



# Article Can Energy Be a "Local Product" Again? Hungarian Case Study

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Abstract: The energy sector is undergoing radical changes, and this transition is expected to accelerate all over the world over the coming years. In our recent research, we conducted a questionnaire survey at different levels and asked the experts in the area, the businesses involved in the issue, the operators and maintainers of existing systems, as well as the potential consumers and end users, about their knowledge and intentions related to renewable energy sources. Our empirical research can be divided into three parts. Our exploratory research was based on expert interviews, which show that the growing importance of localization is unquestionable, but the economic, social, and existing infrastructures impose significant barriers to the widespread adoption of certain technologies. Regarding the population survey, we see that the skepticism experienced in previous years has been replaced by a kind of expectation reflecting openness. In addition, it can be stated that in many cases technological development is faster than the possibility of its adaptation. Our gender tests significantly support men's better knowledge of the subject and the fact that biomass (despite its major importance) is not one of the most known renewable energy sources.

Keywords: renewable energy; knowledge; locality; experience; questionnaire

## 1. Introduction

Eastern and Western Europe face different challenges in the growth of renewable energy. For most of the last century, there was a gap between the two areas in a number of developmental issues [1]. This trend has been sustained in the move towards today's energy transition as the "carbon curtain" has replaced the notorious iron curtain in recent decades. It is forward thinking to attempt to unify the energy politics of the EU, but Eastern Europe simply has a much deeper hole to climb out of than their Western brethren when it comes to the switch to renewables, making it much more of a challenge. The investment climate is influenced by the available tender resources, but, as in Western countries, many energy-related projects are considered investments owing to the low deposit interest rate.

Renewable energy development is still at an early stage in Eastern Europe. Apart from the large hydropower capacity, constructed mostly several decades ago, renewables have started to take off only in a few countries. Yet, significant tender sources, combined with falling technology costs and newfound cost competitiveness, mean that an energy system powered by renewables is closer at hand than ever [2,3].

Biomass used for energy purposes (in particular byproducts) has relatively low value on the site where it is produced and is not economically viable in its original form. Most of the bioenergy is used to generate heat, which can only be utilized locally. All these facts support the importance of local utilization and energy self-sufficiency.

Local utilization refers to the operation of small and medium-sized production units that are more responsive to local resources and needs, where energy is produced and utilized in an efficient and environmentally friendly way, preferably in a circular economy.

#### 1.1. Energy Transition at a Glance

In the two decades since the turn of the millennium, newly installed renewable energy production capacities have significantly increased globally, year after year. According to the International Energy Agency's (IEA) latest report, 180 gigawatts (GW) of new photovoltaic solar, wind, water, and other renewable energy generation systems were installed worldwide in 2018, similar to the previous year. The regional distribution of installations in 2018 in decreasing order is as follows: China (77 GW), the European Union (22 GW), the USA (17 GW), India (14 GW), and Japan (7 GW). In terms of the combined installations of other countries (44 GW), they account for roughly half of China's installation last year and double the new capacity installed in the European Union [4]. The renewable energy investments in the Arab countries and in Russia are interesting parts of the trend, which, in addition to being an excellent investment opportunity, marks the end of an era.

In the member states of the European Union, the economic situation, the energy mix, the supply of resources, and the means and efficiency of energy use vary considerably. Many countries have set very ambitious targets and their long-term strategies have not only produced significant results but also shaped the region and, in many cases, the global renewable energy industry. The flagships of these processes are Germany and Denmark. At the moment, the eyes of the world are on Germany. The big question of the future is whether it is possible to run sustainably such a large industrial economy on green energy, and, if so, at what price it can be achieved.

The European Union's renewable energy objectives and their sustainability can also be seen in the capacity of the Union's smaller territorial units and countries. Renewable energy markets in Central and Eastern Europe with similar conditions (historical, cultural, and geographical) are clearly underdeveloped compared to Western European countries. As a result, there are significantly more opportunities to develop green projects in the future. Energy saving and the increase in the use of renewable energy sources are not only on the agenda due to the fulfilment of the related EU objectives, but can also lead to significant energy import reduction focusing on environmental issues [5,6]. According to Schuster [7], the leading economic and export powers utilizing the globalization processes for years and decades have particular responsibility in the transformation by being examples and giving guidelines.

Hungary's energy demand is high; one-third of the resources to cover energy needs come from domestic production and two-thirds from imports. Before the turn of the millennium, electricity supply relied almost exclusively on fossil and nuclear power sources; nowadays, renewable energy sources are also playing a role in the supply, but the highest volume of electricity in Hungary (40%) is generated in a nuclear power plant. The ongoing expansion of the Paks Nuclear Power Plant includes the construction of two new nuclear power plant units in Paks, besides the four Paks 500 megawatt (MW) nuclear power plant reactor units commissioned in 1982. As a result of the investment to increase the lifetime of the energy mix in Hungary, the capacity of the nuclear power plant will continue to grow in the long run. However, the share of renewable energy in the country is constantly increasing (Figure 1). The country's target for 2020 is to reach 14.65%, which was close to 13% in 2017. In terms of the EU average, this value was 17% in 2017, according to the latest data provided by Eurostat [8].



Figure 1. Share of renewable energy sources in gross final energy consumption in Hungary. Source: [9].

Renewable energy sources play a central role in the construction of low-carbon energy systems, but little is known about the structural factors and practical issues that shape national renewable energy policies and energy transition processes [10,11]. The related national strategy papers [12–14] focus on the national targets and commitments regarding energy and climate change, with particular emphasis on reducing emissions, improving energy efficiency, increasing the share of renewable energy sources, and meeting the objectives of the Energy Union. The connection between the economic and social survival and the renewal of rural settlements, the locality and the utilization of renewable energy is emphasized only in the National Rural Strategy [15]. In this document, just as in the main thread of this study, the new, innovative ways of energy supply appear as an important pillar of rural policy.

According to the latest data of the Hungarian Energy and Public Utility Regulatory Authority in 2019, the share of electricity produced from renewable sources was 7.5% in 2017. Looking at the data from the last 10 years, it is clear that the increase in the share of renewable electricity in 2011 stopped, and from 2013 it started to grow again. This trend was caused by the changes in the regulatory environment of multi-fuel power plants and by the fluctuations in biomass-based energy production. The proportion of renewable energy used in transportation was between 6-7% in the recent period. The share of renewable heating and cooling has been around 20% since 2010. The growth in the share of renewable energy in recent years has been influenced by the increasing use of renewable energy and the decreasing gross final energy consumption [16,17].

In the last decade, the rise in the share of renewable energy was mainly related to the use of biomass at the national level and to the targeted implementation of EU and domestic tenders. The latter improves electricity generation by using solar cells, while geothermal energy, heat pumps, and other biomass-based developments help heat generation. The biggest "loser" of the tender system in Hungary is definitely wind power, as no wind-turbines have been licensed since 2011. The most spectacular area of development is the expansion of photovoltaic systems, both statistically and visibly. In this context, it should also be emphasized that without EU subsidies, growth would probably not be so high, but the strong and favourable investments of the population also play a prominent role.

Recently, as far as Hungary is concerned, several international and national studies have dealt with the expected trends [18,19], potential estimates [20–22], energy policy issues [23–25], and with research on population attitudes [26–28]. These literature sources also highlight some of the challenges in this field and the fact that local levels (municipalities, micro-regions) and credible information have

significant roles to play in the further spread of renewable energies and in the adaptation to climate change. However, the penetration of bottom-up initiatives in Hungarian municipalities is low, whereas government-led policies dominate the issues of climate change and the management of renewable energies. In the present study, based on the results of the previous ones and considering their viewpoints and approaches, we focused on issues prioritising very practical aspects. The rich methodological toolbox (analytical evaluation of the opinions given by experts, professional organizations, and entrepreneurs; experience in the preparation, implementation, and operation of operating systems; comprehensive public knowledge and needs assessment of the topic) allowed the further exploration of several sub-topics, which were mentioned only in the literature on the subject. Our research clearly highlights the complexity of global and local processes in the field of energy as a local product, which is explained and interpreted in the following chapters of this study.

#### 1.2. Decentralization, Locality, Energy as a Local Product

There are many concepts and approaches regarding globalization and localization. According to Gergely [29], localization is the opposite process to globalization; however, it should not completely destroy today's global economic system, but gradually and radically transform it. However, in his opinion, more than just adjusting today's processes, localization means a sharp change of direction, a new way of organizing the economy where social and ecological aspects are more important than market expansion and profit.

Within the context of localization, boosting and developing the local economy is of great importance today. This can have many practical forms, including, but not limited to, strengthening local identity, supporting local products, promoting sales, developing local businesses, or generating alternative energy locally and providing an independent community energy supply [30–32]. The latter is also a realistic alternative in Hungary with respect to local interests and values, in terms of providing residential and institutional energy supply and business energy needs. Thanks to developments in recent years (or even decades, in case of geothermal systems) we can find several examples in the country.

Subsistence economy existed for centuries in food production, energy generation, and many other areas of life. In the light of global energy production and distribution processes, environmental and sustainability issues, the question arises as to whether energy can be local again. Tóth-Kaszás et al. [33] draw attention to the fact that today the vast majority of human needs can be satisfied locally in an efficient way. Today's technological developments make it possible (again) in almost every area. With this in mind, the control over the supply chain must be returned to the local communities.

The concept of local product is not bound by rigid rules and conceptual definitions: it is a product produced in a given settlement or region by the use of local resources, which is created by the local economic system. Local products are typically produced by the local inhabitants and by micro and small businesses. Production, sales, and consumption take place locally, distribution channels shorten. The added value appears at the local level and contributes locally to the development of businesses [34–36].

With the growth of local interests and values, the local product concept must be defined in terms of energy in the future. A baseline to this way of thinking is the simplified approach of MacKay [37], which states that the options for non-fossil-based power generation at country and regional levels are: energy production from local renewable energy sources, renewable energy sources from other countries or regions, and nuclear energy. In our opinion, the energy generation by means of renewable energy installations (private, institutional, communal, or business-related) can increase the use of renewable energy by applying the principle of decentralization and the idea of localization. The vast majority of human energy needs (housing, transport, work, etc.) can be satisfied locally and economically using the latest technological achievements.

Over the past decade, the possibility of installing renewable energy systems in Hungary has become a reality for the investors, businesses, institutions, and the general public. This field had a

rough path even in the relatively short period of time. We can say that in many cases the technological developments take place at a faster pace than their adaptation, but certain technological solutions and their criticism, or even their regulatory environment, can change rapidly. According to Zsarnóczky [38], the role of the time factor in spreading new solutions is exacerbated in disadvantaged regions and among underprivileged social groups. This is supported by a population survey in 2016 [39], according to which the knowledge of people living in underdeveloped areas is limited, the acceptance of new renewable energy investments or the large-scale utilization of available biomass for energy purposes is low. The modern energy supply is the basis of modernization in rural areas. The construction of the electricity network in the 20th century and the electrification of the villages, similarly to other regions, brought about fundamental changes in the life of rural society. Modernization at that time was also accompanied by the transformation of the villagescape; the utility poles, the overhead cables, and the transformer boxes became an integral part of the village environment. Under the aegis of sustainable development, the potential for energy saving and the possibility of producing energy locally (after a few decades of hiatus) enrich the rural view with new spots. State-of-the-art solar panels, solar collectors, and other renewable energy installations are gradually becoming the usual accessories in settlements and rural areas [40]. The investments require increased attention since they are the foundation stones of the renewable energy industry in Hungary; their positive or negative experiences and the evolving public attitude can determine the investment spirit and decisions concerning renewable energy issues for decades. The results of our research presented in this paper were compiled in order to show the supply and demand side of the emerging renewable energy industry by focusing on the issue of locally produced energy, helping Hungary and other countries with similar capabilities in the process of energy transition.

#### 2. Materials and Methods

The process of designing, implementing, and extending renewable energy installations and energy saving systems has accelerated in recent years. Based on the partial results of our comprehensive research project titled "Can energy be a local product again?", we present some of the peculiarities in the use of renewable energy sources in Hungary, the experiences in the preparation, implementation, and operation of the existing systems. The objectives, material, and methods of the research are summarized in Table 1 below.

The overall objectives of the research included summarizing and analyzing the experience of operating domestic renewable energy utilization systems and investments; exploring expert and entrepreneur opinion related to the topic; examining the knowledge and expectations of the population regarding the use of renewable energy sources; (re)interpreting and assessing of expectations concerning certain renewable energy sources. By focusing on energy as a local product, we will identify future local and regional development trends related to this topic. The research took place in 2018. The location of the research was Hungary (Figure 2) and the country's previously mentioned regions.

The first part of the nationwide sub-study (collecting opinions from experts, professional organizations, and entrepreneurs) included the related interview questions about the present and future of the renewable energy industry and several issues concerning the field. We interviewed the experts and the professional organizations by using a longer series of questions, while the entrepreneurs were given a questionnaire with similar structure but with fewer questions (simplified during pre-testing).

The second sub-research took place in the Transdanubian region. The questionnaire to explore the implementation and operational experience of the existing renewable energy investments consisted of three blocks: questions on basic data on renewable energy investments; experience in the implementation, operation, and maintenance, along with issues related to investment satisfaction; questions about the present and future of renewable energy sources from an operation/maintenance perspective. Three-quarters of the 100 existing renewable energy investment projects implemented between 1996 and 2018 are solar-powered (39 solar panels, power range 1–5552 kW, implementation between 2004 and 2018; 19 solar collectors with 3  $m^2$ –200  $m^2$  collector surface, installed between 2001

and 2016) and bioenergy systems (13 biomass furnaces, 10 kW–2100 kW, implementation between 2008 and 2015; 4 biogas plants, 250 kWe–4500 kWe, construction 2006 to 2010). The other solutions studied are deep geothermal systems and ground source heat pumps (6 installations, 16 to 3000 kW, constructed between 2010 and 2013), other (air, water, waste heat) heat pumps (11 systems, 12–1800 kW, implemented 2002 to 2018), wind (3 systems, 1.5–600 kW, constructed 2005 to 2006), hydropower (1 plant, 1500 kWe, constructed in 2009), and combined systems (4 installations, 0.1–45 kW, constructed 1996 to 2014), which involve a combination of heat pumps and pellet, heat pumps and solar energy, solar panels and solar collectors. The implementation year of the examined investments shows the periods when the renewable energy utilization solutions spread in Hungary, the characteristic parameters, and the power ranges reveal the application areas.

	Research Objectives	Target Group	Test Methods	Geographical Areas
I.	Combining, analyzing, and evaluating expert, professional organization, and entrepreneurial opinions on renewable energy sources.	Managers of most competent enterprises, university professors, senior researchers, and leaders of professional organizations familiar with renewable energy options.	Exploratory research–qualitative study with 50 structured deep interviews.	National-Hungary.
П.	Exploring the experience in preparing, implementing, and operating renewable energy investment projects.	Renewable energy investments in operation: solar, wind, hydro, geothermal energy, and biomass, as well as combined systems for residential, corporate, municipal, and institutional use.	Quantitative examination (questionnaires). Finding the creators and operators of 100 existing systems using snowball (expert recommendation) method.	Transdanubian Region (NUTS2/HU2), its three NUTS2 regions: Western Transdanubia HU21; Central Transdanubia HU22; Southern Transdanubia HU23.
III.	Demand analysis-Residential knowledge and demand assessment of renewable energy sources.	Population of the examined area.	Quantitative examination (questionnaires). Population: Hungarian Central Statistical Office. Sample size: 630 people. Method of sampling: by gender. Performing correlation tests with correlation calculations.	Transdanubian Region (NUTS2/HU2), its three NUTS2 regions: Western Transdanubia HU21; Central Transdanubia HU22; Southern Transdanubia HU23.

Table 1. Objectives, material, and methods of comprehensive studies on Energy as a Local Product.

Source: created by the authors.



**Figure 2.** The regions of Hungary and the Transdanubian region serving as the location of the survey. Source: [41].

The third sub-research was a survey on future residential needs and knowledge (familiarity with solar, wind, water, geothermal energy, and biomass, as well as complex systems and related expectations) carried out in the Transdanubian region. The questions regarding the topic consisted of three blocks: general knowledge about renewable energy sources; questions about the impressions, advantages, and disadvantages; questions exploring the present and the future of the issue.

Taking into account the chosen methodology of the abovementioned sub-studies, we can say that our research, which deals with the topic in general, sums up the experience of the investors and the operators of the existing investments, as well as the expert opinions and viewpoints accumulated in the recent period. Studying the various approaches provides a comprehensive and credible representation of the renewable energy market in Hungary, taking its first steps with pessimistic and optimistic views. By doing cross-tabulation analysis we surveyed the knowledge of the different genders on renewable energy sources; furthermore, based on the responses, we formed main components using principal component analysis.

#### 3. Results and Discussion

#### 3.1. Theoretical Approaches to Energy as a Local Product

Collecting and analyzing expert, professional, organizational, and corporate opinions and experiences on the subject, due to the complexity of the economic, social, and environmental impacts, required a multidisciplinary approach. Following this principle, our interviewees were professionals directly or indirectly involved in a segment of the emerging renewable energy industry.

In general, there was almost complete agreement among the interviewees on the issue that, due to today's technological, social, economic, and environmental changes, energy should be taken into consideration as a local product. The overwhelming majority of respondents held the view of "Energy not only can, but should be a local product." The collective view of people with more cautious opinions was that the importance of local energy use can be enormous, but in terms of today's technical solutions (e.g., energy storage), it was only possible to supply the energy needs of an area by using the existing traditional solutions. There will always be a need for peaking or load-following electric power plants to meet demand, or a network that receives and distributes excess production.

Several respondents recommended that local products should be defined in terms of energy, since several practical solutions can be used in everyday life. The most common approaches found by our research, supported by a practical example, are summarized in Table 2.

Based on the data above, the issues of energy import and export must be (re)interpreted locally for each subregion and settlement. The difference between the two shows the extent to which the settlement is dependent on its environment: whether it is an energy exporter or an energy importer. Due to the locally produced and utilized energy, the amount of energy to be procured from outside sources is obviously lower. That is to say, taking into account the technical development of today's renewable energy sources, the objectives of energy as a local product can be set so that the individual communities and settlements have as little energy import as possible in order to achieve partial energy self-sufficiency. In the field of energy as a local product, in order to define the economic (e.g., retaining the money spent on energy, enforcing local interests), social (e.g., job creation, sense of security due to predictability), and environmental (cleaner, nicer environment,  $CO_2$  reduction) indicators of value creation in a narrow and broad sense, we have to perform additional tasks.

Energy Production, Utilization	Typical Solutions	Description of Energy Production and Utilization	Type of Local Renewable Energy Flow	Local Value Creation *
It can be produced and manufactured locally, used only locally, no business transaction (sale/purchase) takes place—it does not leave the region.	Solar power for private use only without producing surplus energy, geothermal energy production to meet private (or public) energy demand.	The profit of the activity remains in the place of production.	Self-sufficiency; export-import of renewable energy does not appear.	High
It can be produced and generated locally, partly utilized locally in the form of energy, partly put up for sale.	Geothermal systems generating heat and electricity, biogas plants, where heat is used locally, electricity is not; excess production of photovoltaic systems.	Some of the energy produced is utilized locally, some is sold.	Self-sufficiency and export of renewable energy.	High
Local energy production partly from local sources, and partly from sources purchased elsewhere.	Wood chips combustion partly from local and partly from purchased (in distant regions) materials.	When the locally available raw materials are not sufficient for the operation.	Partial self-sufficiency and renewable energy import.	Medium
Produced and generated locally, sold as a finished product, leaves the region.	Energy pellets are not sold locally but in distant regions (in many cases outside a given country). Producing bioethanol locally and selling it as a finished product to other regions.	Not marketed directly, but sold (not locally) as a finished product after processing.	Renewable energy export.	Medium
Can be produced and generated locally, sold in the form of energy, leaves the region.	Sale and distribution of wind power, hydroelectric power, solar power in distant regions.	The generated energy is not directly utilized locally; its profit may be retained locally depending on the operator.	Renewable energy export.	Medium
Produced and generated locally; sold as a raw material or intermediate product; leaves the region.	Biomass raw materials (straw, energy crops) for combustion sold as primary or secondary products; sale of corn for bioethanol production.	Sold directly, that is, shipped out of the area; its profit remains only partially in the place of production.	Renewable energy export.	Low
Supply from renewable energy purchases elsewhere, in remote areas.	Purchase and utilization of pellets and bioethanol from distant regions.	The profit of the activity is realized in another region.	Import of renewable energy.	Low

Table 2. Methods and characteristics of local energy production for renewable energy sources.

\* Local Value Creation: (1) High—maximum local value creation, locally produced and utilized renewable energy. In all respects we can talk about a local product (locally produced and utilized, covering the entire value chain); (2) Medium—partial local value creation for a given activity; partially locally produced and utilized renewable energy; (3) Low—minimum local value creation for a given activity; locally produced/generated but not locally utilized energy (product) or non-locally produced renewable energy. Source: created by the authors.

There were unanimous opinions on the increasing importance of local production. However, the responses to the challenges were not clear. Summarizing and structuring the opinions of the interviewees we found that, in focusing on the complex criteria system of sustainability, Hungary has to keep in mind the following issues as well as make progress in each topic.

- Attitude and motivation of individuals and communities: In order to make local interests and
  values important, we cannot ignore the attitude and the motivation of individuals. Knowledge
  and motivation are essential to make these resources useful to local communities. It is quite
  reasonable to think that individuals and communities want to generate energy locally if it is
  more profitable, that is, the energy they get this way is cheaper than buying from the global
  system. In addition to these considerations, renewable energy sources are also commonly found
  among investment methods. Environmental issues mostly appear as binding commitments and
  requirements, they are not decisive factors in customer decisions, but hopefully they will be
  natural, voluntary expectations for young people.
- Investigating settlement types, social needs: Metropolitan environments have other needs and
  opportunities than do small settlements in rural areas. In the former, the concentrated consumer
  needs (housing estates, building blocks) provide a good basis for installing renewable energy
  systems. However, local products may carry a different meaning in rural areas, where local
  conditions determine what is worth replacing. The degree of economic development, or the degree
  of automation, and the leading economic sectors also influence the opportunities. In any case,
  intellectual capital has a key role in recognizing and reflecting on the individual opportunities.

- The technological issues of production, distribution and utilization: In the production and use of
  energy, the roles of consumers and producers are beginning to blur and the process may intensify
  in the future. Companies engaged in energy supply and trade also face the need for renewal. The
  responses to the legal, regulatory, and technological issues generated by the spatial and temporal
  variations in renewable energy production systems dedicated to regional and local self-sufficiency
  are expected to be forced by technological progress.
- Connecting areas with complementary energy mix: If there is no need for the locally produced energy, another region may require it, so the importance of interconnected energy networks and collaboration increases. These factors may lower the energy production costs and reduce the transmission losses, which may bring about more competitive prices. The development of information and communication technology will be an important element in the processes mentioned above. Such solutions for energy distribution and storage can create an investment climate that attracts capital-intensive investments in renewable energy sources.

While focusing on the use of renewable energy sources in terms of local production and their potential for the greatest possible local value creation, we also discussed the biggest obstacles to developments in this area. These can be classified as follows.

Naturally, the economic and social environment and the social relations had a significant impact on the spread of new technologies. The lack of purchasing power affected the developments in the private sector remarkably. However, the business sector first found the related opportunities and, if the potential for real savings came up, it tried to generate the necessary resources and carry out developments from its own resources, from grants, possibly from loans or combinations of them. Institutions could only make renewable energy investments with guided tender resources.

Many people expressed the view that the technology used should be widely applicable and available at an affordable price to become widespread. In many areas of renewable energy, we have just reached this stage of growth, which entailed further developments that could make technologies even more beneficial.

With regard to existing infrastructures as barriers, we discussed the fact that neither the state nor the municipalities nor the companies was motivated to replace a working system with a new one. It happened at individual, municipal, and national levels and had a significant impact on the development of the renewable energy industry. This level of technology change often required a different kind of investment and development, such as network development, physical connectivity, etc., whose inaccessibility was a physical barrier to implementation.

The opinions were divided on the need and extent of state involvement. Opponents said that any state aid distorted the market as it could contribute to the growth of uncompetitive technologies. Many agreed that the state should also take on a role as a catalyst in this matter, as small systems were still expensive per unit. The faster a method spreads, the cheaper it would be. There was also a strong consensus among interviewees that serious results were achieved by countries that implemented their ideas with only limited, absolutely necessary adjustments along a defined long-term strategy.

Discussing the context of the topic, several interviewees also highlighted the fact that if people and decision makers were not aware of these solutions, had partial information, or had no experience in operating systems adapted to individual conditions and circumstances, they obviously had more difficulties making decisions on whether or not the systems were worth using. The objective of our research was to collect and analyze the operational experience in the already existing Hungarian renewable energy systems; some results are summarized in the next chapter.

# 3.2. Practical Approaches to Energy as a Local Product: Implementation and Operational Experience in *Existing Systems*

Our research focused on the implementation, operation, and maintenance of existing renewable energy investments and on the level of satisfaction. In the following, we describe the relationships and conclusions drawn from these sub-studies.

By their nature, the investments examined were classified into the following categories: private, municipalities, institutions, small and medium-sized enterprises, large companies, and other. The "other" included the photovoltaic systems installed in apartment blocks. As for the objectives and motivations for the implementations, the respondents mentioned the following aspects.

- Economic considerations, energy saving, rationality: This emerged as the primary reason in
  almost every case. Major investments (for example, wind farm, solar power plant) were
  obviously dominated by economic interests and considerations. Small-scale developments (pellet
  combustion) were motivated by the choice of a more favorable alternative in the longer term. The
  disposal and rational utilization of the byproducts and waste materials were also becoming more
  and more important in the context of bioenergetic investments; they could be performed using
  wood chips or sawdust, which were considered by-products in the past and often had no value.
- Partial energy self-sufficiency: Both small-scale systems (such as solar panels) and major developments (e.g., institutional solar systems, heat pump systems) were identified as important factors. It is progressive that in many cases the former was motivated by independent decisions regardless of tendering opportunities. In the case of large-scale developments, the implementation was primarily related to tenders. In facility operation, the utilization of existing, previously unexploited potentials also increased, such as the utilization of the favorable geothermal features of the region (geothermal heating plant) or the utilization of waste heat (for example, leaking hot water from thermal springs, which was previously not used for energy purposes).
- Ideal alternatives for new construction, renovation, modernization: While one and a half decades ago renewable energy systems were "unaffordable luxury items" in the area, nowadays they are becoming an ideal and affordable option to traditional solutions. This was confirmed during the survey. However, it was important to distinguish between new construction and the replacement of existing systems. Based on experience, in many cases the replacement of existing equipment with tested solutions—taking only economical aspects into consideration—would not be justified at present prices. However, newly built or fully renovated and modernized houses could clearly benefit from renewable energy systems.
- Tendering opportunities, favorable constructions: Similar to the larger-scale developments mentioned earlier, the implementation of actual investments could be linked to tenders. Since the lack of tender resources and new invitations to tender involved many uncertainties, it was difficult to plan in advance, and experience shows that most people take the "now or never" approach to modernization. For the time being, the majority of investments were financed from tender funds, but the number of investments with own contribution were also increasing.
- Compliance with certain tender criteria: Our survey showed that the constraint on compliance with the requirements of the tender resulted in more innovative developments. A typical example of the latter was the tender announcement entitled "Building energy developments combined with the use of renewable energy sources," where mostly traditional building energy developments (such as thermal insulation, replacing windows and doors, lighting modernization) were considered, and compliance with the tender requirements (mandatory or optional) led to renewable energy developments. Many solar-powered systems were also implemented from this motive.
- Comfortable, state-of-the-art, modern solution: Convenience and modernity were among the motivations behind investments. Modernity was indisputable, but comfort was a subjective factor, depending on the type of change when switching from one solution to another. For example, the comfort level of a heat pump can reach the comfort level of gas heating (which covers almost 100% of the Hungarian households), while pellet combustion can be close to it. However, the wood gasification boiler can provide a lower level of comfort compared to gas heating and other solutions, but at lower costs. In this case, "giving up" comfort meant cheaper operation.

The abovementioned factors cannot be separated sharply; there are significant overlaps between some ideas and approaches (e.g., saving, rationality, self-sufficiency). The same idea might have arisen

in the field of environmental protection, which was not mentioned directly, but was implicitly present in energy saving, rationality, self-sufficiency, and energy production associated with waste disposal. It was important to emphasize regarding "the ideal alternative for new construction, renovation and modernization," that if the upgrade was not based on renewable energy sources, it might be delayed by another 15 to 20 years while using the traditional solutions. Each decision like this slowed down the energy transition of a given settlement or region. This was not "reprehensible" but could be accepted knowing the economic, environmental, or social conditions; however, it could be annoying if an ideal solution was excluded due to lack of information or inadequate knowledge at institutional, corporate, or private level.

The amount and scale of investments varied by type of investment; in the cases examined the scale ranged from a few hundred thousand Forints to a billion. In this respect, it was not possible to compare a solar system, a wind farm, or a geothermal system providing (partly) a municipal heat supply. Looking at the individual solutions, we observed a fall in prices over time. This was most noticeable in solar systems, where the installation of a single solar cell could be realized at half to a third the price of 10 years ago.

The sources of implementation included own contribution, tender funds, loan, and combinations of them. The tender funds were used without exception in all municipal and institutional investments. These were typically building energy investments combined with the use of renewable energy, where the use of renewable energy was a mandatory element of the development. These renewable energy developments alone may not have been implemented, or may have been achieved in a smaller number. Applications for installing photovoltaic systems below 50 kW and for heating modernization were used exclusively to exploit renewable energy sources. The Settlement Development Operational Programme of the 2014–2020 cycle were specifically aimed at exploiting the smaller-scale complex regional energy potentials and the implementation of self-sufficient energy supplies at individual and community levels. By abandoning earlier templates, these tenders took much more account of local conditions, focusing on practicality and cost-effectiveness, and the use of local raw materials as renewable energy sources to create an environmentally friendly, independent, and sustainable energy supply in the long run. For example, the program provided opportunities to procure logistics systems, buildings, and machines to produce and store solid biomass for the direct fuel supply of an institutional energy generation system, and thus to meet their own (public) heating energy needs. There was a mixed picture in terms of financing entrepreneurial and private investments. Each of the different financing solutions appeared on its own or in combination. On the entrepreneurial side, both tendering and own contributions were present. Small-scale systems in family houses and private investments were mainly financed from own resources. The most popular investments in both corporate and private developments were solar systems that were cost-effective and easy to install. An interesting detail we found during the survey was that, in order to save money, discontinued systems were used in two cases (an amorphous silicon solar cell and a biomass burner).

In many cases tender funds were also used, however, the tight deadlines and the time-consuming administrative tasks did not cause insoluble problems. Numerous opinions referred to the over-regulation of certain elements in the support system, claiming that their necessity was questionable from a practical point of view. In our experience, these measures and additional tasks were based on the "compulsion" of compliance with the requirements of the European Union tender system, the plethora of reporting obligations and indicators.

According to our experience with private investments, some of the respondents were familiarizing themselves with the issue for years before making a decision. Instead of being forced to buy, invest, and apply for tenders, many customers became interested in the topic out of curiosity and commitment to renewable energy sources. Several people mentioned the future-proof appreciation in the value of the property affected by the development. Many stated that these investments, with their low cost per unit, were now a kind of investment opportunity. Similar thoughts also led to the installation of solar

photovoltaic systems in apartment blocks financed by the communities' own savings (e.g., reduced heating costs due to thermal insulation).

The operation of the systems was also in the focus of our research. The respondents mentioned the keywords shown in Figure 3 most frequently regarding the investment and the operational experience.



**Figure 3.** The most frequently mentioned keywords concerning the investment and the related operation in 100 investments. Source: created by the authors.

The words "simple," "convenient," "reliable operation," and "the opportunity to reduce energy costs" were mentioned most frequently. In addition, "capital-intensive," i.e., "lower operating costs with higher initial capital," also appeared. The "modern," "efficient," "sustainability" word associations were followed by the terms "eco-friendly," "innovation," and "aware," in terms of the number of references.

We considered it important to examine whether the questions asked in the questionnaire were consistent. Based on our results, the internal consistency of the questions was excellent since the value of Cronbach's alpha was 0.907.

The questions about the operational experience of certain renewable energy investments aimed to find out whether the investments have worked. Looking at the issue with closed questions, the aggregate responses are shown in Figure 4. All in all, the experience was positive.



**Figure 4.** Operational experience of the examined renewable energy investments. Source: created by the authors.

Fifteen percent of the owners and operators of the examined systems said their expectations were only partially fulfilled, while 3% claimed that the installations did not reach their expectations. The main reasons for dissatisfaction included the price-to-performance ratio, the failures, or the excessive

expectations. In some cases, the original idea was abandoned due to the technical modifications required by the tendering system, which also brought about disappointment. This was, however, compensated by the fact that 60% of the respondents were satisfied with the investment because they came up to their expectations. In fact, 16% of the respondents felt that the implemented system exceeded the original expectations. This means that the total number of responses reflecting satisfaction was 76%. Some respondents did not take a position yet; 6% were still collecting operational experience of the "fresh" investment.

When exploring the strengths/advantages and weaknesses/disadvantages of the investments, systems that did not use raw materials (such as solar panels, wind power, geothermal energy) were clearly favored, while bioenergy utilization constantly required available raw materials in sufficient quantity, quality, and price. Depending on the size of the investment, greater caution should be taken during preparation. Operation was also made more difficult if the energy produced was to be used immediately (for example, some solar systems). The maintenance and its costs, minimizing the potential for failure, the service life of spare parts time, or the possibility of modular expansion also generated demand for simpler solutions. In practice, we found contradictions several times: the customer did not necessarily desire high-quality technical implementation but low price. In contrast, in the event of inadequate operation, malfunction or other problems, the contractor was made responsible for the quality. If price was the only factor considered when choosing investment alternatives, we might encounter dissatisfaction in the long run after a short-term "good deal" feeling. A key to successful renewable energy investments was to implement the project on a property that was truly ready to accommodate these technologies. For example, lighting modernization should be performed before the installation of an institutional solar system.

The questions exploring the future of renewable energy sources from the perspective of the maintainers focused on the areas in which these alternative solutions played a significant role and whether we could expect the share of renewable energy in Hungary to increase. The overwhelming majority of the 100 surveyed investors were optimistic regarding the latter issue. In their opinion, the share of renewable energy in Hungary will increase significantly in the short term, within five years. Significant progress was forecast (in descending order) in the category "institutions, municipalities, parts of settlements," in "home, residential," and in "small and medium-sized enterprises." The next category included "big enterprise" as a potential development area.

All in all, the examined systems offered a promising future to the technological achievements of a continuously developing industry in Hungary. Of course, the question was how the experience could be generalized and adopted in various environments. What were the results and lessons that everyone should consider? However, we thought it was important to emphasize that the investments carried out nowadays require increased attention, since they are the foundation stones of the domestic renewable energy industry; the positive or negative experience can determine the investment spirit and decisions concerning renewable energy issues for decades.

#### 3.3. The Issue of Energy as a Local Product from the Aspect of the Population and Households

The key players in energy as a local product are the population and the individual households. Experts unanimously say that, although we should not generalize, the public, municipalities, and decision-makers have low levels of knowledge about renewable energy sources. They are struggling with daily problems and the lack of information about the available technologies and their advantages/disadvantages, costs, and opportunities in this area. Our research on this target group only partially confirmed this.

In a representative survey among the general public, we analyzed what the first phrase was that came into people's minds when the issue of renewable energy was raised. We grouped similar topics and references (for example, related to solar energy, related to environmental protection). Responses related to renewable energy sources are shown separately for women and men. The results are illustrated in Figure 5.



**Figure 5.** Responses associated with renewable energy sources for men and women. Source: created by the authors.

The most commonly used terms in both categories were the terms "solar energy, solar cell, solar panel" and "wind energy, wind farm, wind." For men, the former category received 38% and the latter 20%. Both sexes referred to the terms "environmental protection, eco-friendly, environment" and "hydropower, hydroelectric power plant, water" at similar rates. In addition, "bioenergy," "sustainability; nature; green energy; recycling," and "economy," "geothermal energy," "selective waste," and "electric cars" were mentioned. Slightly more than one-tenth of the respondents (13% men and 12% women) could not be classified into the groups above. The unique responses and approaches in our "other" category ranged from "nothing" to "petroleum; smoke; bottle" and to the much more promising "opportunity; innovation." The respondents answering not in one word but in longer sentences were typically men. The wording "not to use up but to use" was highlighted. The association "it reminds me of my friend's house" brought us to the next section of our study, where we were interested in their experience with each solution.

Regarding renewable energy sources, only the knowledge of solar energy had a significant difference between the sexes in favor of women ( $\chi 2 = 6.915$ ; df = 1; P = 0.009).

The local renewable energy system justifies its use in households where women have a greater say [42]. In Hungary and abroad, the use of household-size solar panels is the fastest growing source of renewables, which confirmed our results that statistically demonstrated the over-representation of women in solar panel issues.

Moreover, almost 70% of the respondents to the survey of the International Renewable Energy Agency (IRENA), which included 1500 participants, were women, which reflected a much greater interest of women in renewable energy research and utilization.

Studying renewable energy utilization, the respondents were offered three additional options besides "I have not heard of it yet" and "It is in use in my immediate environment" (for example at home, in the neighborhood, at work, in a friend's house) and they were asked to choose only one option (see Figure 6).



**Figure 6.** Experience with renewable energy solutions for men and women (only one answer was possible). Source: created by the authors.

It was promising that a total of 40% of the men surveyed had already come across renewable energy systems, while women had less experience. The category "I have not heard of it yet" had a modest share in the responses: 1% for men and 4% for women.

The result of the cross-tabulation based on Figure 6 shows that women were statistically more likely to have never heard of any renewable energy source ( $\chi 2 = 5.603$ ; df = 1; P = 0.018). In terms of deeper knowledge, men were dominant ( $\chi 2 = 6.049$ ; df = 1; P = 0.014). The latter is probably due to the fact that, in their immediate environment, it is mostly the men who find examples of using renewable energy sources ( $\chi 2 = 3.972$ ; df = 1; P = 0.046).

Generally speaking, men excel at following technical and technological development, while the extent of differences in the survey may be a Hungarian feature. The reason for this is found in the sharper segregation of social roles or in the differences in the gender distribution of certain training areas. The latter is supported by the statistics claiming that in Hungary women have equal access to higher education (they have been in the majority among students since 1993), but there is significant male dominance in technical and IT training. In the academic year 2014/2015, the proportion of women in the field of technology was 23.8%. However, this training area is also characterized by a much higher than average dropout rate [43].

Similarly, in the U.S., women make up only 32% of the renewable energy workforce and 27% of the solar energy workforce [44], which explains why men's knowledge of the subject is more advanced worldwide.

When discussing this subtopic, a study on the situation in Germany [45] similarly concludes that a "balancing force," a novel approach will be needed in the future to avoid social imbalances during the integration of renewable energy solutions into energy systems.

Women's lesser knowledge of renewable energy sources, compared to men and men's primary concern with RE applications, may be explained by women's lower willingness to pay [46]. A further explanation may be that investments and developments are largely coordinated by men, which provide them with deeper professional knowledge when planning a given energy system's modernization

and discovering alternatives. According to Karytsas-Theodoropoulou [47], the knowledge and the application of RE sources are clearly influenced by socioeconomic factors, including gender, place of residence, wage level, educational level and area, and the parents' qualifications, as well.

Conversely, Martins, Gonçalves, and Viegas [48] expressed the view that gender has no impact in Portugal, as behavior is mainly determined by attitudes and beliefs in this area. According to a questionnaire survey by Sardianou and Genoudi [49], gender has no significant role in the use of renewable energy sources in Greece. Due to the geographical location of the country, most of the respondents were familiar with the potential for solar energy, followed by wind, hydro, geothermal, and biomass-based energy sources.

Overall, there was considerable interest from women in renewable energy solutions [45]; however, according to our surveys, beyond men's motivation to explore and develop, women's contact with practical, individual solutions was yet to happen.



We also wanted to study their knowledge about the present technical solutions (Figure 7).

**Figure 7.** Knowledge of some technical solutions among respondents. Legend: NO KNOWLEDGE = I have not heard of it yet; INSUFFICIENT KNOWLEDGE = I have heard about it, but I do not know the details; GOOD KNOWLEDGE = I have heard about many things, I know a lot about the subject; THOROUGH KNOWLEDGE = I have broad knowledge of the subject. Source: created by the authors.

The knowledge about "solar cell-solar panel," "solar energy-solar collector," "wind power," and "hydropower" was classified as GOOD (I have heard about many things, I know a lot about the subject). The other solutions listed (such as heat pump systems) received responses that indicated mainly INSUFFICIENT or NO KNOWLEDGE. Interestingly, biofuels were also included in this category. Referring back to the research section on "renewable energy word associations," electric transport also appeared several times in the responses, so we can state that the respondents were more concerned with electricity than biofuels in present and future transport. In the latter case, the mandatory biofuel mixing ratio at the filling stations was probably also a lesser known fact.

The correlation between hydro, wind, and the two solar technologies was medium or stronger (Spearman's rho = 0.539-0.785), which, based on the aforementioned surveys on knowledge, confirmed that the knowledge of solar, wind and hydropower was significantly higher than other renewable energy sources. As for the other renewable energy sources, we found that the relationship between them was weaker (Spearman's rho = 0.414-0.631), which indicated more heterogeneous knowledge.

By gender, we also used the Mann–Whitney test to see if there was a difference in the knowledge of energy sources or processes studied in the research. With the exception of modern biomass firing

and energy crops, there was a significant difference in favor of men in all cases (Z = 2.762 - 4.413; P = 0.001-0.006).

Based on the responses concerning knowledge, we further investigated what principal components can be defined (Table 3, Figure 8).

Variables	Component I	Component II
Cultivation of energy crops	0.804	-
Biogas	0.782	-
Heat Pump	0.760	-
Modern Biomass Firing	0.728	-
Biofuels	0.618	-
Geothermal	0.616	-
Wind Energy	-	0.863
Solar Panel	-	0.854
Solar Collector	-	0.779
Hydropower	-	0.756
Eigenvalue	3.454	3.215
Explained % of Variance	34.537	32.147
Cronbach's Alpha	0.886	0.868

**Table 3.** Characteristics of the main components based on the knowledge of renewable energy systems.

KMO (Kaiser–Meyer–Olkin) Measure of Sampling Adequacy = 0.893; Bartlett's test of Sphericity:  $\chi^2$  = 3641 df = 45 P < 0.001; Communalities: 0.506–0.807; Total Variance: 66.684%. Source: created by the authors.



**Figure 8.** Characteristics of the two principal components based on the knowledge of renewable energy systems. Source: created by the authors.

Table 3 also shows that two main components were distinguished, the second being wind, solar, and hydro energy (component values: 0.756–0.863) and the first being the remainders (0.616–0.804).

This grouping proves that there was a relatively close relationship between the knowledge of the energy sources that made up the different main components, based on the respondents' opinions (Figure 8).

An interesting contradiction regarding the knowledge of individual technical solutions was that while biomass firing had the highest proportion in renewable energy utilization in Hungary, the respondents marked the answers "no knowledge" and "insufficient knowledge." Similarly, these answers were predominant in biogas and biofuels. These partial results of our research support the view that the use of biomass for energy purposes is still widely recognized as conventional wood burning in the public mind and is not necessarily classified as a renewable energy source. Norton et al. [50] and their research point out that the issue of firewood as a renewable resource divides the professional, and, consequently, the political and the lay public opinion not only in Hungary, but also throughout Europe. The information provided in the (Hungarian) media, mostly related to solar panels, contributes to this.

One of the open-ended questions about the future was "In your opinion, which factors hinder the spread of renewable energy sources?" Based on keyword searches, the following result was generated by processing the responses:

- The words "money, capital, price, cost, expensive, returns, financial (impact), financing" were mentioned more times (363) than all the other (consolidated, categorized) references.
- "Knowledge, information, ignorance, lack of information, lack of interest," came in second, mentioned 94 times.
- The terms "politics, (lack of) support" (49 references) and "interests, lobby" (47 references) appeared in a similar order of magnitude.
- The category "Other (I do not know, I have no insight)" (77 references) was well represented in the representative survey of 630 people.

In the latter category, more detailed answers, like "Lack of knowledge, scarce financial resources, lack of incentive" and "People are more familiar with traditional resources," were given in many formulations, highlighting the issue. According to the public opinion, investment costs and the lack of information were the main obstacles to the spread of applications. It takes a lot of work to provide the most important players in the renewable energy industry—consumers and end-users—with proper quality and quantity of information.

#### 4. Conclusions

The development of a global renewable energy industry offers more and more alternatives. However, individual developments raise new research and development issues. In each case, the solutions and the scheduling of the developments have to be adapted to the regional and local (infrastructure, social, economic) conditions. Both the companies involved in the energy sector and the end-users are forced to switch, so (re)defining the concept of energy as a local product is relevant and timely by prioritizing locality. For now, the factors (environmental aspects, local value creation, job creation linked to economic restructuring, change of attitude), which need to be addressed in municipal and regional energy investments and innovative solutions, cannot be quantified or are difficult to quantify.

The discussion of the topic of energy as a local product clearly highlights the complexity of the subject and the complexity of the processes. Nowadays, the efforts of the public, corporations, and local governments, as well as the companies seeking to find a position in the renewable energy industry, are clearly visible as some kind of "drone shot."

The issues of energy import and export must be (re)interpreted locally for each subregion and settlement. At the regional level, it is important to define and specify the role that cities and smaller settlements can and wish to undertake in meeting certain sustainability goals.

When examining issues related to the area, the emphasis should be on changing attitudes to energy use and the way people interact with the environment, as needed. According to our survey, the population is open to alternative options, however, old routines, misinformation, the existing infrastructure, and high initial costs keep them away from the new solutions—but progress is indisputable. The motivational power of working (positive) examples has an outstanding attitude-shaping effect. Presenting best practices and making them available could bring demand closer to supply. In our opinion, it takes a lot of work to provide the most important players in the renewable energy industry—consumers and end-users—with adequate quality and quantity of information. Inadequate information (being ill- or misinformed) may hinder the energy transition of a real estate to alternative solutions for decades.

Our research also confirmed that the use of biomass for energy purposes in the public mind is separate from other renewable energy solutions, and in many cases it is regarded as a non-renewable energy source.

In Hungary, besides traditional wood burning, modern biomass firing has appeared both in small size (family homes) and larger size units (heating plants and power plants), but according to our research, renewable energies are still more commonly identified with solar, wind, and hydropower utilization. For the time being, these technologies are the most practical and spectacular, and can be encountered by most lay users in everyday life, in the media, or in awareness-raising activities related to the use of tendering sources.

Based on our gender studies, we believe that low employment rates and growing interest may justify increased training for women in renewable energy sources, especially solar panels, in order to achieve greater equal opportunities in the future.

Although the main directions of the energy transition and the technologies necessary for the implementation are known, the motivations and obstacles to the transition vary from country to country. Our research sheds light on the key issues in this topic via a case study in Hungary. The findings and conclusions drawn can provide a good basis for the exploration of energy transition problems in countries with similar capabilities. Countries with different characteristics may also apply our research model, which examined the attitudes of all major players in the renewable energy sector for multilateral comparisons. We performed various survey techniques (questionnaire, in-depth interviews) in our study, which could be used in the BioEast cooperation (BioEast Initiative, Central-Eastern European Initiative for Knowledge-based Agriculture, Aquaculture and Forestry in the Bioeconomy) covering 11 EU Member States, involving a much broader and comparable sample of respondents.

Creating the motivation needed for widespread deployment requires significant government participation, primarily in the fields of segment-specific application of tools to build competitiveness, prioritization of small and medium-sized production units, simplification of licensing procedures, utilization of job creation potential in related industries, development of public information, raising awareness of the purpose of each process and regulation, and in researching and developing technical solutions with local interests and capabilities in mind.

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