Preparation of the concept and model of an energy self-sufficient region based on distributed generation in the Chrzanów district - Poland

Mariusz Badura

mariusz.badura@tecnico.ulisboa.pt

Instituto Superior Técnico, Universidade de Lisboa, Portugal

September 2022

Abstract

The purpose of this thesis is to prepare a concept of an energy self-sufficient district, at the same time eliminating gas and coal from the current energy utility process. Within a study such a district is understood as an energy cluster. The analysed area was defined as Chrzanów county, located in the south of Poland. Concepts was based on three levels – energy, community and financial. On the first level the county's RES potential and energy consumption were investigated. Based on obtained data, the energy balance model was developed together with innovative technology proposal. At the societal level, an innovative governance and administrative structure for the cluster was proposed. The social challenges associated with the transformation of the region were also identified and initiatives were proposed to assist this process. At the financial level the estimation of investment and operational costs was performed. Moreover, research was presented with regards to potential sources of project funding. In addition, it was identified which actions are beyond the scope of the study but are recognized as necessary for project implementation. In conclusion, it was found that an energy cluster is currently a very complicated entity on each mentioned level, however its implementation is possible under certain conditions like liberalization of legislations regarding wind energy in Poland. Overall construction of energy renewable self-sufficient district requires a great investment. However, it is a very effective way to facilitate the energy transition and contribute to climate neutrality through energy efficiency and net zero energy balance. The entire developed concept as well as its individual elements can be treated as a basis for further energy self-sufficient districts studies and even be an inspiration of an actual model implementation

Keywords: Energy transition, Renewable Energy, Energy management, Energy clusters

1. Introduction

As energy demand increases, so does awareness of the importance of properly distributing energy sources in order to achieve energy security and independence. There are multiple ways to do so, however according to global trends, what can be observed is a diversification of energy sources. Such diversification also raises further challenges and must be very well thought out if it is to be implemented on a large scale in, for instance a country. Within this study a concept for an energy self-sufficient district, which could eventually be disconnected from external coal and gas supplies is proposed. It is named as energy cluster. Such solutions are already present in several places in Europe, while in Poland they are still innovative and require a lot of work on many levels. The study area was identified as the county of Chrzanów, as one of the energy-poor and environmentally distressed areas. Based on the energy data for the district, an extensive analysis was carried out and a concept was prepared to transform the county into an energy cluster that meets the energy and subsistence requirements of the stakeholders involved in the regional transformation.

2. Project Background

The European Union has set very specific and ambitious targets, including a reduction in greenhouse gas emissions of at least 40% by 2030. A long-term strategy has been created with the main goal of achieving climate neutrality by 2050 [1]. The whole movement associated with a series of actions to achieve this state is now known as the energy transition. The main aim of the transformation is to decarbonise the energy sector by switching to renewable energy production and use.

Poland is one of the European countries that are unfortunately in an earlier stage of energy transition. The energy system in Poland is seemingly fragmented however the distribution itself is centralized. There are 4 major companies that are based on the principle of building a value chain to include extraction, generation, and distribution. The vast majority of electricity is generated in coal-fired thermal power plants. Long-distance transmission of energy from power plants to the consumer is possible thanks to an extensive network of power lines and substations. This is the exact opposite of distributed energy system and sources. The share of coal in 2021 was 72.4%, corresponding to 130 TWh of energy. Energy production from all RES sources reached a record high of 30.4 TWh. However, despite this, the share of RES in the production mix fell from 17.7% (in 2020) to 16.7%. The first place in terms of green energy generation is taken by wind farms. At the end of 2020 wind was responsible for 70% of energy production from RES despite the fact that wind energy in Poland is extremely limited by legal barrier so-called 10H rule [2].

The Polish government's response to the high values of coal consumption and to the strong requirements of the European Union's climate policy was to be the plan "Energy Policy of Poland until 2040" (PEP2040) approved on 2 February 2021 [3]. The document sets the framework for the energy transformation in Poland. It is based ona few key assumptions where one of them says: “locally driven, bottom-up participation in the transition process - everyone will be able to contribute in it” [3]. It indicates that the best way to reach consumers, which are the potential beneficiaries of the transition, is to engage them directly This is where we come to the concept of the energy cluster [4] - an energy self-sufficient area, which needs the engagement of almost its every inhabitant in order to successfully operate.

The idea of clustering promotes a local perspective on energy and fits into the trend of supporting distributed generation based mainly on the use of renewable energy sources and co-generation of electricity with heat and cold. A cluster is defined as "a civil law an agreement, which may be made up of private entities, legal entities, scientific entities, research institutes or local government units, concerning the generation and balancing of demand, distribution or trade in energy from renewable energy sources or from other sources or fuels, within a single distribution network, respectively within the boundaries of one municipality or county" [5]. In this paper, the subject is to develop the concept of an energy self-sufficient area understood as an energy cluster within the Chrzanów county, which is the district consisting of several municipalities, towns, many neighbourhoods Therefore, in order to create a sensible proposal for such a large undertaking it is necessary to get familiar with the area to be transformed and the necessary data.

Chrzanów county is located in Małopolska voivodeship and consists of 5 communes. Its overall condition in terms of environment and energy is not satisfactory. The CO_2 emissions in the district. 1.33 million tons per year is the highest value in all the sub regions of Malopolska voivodeship. It is estimated that there are a total of 1 752 RES installations based on photovoltaics, solar panels, heat pumps, biomass and biogas with a capacity of approximately 4 436.3 kW [6]. There are no RES installations based on hydropower, wind energy, geothermal and cogeneration.

Within the work area, the main objective was defined as the elimination of coal and gas from the selected region’s energy utility process. Furthermore, it should be noted that the prepared concept especially technically covers the state of the district after the transition to an energy cluster. This means that the exact timeline for carrying out the project is outside the scope of this study. The whole concept, due to its complexity, is based on 3 levels, which form the main part of the study and are developed sequentially.

3. Energy level – Energy balance model

The concept at energy level is based on several stages. The first was to investigate the RES potential in the county. It was decided to investigate the potential of RES such as: solar energy, wind energy, biomass, deep geothermal, hydropowe and additionally heat pumps. The values determined in this section come from independently conducted research and analysis of available data. For the first three a specific study was used, called ENSPRESO - ENergy System Potentials for Renewable Energy SOurces, an EU-28 wide, open dataset for energy models on renewable energy potentials based on three types established scenarios (EU-Wide low, high and reference restrictions) at national and regional levels for the 2010–2050 period [7]. After the extensive analysis it was concluded that the RES which has the highest utility potential have solar, wind and biomass. Heat pumps were also found to be useful solutions provided that their power supply comes from the listed sources. A summary of RES potential is shown in Table 3.1.

Tab. 3.1: Summary of annual potential of RES selected in Chrzanów county

RES Type	Total energy potential value (TWh)
Solar potential	0.972
Wind potential	0.313
Biomass potential	0.431

The next step was an analysis of energy consumption in the district. These data were provided externally for the purpose of this study. They were taken from the document "Assumptions for Territorial Plan of Fair Transformation of Western Małopolska" prepared by the Marshal's Office of the Małopolska Region [6]. The document itself was developed as part of the EU LIFE integrated project "Implementation of Air Quality Plan for Małopolska Region - Małopolska in a healthy atmosphere".

The analysis consists of 3 sectors: Economy, Buildings, and Agriculture and forestry. In addition to the sectoral breakdown, analysis also lists the non-renewable energy carriers used by each sector. These are: solid fossil fuels, oil and petroleum products, natural gas, others fuel, heat, and electricity. The consumption values of aforementioned energy carriers are treated as energy demand to be met by the green alternative presented in terawatt hours (TWh) in table 3.2.

Tab. 3.2: Final annual energy consumption of the county from non-renewable sources in TWh.

Specification	Solid fossil fuels	Oil and petroleum products		Natural gas
Economy	0.126	0.023		0.254
Buildings	0.216	0.000		0.248
Agriculture & forestry	0.012	0.026		0.000
Total fuels cons. (TWh)	**0.354**	**0.049**		**0.501**
Specification	Other fuels	Heat	Electricity	**Total sectoral cons. (TWh)**
Economy	0.006	0.029	0.206	**0.644**
Buildings	0.027	0.07	0.258	**0.819**
Agriculture & forestry	0.003	0.000	0.005	**0.046**
Total fuels cons. (TWh)	**0.036**	**0.099**	**0.47**	**1.509**

Having both energy consumption and potential production, it was possible to create an energy balance model. The proposed approach was to analyse each of the identified sectors separately in order to better match alternative energy sources to the specifics of the sector. It was also attempted to ensure that the proposed alternative could cover 100% of the demand of its assigned type of fuel, heat, or electricity. A flowchart showing the process on which the model is based is presented in figure 3.1.

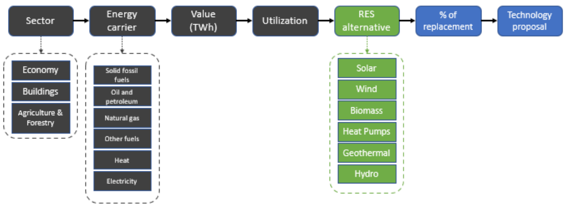

Fig. 3.1: Flowchart of energy model development

To fully illustrate the energy model development procedure, it is useful to analyse the individual steps shown in figure 4.1. For the purposes of the concept, the county's consumption was divided into the 3 sectors described earlier. Based on the data that was provided to the author for the purpose of the paper, the consumption of each energy carrier by each sector was known. All the carriers were also listed on the flowchart. Knowing the value (TWh) that the consumption of each carrier brings, it was then necessary to identify what this energy is used for. This was referred to in the model as "utilization." The next step was to match an appropriate renewable energy source that can meet the requirements of the sector possibly at 100%. The selection of appropriate RES alternatives and the energy balance, as well as the analysis of data on the district's energy potential, was done independently and is an original part of the presented concept. At the stage of energy balancing, the first major problem was identified. At the stage of energy balancing, the first major problem was identified. Based on the collected data on RES potential in the county and energy consumption, it was found that under the reference scenarios used to determine the RES potential, the values do not balance. This means that there is simply not enough energy to achieve energy self-sufficiency. The solution to this problem is to assume that Poland, under pressure from current energy trends, will decide to abolish the current 10H rule for wind power. In the context of this paper, this means using an EU-Wide low restrictions scenario for wind potential estimations. The procedure outlined above resulted in an energy model balancing consumption with RES energy potential for each considered sector, presented in the tables from 3.3 to 3.5.

Tab 3.3: Energy balance model – Economy

Energy source	Used value (TWh)	Utilization	RES alternative	% of replacement
Solid fossil fuels	0.126	Heating	Biomass	100.00%
Oil and petroleum products	0.023	Electricity	Wind	100.00%
Natural gas	0.254	Heating	Wind	100.00%
Others fuel	0.006	Heating	Biomass	100.00%
Heat	0.029	Heating	Biomass	100.00%
Electricity	0.206	Electricity	PV	100.00%

Tab 3.4: Energy balance model – Buildings

Energy source	Used value (TWh)	Utilization	RES alternative	% of replacement
Solid fossil fuels	0.216	Heating	Biomass	100.00%
Oil and petroleum products	0.000	-	-	-
Natural gas	0.248	Heating	PV	70.00%
Natural gas		Cooking	PV	30.00%
Others fuel	0.027	Heating	Biomass	100.00%
Heat	0.070	Heating	Heat pumps	100.00%
Electricity	0.258	Electricity	PV	100.00%

Tab 3.5: Energy balance model – Agriculture and forestry

Energy source	Used value (TWh)	Utilization	RE alternative	% of replacement
Solid fossil fuels	0.012	Heating	Biomass	100.00%
Oil and petroleum products	0.026	Electricity	PV	100.00%
Natural gas	0.000	-	-	-
Others fuel	0.003	Heating	Biomass	100.00%
Heat	0.000	-	-	-
Electricity	0.005	Electricity	PV	100.00%

The summary in Table 3.6 shows the final balance of renewable potential, utilization, and potential energy stock. The energy needed for heat pumps has been subtracted from the balance described above and is therefore also included in the summary. It can therefore be seen that with the right assumptions, RES can successfully replace the current state of use of non-renewable energy sources. It should be remembered that these are only estimations, which should be directly confronted with the data provided by the county in case of an actual project and transformation of the region.

Tab 3.6: RES potential utilization - summary

RES source	Total RES potential	Potential used	Potential left
Solar power	0.972	0.743	0.159
Wind power	0.313	0.277	0.036
Biomass	0.431	0.419	0.012

Additionally, to the concept “Energy level”, a technology proposal was made. These are solutions that are not introduced especially in Poland on a large scale, but which would be necessary to carry out a successful transformation of the Chrzanów county. The aim of this part is to present individual technologies which can be considered as innovative. It is focuses on general system solutions responsible for energy production, energy management or storage rather than detailed specification of PV panels or wind turbines, such as:

- Low-temperature district heating and cooling networks
- Power to heat technologies – electroheating
- Microgrids

The detailed system architecture including these technologies is beyond the scope of this work, but without any technological proposals, the concept could be considered incomplete. However, the research carried out certainly provides a direction for further activities aimed at the transition of the studied county, which is one of the main objectives and assumptions of this paper.

4. Community level – Energy community model and social perspective

An energy self-sufficient area is not only about the balance of energy consumed and produced. It is, above all, a place where people live and where many stakeholders have their interests represented. The structure of this chapter is divided into two larger issues which are the management structure of the cluster and the role of society and local authorities in the energy transition of the region. With a particular focus on the potential opportunities and benefits for the local community in the Chrzanów county. Why are these two issues linked? Because in the case of projects like the building of smart, eco-friendly neighbourhoods, estates or regions, the residents are directly involved with them. Based on Polish housing policy and the structure of the energy system, within the project, the following stakeholders were identified as: local authorities of Chrzanów county, residents and local community, Małopolska Marshal's Office and other higher institutions, distribution system operator (DSO), district heating supplier,

Knowing the main stakeholders, it is therefore possible to move on to an administrative and management model for the cluster and to find a place for each of them within it. Based on research and gathered experience, it was attempted to create a unique solution that consider the characteristics of involved entities. The energy community model brings together the business aspect of the whole project and the management structure with a breakdown of the roles of individuals and their responsibilities. The model overview is illustrated in the figure 4.1.

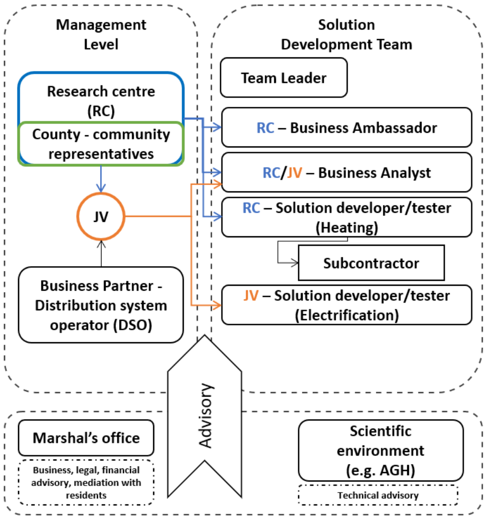

Fig. 4.1: Energy community and management model diagram

The "Management Level" brings together cluster administration, business case, community role and overall decision-making scheme. Within this level a Research Center was established. Its goal would be bring together and employ specialists from the world of technology, law and business, who would have decision-making power in the development of Chrzanów county as an energy self-sufficient area. The diagram shows that the Research Center includes "County - community representatives" block. Such a scheme is intended to show that local authorities would also have a vote on the development of the district. A third, significant stakeholder within this structure is the DSO - Tauron Polska Energia S.A. It is a huge player in the Polish energy market operating in 7 voivodeships. The model proposes to invite Tauron to work with the county as a business partner and form a joint venture for the energy cluster project. This is an uncommon solution and rarely seen in Poland, however it creates a vital business case for Tauron, giving him the opportunity to grow as a company.

"Solution Development Team" (SDT) [8] is a model layer strongly inspired by Agile Management method [8], however it was modified in order to be well tailored to project requirements. This is a strictly task team, which shares a specified objective to provide a technical solution needed for the cluster to operate safely and effectively It is required to report its work to the management level and thus to the district authority. The individual roles are outlined in the figure 4.1.

Given the complexity of the county's transformation into an energy cluster, additional stakeholders were intruced that can play an advisory role. The first advisory component of the system should be the Marshal's Office that could assist local authorities in assessing options and steps to engage local governments in the production and distribution of clean energy, be involved in developing and implementing demonstration initiatives, support decision-making processes related to legal, financial or social aspects and assist with fundraising and contacts with external investors.

As a second advisory body, the scientific environment like a AGH University of Science and Technology is proposed as one of the best technical universities in Poland, located in the capital of the Malopolska voivodship, Krakow. The team established for the development of the energy cluster would be employed on a salaried basis at the university and their task would be to advise on technological and IT solutions within the project scope.

At the "Community Level" another issue identified were social and legal challenges in the face of county transition. Studies have shown that the most important of these are the cluster strategies which often are partial, uncommitted, and primarily focused on the benefits of cheap energy rather than the broader socio-economic benefits [4]. Local authorities are often not prepared to take on new responsibilities and propose effective policies to support economic activities mainly due to the fact that The Western Małopolska region (where Chrzanów county is located) is highly industrialised, especially around the mining municipalities. The economy of these municipalities is largely based on the mining industry and thus guarantees a huge number of jobs [4].

Nonetheless, there are also numerous benefits that could be addressed. For example, local participation in clean energy can be encouraged by the possibility of achieving better value and lower prices for local consumers and residents. As a result, consumers can better manage their electricity spending because of better quality and a more reliable energy supplier, lower electricity bills or more stable and predictable electricity costs. Moreover, development of local energy solutions can also be encouraged by the potential for income generation. The revenue generation potential and associated risks will depend on the operational model chosen by the local administration and community, while appropriate revenue estimation is one of the most effective methods for dialogue. Another benefit is an increase in the value of the property financed by external measures. e.g., insulating the house with county money or installing PV as part of a transition programme [4]. Nevertheless, the most important step to achieve social acceptance among residents is a series of educational initiatives and an open information and dialogue campaign.

5. Financial level – Cost assessment and funding

Renewable projects are characterised by high investment costs (CAPEX), but relatively low operating costs (OPEX). Self-sufficient energy clusters are unfortunately not that popular projects, but as they consist of RES installations, it is possible to estimate (with a high tolerance) their costs. Thus, the main purpose of this section is to give an approximation of the expected expenses associated with the construction of a clean, green energy installation, according to the energy model proposed at an earlier stage of concept development. The project distinguishes 4 types of RES installations: Wind, solar, biomass and heat pumps. CAPEX and OPEX were estimated for each of them. The values were converted into euros based on the exchange rate forecast by the Polish Ministry of Finance. OPEX estimations were based on the recent inflation forecast provided also by Polish Ministry of Finance [9]. Results of the entire project CAPEX estimations are presented in table 5.1.

Tab 5.1: Project CAPEX summary

Specification	CAPEX (MM EUR)
Wind installations	128.12
Solar installations	395.32
Biomass installations	76.45
Heat pumps	14.94
Total	**614.83**

Summing up, the total CAPEX including the renewable energy technologies used in the concept was estimated at €614.8 million. Of course, in reality, investment costs also spread out over time depending on the development and implementation plan of the project. Moreover, the pace at which individual investments are realised is often dependent on the pace at which the relevant funds are raised. This means that both investment and operating costs will fluctuate over the years as macroeconomic indicators dependent on the global geopolitical situation change. There is no reason to aggregate OPEX for all installations, due to the lack of a timeline for the implementation of the concept. Thus, OPEX estimates need to be presented individually for each technology. The OPEX base year is 2021, due to the availability of data on the costs of RES installations, hence 2022 is taken as the potential first year of realisation. Taking into account the average lifespan of the installations, i.e. 25 years, the investment cost projections therefore reach 2047.

Tab 5.2: Wind farm - OPEX forecast

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Project OPEX (MM EUR)	3.95	4.07	4.18	4.28	4.39	4.50	4.61	4.73	4.85	4.97	5.09	5.22	5.35
Year	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047
Project OPEX (MM EUR)	5.48	5.62	5.76	5.90	6.05	6.20	6.36	6.52	6.68	6.85	7.02	7.19	7.37

Tab 5.2: Solar installations - OPEX forecast

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Project OPEX (MM EUR)	3.53	3.63	3.73	3.82	3.92	4.02	4.12	4.22	4.33	4.44	4.55	4.66	4.78
Year	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047
Project OPEX (MM EUR)	4.90	5.02	5.14	5.27	5.40	5.54	5.68	5.82	5.97	6.11	6.27	6.42	6.58

Tab 5.3: Biomass installations - OPEX forecast

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Project OPEX (MM EUR)	4.36	4.49	4.61	4.72	4.84	4.96	5.09	5.21	5.34	5.48	5.62	5.76	5.90
Year	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047
Project OPEX (MM EUR)	6.05	6.20	6.35	6.51	6.68	6.84	7.01	7.19	7.37	7.55	7.74	7.93	8.13

Tab 5.3: Heat pumps installations - OPEX forecast

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Project OPEX (MM EUR)	1.54	1.59	1.63	1.67	1.72	1.76	1.80	1.85	1.89	1.94	1.99	2.04	2.09
Year	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047
Project OPEX (MM EUR)	2.14	2.20	2.25	2.31	2.36	2.42	2.48	2.55	2.61	2.68	2.74	2.81	2.88

As can be deduced from the results of the financial estimations, the transition of the district into a cluster requires significant financial resources. The county alone would obviously not be able to finance such a project within a reasonable timeframe. Therefore, in the second part of the financial model, research was carried out into potential sources of funding. Fortunately, Poland is a member of the European Union, which is the main promoter of initiatives to deal with the negative effects of climate change, but at the same time provides a substantial funding. Hence, Chrzanów couty can count on two funding sources national and local.

From a national perspective, on the basis of the already mentioned document describing Poland's energy policy until 2040, it is known that the quoted amount of the national energy transformation by that time is PLN 1 600 billion (€352 billion) [3]. This amount is to be distributed through various programmes and financial instruments. The most important of these are:

- Cohesion Policy (pl. Polityki Spójności): approx. €17 billion,
- Instrument for Reconstruction and Resilience (pl. Instrument na rzecz Odbudowy i Zwiększania Odporności): approx. €21.5 billion,

- Fair Transformation Fund (pl. Funduszu na rzecz Sprawiedliwej Transformacji): allocation for Poland of approx. €3.5 billion.
- New instruments like the Modernisation Fund and a national special-purpose fund fuelled by funds from the sale of CO_2 emission allowances, i.e. the Energy Transformation Fund: above €10.5 billion

In case of local funding each region of the country has to apply separately for a given share of the funds. The concept of an energy self-sufficient county fits into most of the objectives of funding programmes. The main purpose of this list is to show that the much-needed money for this concept can indeed be obtained if the assumptions and plan of the concept are well presented as a coherent proposal.

- Program LIFE: €15.5 million - For implementation of the Regional Energy and Climate Action Plan,
- Clean Air Programme: €1.8 billion - For improving the energy efficiency of single-family buildings,
- Thermo-modernization relief: €440 million - For energy efficiency and renewable energy improvement measures,
- Program Stop Smog: €55 million - For improving the energy efficiency of buildings for people affected by energy poverty
- Thermo-modernization relief: €440 million - For energy efficiency and renewable energy improvement measures.

6. Summary and Conclusions

The aforementioned aspects create a complete concept of the region, which undoubtedly has the potential to become one of the pioneering areas based on green distributed energy, eliminating dependence on fossil fuels and gas in the main local energy consumption sectors. Within the framework of the concept being developed, it is highly recommended that the proposed technological, administrative and management solutions are taken into account in the event of the actual development and implementation of the presented concept. The entire work is prepared and conceived as a coherent entity, however, it is possible to use the individual solutions proposed at individual levels.

The measures taken and analyses carried out within the framework of this work allowed the author to formulate the following conclusions:

- An energy cluster in the form of an energy self-sufficient area is currently a very complicated entity in terms of technical, economic, legal, and social aspects.
- The Polish government assumed the creation of 300 energy clusters by the end of 2030. To meet this goal, it should definitely simplify the current system of national cluster certification and create clear guidelines on, in particular, cooperation with distribution system operators.
- Despite its complexity, building an energy self-sufficient county is one of the best ways to involve citizens at every community level.
- Currently, Chrzanów County is heavily dependent on coal. This primarily concerns the structure of the energy system, but not only. A sizable part of the population has coal-based jobs, which poses a major challenge in terms of its elimination.
- The transformation of Chrzanów County into an energy self-sufficient district based on RES is possible provided that legislation limiting the potential of wind energy in Poland is abolished.
- The largest energy potential in the analysed county has solar energy (0.972 TWh/year), which, with proper utilization, could cover the entire county's electricity needs.
- The energy carriers used for heat production could mostly be covered by the potential from agricultural, forestry and waste biomass (0.431 TWh/year).
- As part of the region's transition, it would be necessary to electrify housing and the agricultural sector, as well as increase the energy efficiency of buildings by, for example, properly insulation.
- It is a very good practise to have specially identified coordinating unit within the cluster structures, which would be responsible for the development, mobilisation, and management of

relationships between cluster members and for providing specialised services to them.

- Support from the voivodeship Marshal's Office in legal, financial, coordination of contacts with potential investors and mediation between stakeholders is essential for this project.

- Lack of public acceptance can result in the suspension of a project at almost any stage of its implementation, which is why it is so important to undertake a number of social initiatives targeting end users.

- The construction of energy renewable self-sufficient district requires a great investment. However, it is a very effective way to facilitate the energy transition and contribute to climate neutrality through energy efficiency and net zero energy balance

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