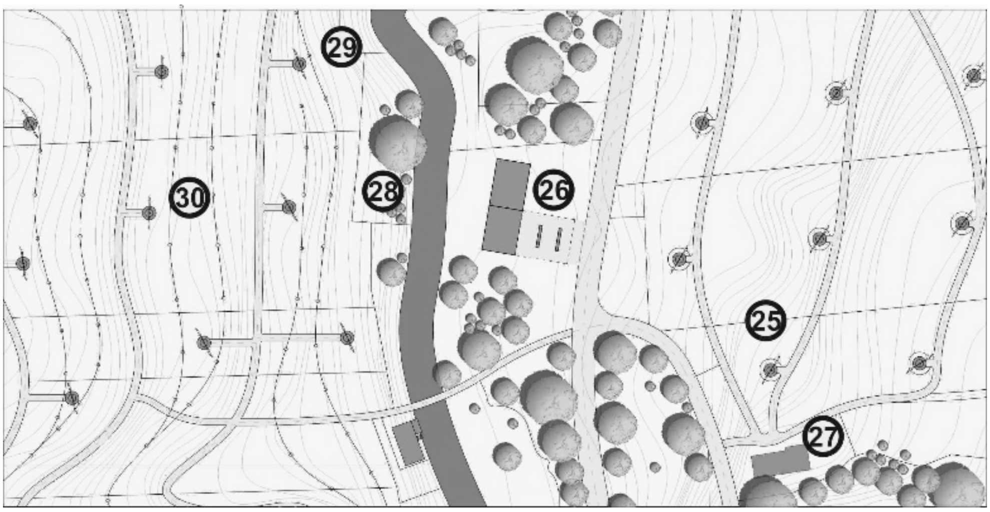


Fig. 11. Section 5 – WIND, designed by KB, 2014

25. An industrial wind power plant on cultivated fields, producing energy for the power grid.
26. A biofuel station – power supply for electric cars; biofuel refuelling (bio-diesel, biogas) for agricultural vehicles.
27. Production, storage and inventory buildings with energy recovery from tech-nological processes; drying rooms, cold stores, livestock buildings, air condi-tioning and ventilation, heat recovery from animal faeces.
28. Heat pump systems for heating process water (irrigation, equipment washing), heating of ventilation air in production rooms, direct heating of production fa-cilities (e.g. greenhouses, film tunnels).
29. Domestic wind turbines for the household's own needs – horizontal and verti-cal axis wind turbines.
30. Arable land – for ecological use (willow, rape, wheat, maize, rye, flax, other).

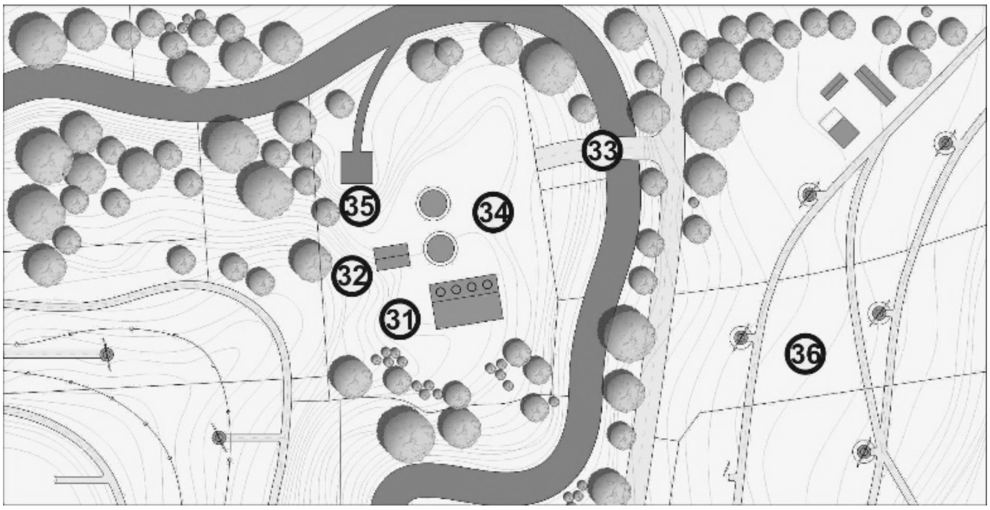


Fig. 12. Section 6 – GEOTHERMAL, designed by KB, 2014

31. A geothermal power plant generating electricity from geothermal heat, supplying the power grid.
32. Domestic heat pumps with ambient energy (ground, water or air), ground probes with a horizontal or vertical collector.
33. A bridge or a viaduct equipped with a heat pump – for de-icing and snow removal, with collectors mounted in the bridge pillars.
34. Petro-thermal energy – production of electric energy by obtaining thermal energy contained in heated rocks.
35. Hydrothermal energy – obtaining secondary heat for building heating systems and technological processes.
36. Low and medium temperature hydrothermal energy for heating water and soil in agricultural production processes.

4. SUMMARY

The presented theoretical eco-space model, indicating directions and possibilities of revitalisation of rural areas, especially in relation to renewable energy systems, probably does not discuss the subject matter in all the details and does not indicate all possibilities of using RES technologies. However, it has proved to be an important tool in the process of environmental education in the branches related to agriculture and accompanying services. The model together with the display boards and the multimedia presentation are mobile exhibits, which can enrich numerous exhibitions, conferences and workshops for interested parties. The attractive form of the spatial model, enriched with display boards, stimulates the imagination of the viewers, indicates a wide range of possibilities of using various RES technologies and inspires those interested in the subject to deepen their knowledge and look for innovative technological solutions. Sources of energy production from conventional fuels are running out and their use is causing considerable environmental pollution. Therefore, it is worth promoting and showing to potential users modern systems of energy production from renewable sources, which are equally effective and, most importantly, clean for the environment.

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TEORETYCZNY MODEL EKOPRZESTRZENI DLA ZASTOSOWAŃ W REWITALIZACJI OBSZARÓW WIEJSKICH

Streszczenie

Przedmiotem referatu jest przedstawienie wyników programu badawczo-edukacyjnego „Promocja zrównoważonego rozwoju obszarów wiejskich poprzez promocję wykorzystania odnawialnych źródeł energii”. Omówiono w sposób syntetyczny zakres i metodykę ekologicznego projektowania budynków wraz z wytycznymi do projektowania ochrony środowiska. Opisano oryginalny model teoretyczny przestrzeni przyjaznej dla środowiska. Przedstawiono współczesne metody, technologie i narzędzia wykorzystywane do pozyskiwania energii ze źródeł odnawialnych i ich zastosowania w budownictwie. Szczegółowo omówiono wykresy i modele przedstawiające możliwości zastosowania nowoczesnych systemów wytwarzania, magazynowania i dystrybucji energii z wiatru, słońca, wody, ziemi i biomasy w kontekście przestrzeni urbanistyczno-architektonicznej teoretycznego obszaru wiejskiego.

Słowa kluczowe: urbanistyka ekologiczna, odnawialne źródła energii, rewitalizacja obszarów wiejskich