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# The European Education Initiative as a Mitigation Mechanism for Energy Transition

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**Abstract:** The transformation of the European energy sector is becoming a priority for the European Union. This is indicated, for instance, in the European Union strategy known as the European Green Deal. According to the Green Deal, the area of 'research and innovation' is one which can counteract climate change. Universities can play a significant role in this by adopting a pedagogical approach aimed at mobilizing the spirit of innovation and entrepreneurship in young professionals. In addition to modifying curricula related to mining, energy, and environmental engineering, i.e., activities in recognized, traditional schemes, one prospective tool may be the involvement of students and PhD candidates in European initiatives such as the InnoEnergy PhD School (which is funded by the European Institute of Innovation and Technology). This paper aims to discuss the InnoEnergy PhD School programme as a possible instrument for mitigating the negative effects of energy transformation. The article analyzes the programme using a case study method, including surveys and open interviews. The paper draws attention to and highlights the role of human resources in the field of education and the stimulation of innovation, as well as the need to strengthen the business component in the education of PhD candidates.

**Keywords:** energy transformation; Green Deal; InnoEnergy; innovative education initiatives; European Institute of Innovation and Technology (EIT)

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## 1. Introduction

The coal sector operates in 12 EU countries and 41 European regions (as of 2021) [1]. The European Commission, United Nations, and Climate Alliance, as well as others, have indicated the need to reorient carbon-intensive sociotechnical systems. In the 2030 Climate Target Plan [2], the European Commission proposed intensification of activities aimed at reducing greenhouse gases by at least 55% by 2030 compared to 1990 levels. This change in goals significantly differs from the previously adopted target of at least 40%. The new resolutions meet UN Sustainable Development Goal 13 and the European Green Deal (including the Fit for 55 package), and are in line with the Paris Agreement of 2015. The Paris Agreement emphasizes the need to limit global temperature increase to 1.5 °C [3]. Other EU legislation and strategies dealing with climate issues include:

- United Nations Framework Convention on Climate Change (UNFCCC) (2020) [1].
- EU Emissions Trading System (ETS) [4].
- Effort Sharing Regulation [5].
- European Climate Law [6].

EU member states are obliged to develop long-term national strategies aimed at implementing EU objectives and the provisions of the Paris Agreement at the national level. Strategies must be focused on the reduction of greenhouse gas emissions caused by natural systems (including forest fires) and anthropogenic activities (including energy production) [7].

At the same time, attention must be paid to the COVID-19 crisis and the focus of policymakers on protecting lives. The global pandemic, which began in March 2020, is acting as a catalyst for long- and short-term changes and requires the empirical and theoretical attention of researchers [8]. The literature articulates the difficulties that need to be addressed. Post-pandemic challenges include job losses, declining revenues in certain sectors, and economic recessions, as well as sharing economy (SE) activities and other issues [9,10]. Financial losses associated with the COVID-19 crisis have been estimated at approximately 2.96 trillion US dollars in lost economic output [11], and Europe is experiencing a high level of inflation (6.2%, February 2022) [12]. Moreover, the crisis caused by the pandemic has been compounded by the Russian invasion of Ukraine. It is not clear what impact this geopolitical conflict will have on the pace of energy transition [13]. On the one hand, this event may cause a change in the energy policies of many countries and turn them more toward energy security than the goals of transitioning to green energy. However, it may require European policymakers to decide to support green technologies that will facilitate the decarbonization process and fit with the energy policy goals of the European Union [14]. It might reasonably combine the two approaches; an example is Germany, which in response to the current situation in the political arena has taken measures to accelerate the deadline for achieving full renewable energy from 2050 to 2035 [15]. However, this has not prevented them from deciding to renew the start-up of closed coal-fired power plants, which they explain by the need to secure gas reserves for winter by switching off gas-fired power plants and switching on coal-fired ones [16].

In general, divergence has been observed among member states in dealing with climate change [17]. Responses have included support schemes for renewable energies in addition to a lack of public acceptance and a fossil fuel lock-in, as well as inadequate National Energy and Climate Plans with collective targets in EU and UNFCCC policies [18]. The energy transition in Europe's mining regions poses many complications for the years between 2030 and 2050, and key among these is the reduction of greenhouse gas emissions [1]. In Europe, Estonia, Latvia, Lithuania, Belgium, Malta, Luxembourg, and Cyprus are carbon-free [19]. The countries that will face the biggest problems related to energy transformation are Poland, Bulgaria, the Czech Republic, and Romania [20,21]. Table 1 presents information on the direction and problems of the green transformation of the energy sector in selected countries. Decarbonizing national carbon-based economies is an ambitious and difficult undertaking and requires attention to local issues in developing economies to ensure global growth and common goals. The Joint Research Centre (JRC), in its study of opportunities and challenges in EU coal regions [22], stated that about 238,000 jobs may be lost as a result of the energy transition, and the operating horizons for coal-fired power plants in the EU indicate that two thirds are expected to have shut down by 2030. Moreover, indirect activities in the value chain of the coal industry, including power generation, equipment supply, research and development services, and others, provide thousands of additional jobs. The European Commission's platform for the European coal regions outlines that coal-fired power plants in the European Union and the United Kingdom account for 150 GW of total capacity, including 207 power plants and 53,000 direct job positions. There are 150 coal mines across 11 countries in Europe [20]. A particular difficulty is the so-called NUTS-2 region (one of the three levels according to the subdivisions of countries established by Eurostat), where 85% of the jobs related to hard or brown coal are concentrated [23]. Poland is in a unique situation; of the 53,000 jobs in the mining sector, as many as 13,000 of them involve workers from Poland [1].

**Table 1.** Selected information on the energy sector in different countries and the challenges involved (source: own elaboration, based on [19,24–27]).

| Country | Main Source of Energy | Share of Coal in Electricity Generation | Share of RES | Declared Year to Move Away from Coal | Selected Problems of the Energy Sector and Energy Transformation |
|---|---|---|---|---|---|
| Czech Republic | Coal/Atomic | 40% | | 2038 | Nuclear power plant infrastructure to replace coal. |
| Poland | Hard coal | 72% | 17% | | Pace of expansion and modernization of generation units is still insufficient; organizational structure of energy companies. |
| Romania | Coal and gas | 17% | 24% | 2032 | Infrastructure for RES sources. |
| Slovakia | Atomic | 7% | 17.48% | 2023 | Infrastructure for RES sources. |
| Spain | Oil and gas | 2% | 38% | 2030 | Infrastructure for renewable energy sources at 74% by 2030 and 100% in 2050; |
| Germany | Wind | 24% | 46.4% | 2038 | Synchronization of renewable sources with the grid transmission capacity power engineering; energy storage. |

A McKinsey company study emphasized that Poland must intensify its decarbonization processes fourfold compared to the pace of the previous 30 years in order to achieve the goals of the EU and the Paris Agreement [28]. In 2021, a contract was signed to transform the coal mining sector [29]. This document outlines systemic solutions aimed at protecting the employees of mining plants while maintaining national energy security. The agreement includes, among other things, provisions for financing mechanisms for the hard coal sector and a guarantee of employment for workers and others. Moreover, the necessity is emphasized of additional investment outlay in the subsequent years projected at the level of EUR 10–13 billion per year, or alternatively 1–2% of GDP, for areas related to the decarbonization of the Polish economy. The challenges of decarbonization cover all sectors of the economy. This paper focuses on the mining industry, including the hard coal sector.

One of the ways to mitigate the forthcoming energy transition is to use a pedagogical approach aimed at mobilizing the innovative and entrepreneurial spirit of students, including PhD candidates. The literature emphasizes the rationale of directing young professionals to build innovative solutions in the field of energy [30–32]. One resource that will embody an assertive and equitable shift during the energy transformation may be represented by educational programmes such as the InnoEnergy PhD School (which has EIT funding) [33]. The InnoEnergy PhD School survey was completed in 2021 and the results form the content of this paper. The purpose is to discuss the InnoEnergy PhD School programme as a tool for mitigating the energy transition. The authors of this paper hypothesize that an appropriate pedagogical approach and suitable human resource training outside the traditional model can contribute to tangible benefits in the context of the economic transformations that European countries must face in the coming decades.

This article provides a basis for future analysis in the context of sustainable energy transition at the educational level. At the same time, it should be emphasized that the article also analyzes and considers the negative aspects of the energy transformation.

## 2. Materials and Methods

Qualitative methods were used in the presented paper. The case study method was adopted, incorporating surveys and open interviews (IDI—in-depth interview). These are typically used in social and environmental research focused on practice, including, among other sectors, education [34], health care, nursing, sociology, anthropology, psychology, management, and information systems [35]. The scope of the investigation undertaken in this study means that the use of this method allowed in-depth analysis of the selected project, policy, and programme, including its application in a real-life system [36].

Reference was made to a case study of a retrospective nature. Ethnographic research was carried out in the form of individual interviews. The challenges posed by the European Union in the context of the transition were characterized. As part of the paper, the issues of higher education in the coal mining industry in the context of transformation (the desk study method) were analysed. The InnoEnergy PhD School educational programme is discussed in terms of the results of the unit centred around the InnoEnergy Central European Office. The effects of implementing new business ideas in the socio-economic environment are presented. These are the results of the participation of young researchers in the InnoEnergy PhD School process, and offer a potential future opportunity to mitigate the energy transition to result in a transparent and fair transition. This paper's structure consists of several stages; the first identifies general challenges affecting the energy sector. General problems and strategic challenges related to the European energy transition are indicated. Furthermore, attention was paid to PhD students' education programmes oriented toward the energy sector. The research subject was defined as the EU InnoEnergy PhD School programme. Research methods and research tools were defined, and are described. Discussion addresses Poland's challenges in the context of energy transformation and the participation of Polish doctoral students in the InnoEnergy PhD School programme. The results of the research are presented. The results are discussed and conclusions drawn. Directions for further research are signposted. The stages of the research process are presented in Figure 1.

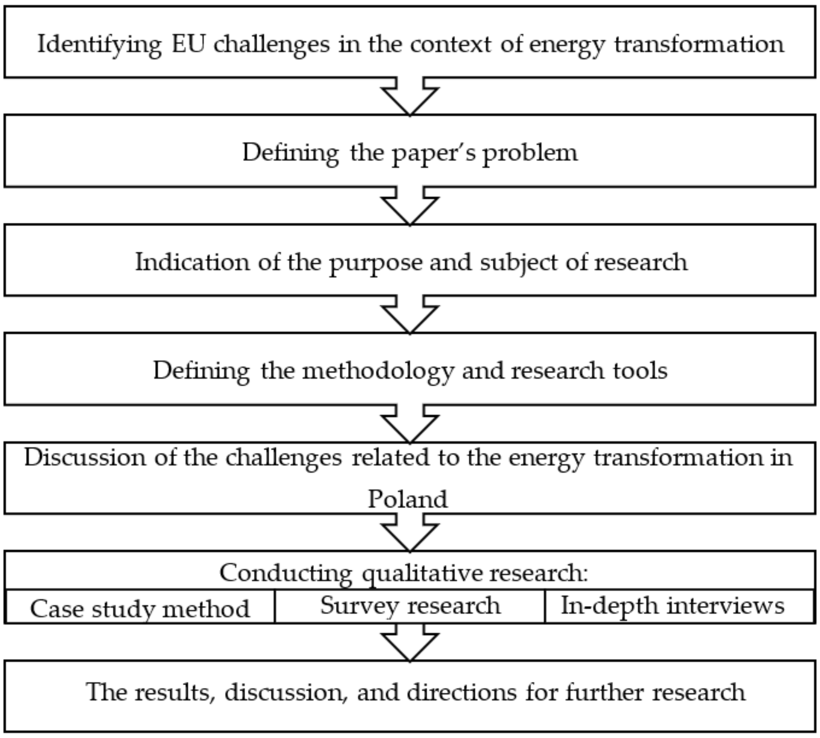


**Figure 1.** Stages of the research process (source: own elaboration).

## 3. The Role of Higher Education in the Energy Transition

Particularly important in this context is the aspect of innovation and commercialization in the education of doctoral students. An interesting and valuable perspective is presented in the research by Dooley et al. [37]. The results of the authors' research indicated that doctoral students wanted to increase their business and entrepreneurial skills and were convinced that educational modules could benefit them. At the same time, it is worth paying attention to studies by Pruett et al. [38] who put forward the thesis that the greatest predictor of the will to develop entrepreneurship depends on personal preferences and the subject's own conviction about their entrepreneurial abilities. The European University Association [39], in their paper on fostering creativity and innovation in doctoral education, cites the position that the best mechanism is to bring together doctoral students from various disciplines and encourage their dialogue. Examples of such platforms are summer schools, and specialized institutional and inter-institutional centres [39]. Examples of such centres include ESADE Business School, Grenoble Ecole de Management, etc.

The European Commission is placing increasing emphasis on addressing the topic of developing innovative knowledge and skills in mining activity. New mining projects related to critical raw materials are particularly important [40]. This is evidenced, for example, through the themes of Future Trends Innovation and Skills for Raw Materials during flagship industry events such as Raw Materials Week or the Raw Materials Summit. These events gather a wide range of European stakeholders to discuss policies and initiatives in the field of raw materials (EU Raw Materials Week 2021). Numerous educational projects are oriented around the social licence to operate (SLO), which is one of the major challenges facing the mining industry on the threshold of transition [41]. Examples of such projects include RM@School [42], AMIC [43], BetterGeoEdu [44], RawDTrip [45], TrainESEE [46], and others. In addition, the relevance of the creation of master projects in the context of the implementation of the development strategies of the European Union, and its initiatives related to the Green Deal and the energy transition, is emphasized by the RaVeN (Raw Materials Value Chain) project team [47].

According to the goals of the National Development Strategy, the conditions for the formation of attitudes through lifelong learning approaches will be improved over the next decade [48]. The McKinsey company, in the study 'Carbon-neutral Poland 2050' [28], point out that incentives are needed for universities to promote fields of education that are critical for low-carbon industry. This action fits into the concept of carbon-neutral education (CNE), in which a higher education institution (HEI) operates a dual strategy. First, the HEI aims to implement low-carbon practices in its activities, and second, to orient curricula and pedagogical approaches in order to teach students knowledge and skills relating to carbon-neutral practices [49]. The determinant of successful decarbonization is the modelling of change that results from the interaction of science with industry, government, and society. This approach helps to develop strategies that transcend traditional disciplinary boundaries to include political and social realities [50,51].

In addition to the dualistic CNE strategy outlined above, the concept of education for sustainable development (ESD) has become very popular [52,53], as coordinated by UNESCO [54]. Apart from promoting a more radical learning-centred social transformation in relation to sustainability in the education system, involving changes in the underlying epistemology of its culture, thinking, and practice, the need for discussion around areas such as climate change in the teaching and learning process in higher education has also been asserted [55]. Many studies have highlighted the importance of innovation in building a sustainable future [56]. The JRC has contributed in this area by researching the impact of the introduction and development of ICT (Information and Communications Technology) as a catalyst for teaching and learning innovation [57]. Many projects such as OpenEdu [58], DigCompEdu [59], and DigCompOrg [60] have shown advantages and disadvantages of the innovative use of digital technologies in education, for all parties involved, with a focus on higher education [61]. In addition, the JRC has helped to highlight the importance of raising digital competence throughout teaching and learning processes [62]. A combination of institutional support and technological self-efficacy ensures the development of good educational practices. This approach translates into achieving a sustainable education system by linking ESD to the innovation stream [63]. An example of an initiative that fits into this concept is the Intercollegiate Climate Academy (MAK), which is implemented in cooperation with the AGH University of Science and Technology (AGH UST) in Krakow, the Warsaw School of Economics, and the University of Wroclaw (Poland). This is a consortium of postgraduate programmes designed to impart interdisciplinary knowledge in combination with the industry's professionalism [64].

## 4. Poland's Energy Challenge

Hard coal mining in Poland has been decreasing over the last 20 years [65]. In 2020, hard coal extraction amounted to 54.4 million Mg (Mg = 1 tonne; 1000 kg), which was more than 7 million Mg lower than in 2019. At the same time, it should be noted that Poland remains the production leader in the EU. On the international global scale, it ranks in the top 10 for global extraction, at 0.8%. Among Poland's 21 operational coal mines, 20 are located in the Upper Silesian Coal Basin. The other, Bogdanka S.A. Lubelski Wegiel, is located in the Lublin Coal Basin (Figure 2) in the east of the country [66].

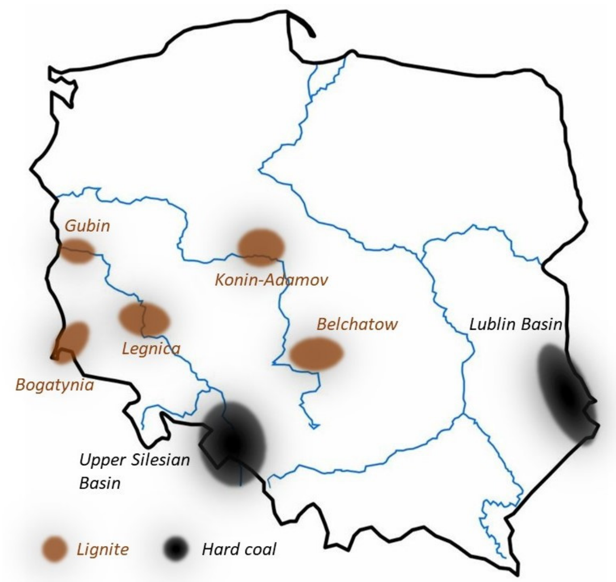


**Figure 2.** Coal regions in Poland (own elaboration, based on: https://euracoal.eu/, accessed on 2 September 2022).

A downward trend in output has also been observed for lignite. Until 2020, the raw material was extracted in five mines: Bełchatow, Turow, Adamow, Konin, and Sieniawa. The Adamow mine is currently being decommissioned. Poland, with a lignite output of approximately 47.3 million tons (data from 2020 [67]), ranks second in Europe.

The transmission system operator in Poland—the Polish Power Grid (PSE)—indicates that the structure of electricity generation (by power plant group according to fuel type) did not change drastically in 2018–2020 [68]. In 2020, coal-fired power plants continued to dominate generation (just over 70%), followed by renewable energy sources (RES), and an increasing share of wind power plants. Natural gas recorded the next highest growth rate over the three years in question (see Figure 3).

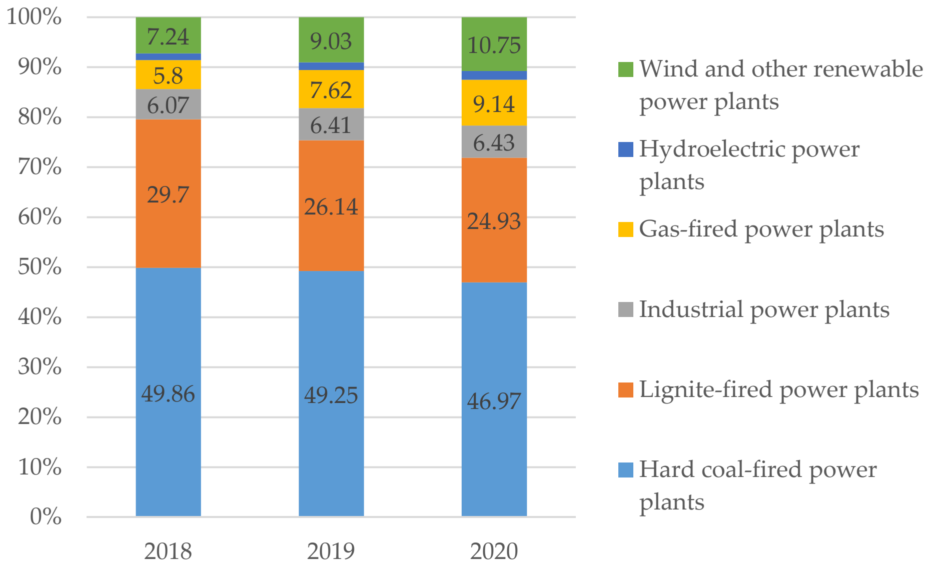


**Figure 3.** Electricity generation by power plants in Poland according to fuel type, 2018–2020 (source: own elaboration, based on: PSE data).

The origins of the changes in the structure of electricity production in Poland can be traced in this example in line with the strategy presented in the 'Energy Policy of Poland until 2040', which was adopted by the government in September 2020 (hereinafter EPP2040) [69]. The EPP2040 implementation indicators include reducing the share of coal used in electricity generation to 56% and increasing the share of RES to 23%. In addition to the numerical direction of changes in the Polish energy sector, the document presents a scenario framework for the future energy transition, based on three pillars:

***1. Just transition.*** It establishes the 'transition of coal regions, reducing energy poverty and developing new branches of industry related to RES and nuclear power'.

***2. Zero-emission energy system.*** This will be based on 'offshore wind energy, nuclear energy as well as local and civic power generation'.

***3. Good air quality.*** This initiative by every citizen 'is one of the most noticeable signs of moving away from fossil fuels'. Clean air is guaranteed by 'investing in the district heating sector transition (system and individual), electrification of transport and promotion of passive and zero-emission houses using local energy sources'.

In the era of climate change, all these activities are aimed at ensuring Poland's energy self-sufficiency by using, among other things, domestic economic and raw material potential, as well as technological and personnel capacity [70]. Signposts for the direction of changes taking place in Poland include, among others, European Union regulations, which place great emphasis on sustainable economic development. According to the document 'Europe 2020—A strategy for smart, sustainable and inclusive growth', the priorities in this area are 'developing an economy based on knowledge and innovation', as well as 'promoting a more resource efficient, greener and more competitive economy' and 'fostering a high-employment economy delivering social and territorial cohesion' [71].

The education system, including technical and vocational schools as well as universities, is one of the elements of the Polish economy in which such shifts can be seen already to have had and will continue to have a visible impact. Linking science with industry, increasing the importance of innovation in the creation of new products and services, and increasing the environmental self-awareness of young people are the main points of change in higher education [72]. This article, in keeping with its premise, focuses on activities undertaken by universities in these areas. Expanding the didactic offer by reorganizing the old and creating new majors or specialties, such as 'Renewable Energy and Energy Management' or 'Revitalization of Degraded Areas' [73], are changes that can be observed at AGH UST, one of the three universities in Poland that provide education in mining [74].

This approach can meet the future challenges of the Polish mining sector. The preparation of doctoral dissertations may be carried out in different forms in Poland, e.g., as part of a doctoral school, through doctoral studies, or as an employee of a particular organization (the so-called 'implementation doctorate'). Dissertations on topics closely related to counteracting climate change may also be a part of the package of necessary, discussed changes. According to the points made in the work 'Research in EE and ESD in Portuguese Public Universities' [75], the production of doctoral theses is an important indicator of scientific and academic development within a discipline. The initiatives mentioned above are not the only ones being undertaken by Polish universities in order to meet the requirements posed by energy transformation. In addition to research conducted within universities [76], collaboration between universities and research institutions is another example of initiatives contributing to sustainable development goals, and adds value to society and the economy.

Several articles that are the results of cooperation between representatives of AGH UST (scientific staff and students) and the Central Mining Institute (GIG) include work on modern mining or its alternatives [77–82]. Participation in those educational projects co-financed by European institutions is an integral part of building a self-aware, innovation-oriented, business-connected, multicultural scientific community. An example of an educational initiative that addresses the challenges of energy transition and new business models in the energy sector is the InnoEnergy PhD School programme.

## 5. EIT InnoEnergy—Brief

Being a leader in cleaner energy production in the European Union is inextricably connected to the European Union's innovation efforts. According to the European Green Deal strategy, by 2050 Europe will become the first climate-neutral continent, largely due to research and innovation. Though modernization of the economy as well as society, the EU aims to help 'accelerate and navigate necessary changes', 'implement, demonstrate and remove risks', and 'engage citizens in social innovation' [83]. The Active Innovation paradigm [84] indicates that entrepreneurship and intrapreneurship, and thus use of the values of all those authorized to take action in the innovation process, have become a business imperative. The evolution of education—from traditional to environmentally oriented, encompassing social inclusion—means that 'future engineers' should be equipped with values and experiences that meet real societal challenges [85]. The European Institute of Innovation and Technology (EIT) has stated that the EU is facing an 'innovation crisis'. This is evidenced by the fact that Europe's share in global GDP decreased from 30% in 2006 to 22% in 2016 [86]. The response of the European Parliament and Council to global issues ranging from climate change to sustainable food production, etc., included the establishment of the EIT Innovation Community in 2008. It functions as an independent institute and brings together Europe's leading business, education, and research organizations. Together, they aim towards innovation solutions for Europe. The EIT consists of eight Innovation Communities (Table 2), including EIT InnoEnergy (marked in green).

**Table 2.** EIT Innovation Communities structure (source: own elaboration, based on: www.eit.europa.eu, accessed on 2 September 2022).

| | |
|---|---|
| EIT Innovation Communities | EIT Climate-KIC |
| | EIT Digital |
| | EIT Food |
| | EIT Health |
| | EIT InnoEnergy |
| | EIT Manufacturing |
| | EIT Raw Materials |
| | EIT Urban Mobility |

InnoEnergy's mission is: 'Accelerating sustainable energy innovations', connecting all actors from the knowledge triangle: industry, research, and education [87]. InnoEnergy invests in new technologies ranging from renewable energy sources to energy storage. The results of InnoEnergy's activities so far are presented in Table 3.

**Table 3.** EIT InnoEnergy results (source: own elaboration, based on: www.eit.europa.eu (accessed on 2 September 2022).

| | |
|---|---|
| Investments | 560 mln euro |
| Products | 480 |
| Sales amounting | 5.3 mld euro |
| Alumni | 1100 |
| Community | 500 key players 18 countries |

EIT InnoEnergy strengthens the links between young researchers across Europe. One tool is the InnoEnergy PhD School programme, which is dedicated to PhD candidates. The main goal and motto of the InnoEnergy PhD School is to 'enable doctoral candidates to complement their research with essential entrepreneurial, innovation, business and personal skills'. The programme's emphasis on soft skills education, including teamworking and cross-cultural collaboration, should also be noted. The InnoEnergy PhD School is estimated to have over 260 alumni who understand the energy industry and have the skills and knowledge to deliver the industry's needs [88].

Due to the specific nature of the research, the PhD candidates work in eight critical thematic fields; clean coal and gas technologies, energy storage, energy efficiency, energy from chemical fuels, renewable energies, smart and efficient buildings and cities, smart electric grids, and nuclear instrumentation. The model of education consists of conducting research in the parent institution, where a doctoral thesis is prepared. The InnoEnergy PhD School provides complementary courses and training that should be carried out in entities cooperating with InnoEnergy. These are the flagship European universities and research centres.

The PhD candidates are required to participate in at least three courses from the group of core courses, and at least one from the pool of elective courses. A supplement to the education programme in addition to the courses is a fellowship in a foreign unit. Non-academic locations are recommended. This approach offers the opportunity to expand the student's experience and to strengthen cooperation within the so-called knowledge triangle (universities–business–research centres). The 'Innovation Doctorate' project proves the value of tightening cooperation within the knowledge triangle. PhD candidates working on innovative solutions as part of a doctoral dissertation, in cooperation with an industrial partner, can apply for funding for further studies and substantive support from the EIT. In addition, participants have the chance to transform their research into innovation by preparing an Innovation Project proposal. This is a research and development project that aims to develop a new technology or service that has the potential to become a commercial product, thus contributing to the energy transition.

Finally, the InnoEnergy PhD School is complemented by tutoring, mentoring, and coaching activities throughout the programme's life cycle. Figure 4 presents the InnoEnergy PhD School education model. This approach offers access to supplementation of basic research with key skills, including in the fields of management and innovation. Finally, networking is also an important topic. A three-day conference is organized annually in which all PhD candidates from the InnoEnergy PhD School participate. This provides opportunities to build potential cooperation, establish contacts (including within the business environment), and draw inspiration from each other [89]. Cooperation between PhD candidates and the mobility host is significant (AGH UST-SGPR.tech; AGH UST-Cepsis).

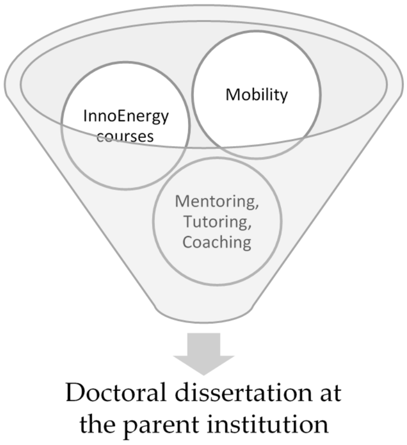


**Figure 4.** EIT InnoEnergy PhD education structure (source: own elaboration).

## 6. Results and Discussion

### *6.1. Polish Participants of the Programme*

In 2018, 24 Polish PhD candidates participated in the InnoEnergy PhD School programme, 66.7% of whom were men. Throughout the life cycle of the programme, men dominated among the participants (see Figure 5). In 2018, eight doctoral students applied to the programme, of whom five were qualified. They were the last recruited PhD candidates to the programme from Poland. That year, one of the participants defended his PhD thesis and received an EIT certificate. An analogous interpretation of the data presented can be undertaken for future years based on Figure 6, which details the number of participants from 2018–2021.

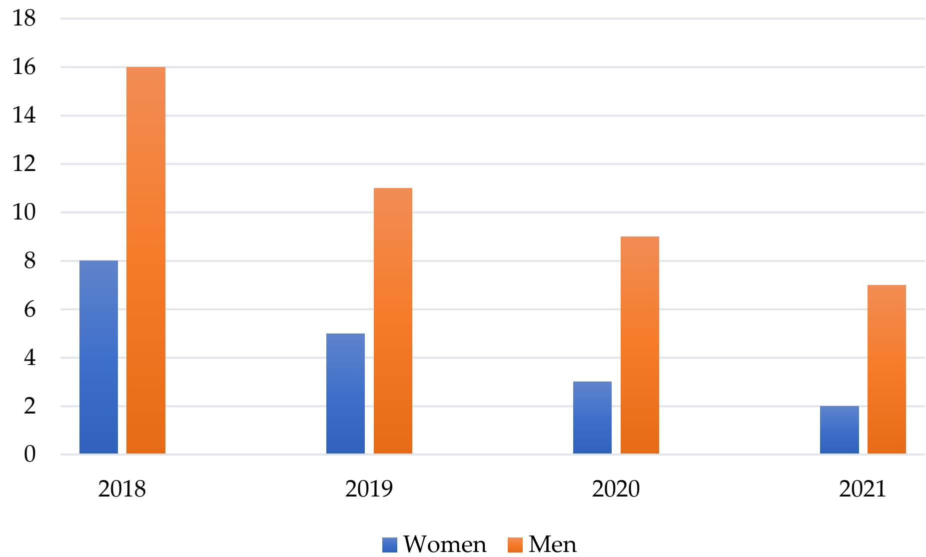


**Figure 5.** Gender of the participants.

In terms of research areas, the participants developed their scientific interests in the following topics:

- Clean coalfields (seven PhD candidates).
- Renewables (four PhD candidates).
- Smart grids (two PhD candidates).
- Energy efficiency (eight PhD candidates).
- Energy storage (two PhD candidates).
- Chemical fuels (one PhD candidate).

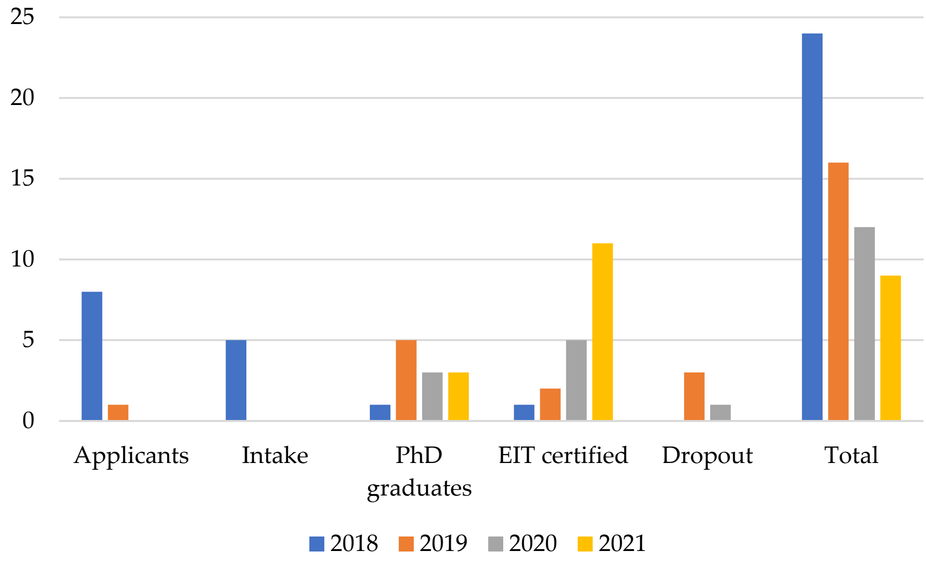


**Figure 6.** Programme participants from 2018–2021.

*6.2. The Results of the Research Analysis*

The benefits and results to be gained from participation in the InnoEnergy PhD School programme include the acquisition of skills as well as business and decision-making competences enabling the transformation of basic research into projects applicable to the energy sector. One of the tools for verifying the progress of PhD candidates in these areas was a qualitative study conducted using a survey and an open-ended interview (IDI) technique. The survey was conducted annually by the PhD InnoEnergy Officers.

The study was divided into five areas: Section I: Scientific progress; section II: Capacity for innovation; section III: Personal professional plan; section IV: InnoEnergy PhD School activities; section V: General feedback and suggestions for the programme. The responses were varied in nature. The interviews were semi-structured and included the following:

- Beforehand preparation
- Opportunity to collect more in-depth information
- Allowing respondents time to open up about sensitive issues
- Providing qualitative data for joint models.

The following is a summary of the interviews conducted at the end of 2021. Nine active PhD candidates (two women and seven men, ranging in age from 29–38) participated in the interviews.

Section I: Scientific Progress

This section was the broadest section, consisting of four questions.

The first question was about the progress made in 2021. In general, for most students, the main progress in 2021 focused on finalizing their work, i.e., summarizing past studies (such as experimental and computational research) and developing scientific conclusions. Some candidates pointed out that the tremendous support from Knowledge Innovation Community InnoEnergy during those years had simplified the development of their PhDs, including the incorporation of a business approach into an extremely technical thesis.

The second question was 'Which academic competences have been reinforced for your research progress while undertaking InnoEnergy PhD School programme participation?' Among the academic competencies that were reinforced, the PhD candidates listed seeking funds and applying for grants, writing papers and reports, and making research logs and notes, as well as public speaking, teamwork, and networking. Most of them emphasized their improved English. A good example was one of the participants who conducts classes with ERASMUS+ students, who, due to InnoEnergy, feels confident teaching foreigners in English. Some candidates became oriented towards business and opportunities, and opened up to others. Participants also become project managers or task managers by participating in projects, including European schemes (Horizon Europe, Cost, EIT).

The answers to the third question 'Could you give a highlight from the last year, that you are proud of?' were varied, among which may be distinguished those relating to the PhD itself. The PhD candidates were happy and proud that they were finishing their theses and of having completed the courses provided in the EIT InnoEnergy Programme. One mentioned that he participated in the Battle of Green Talent organized by EIT InnoEnergy and his start-up sent the first samples of its product to China, Switzerland, Germany, Poland, Australia, and Argentina. Another was proud of beginning to cooperate with a start-up from Poland. Some of them specified that they applied for financial support for projects. It is worth mentioning that one of the students received financial support of 1.3 million euro for a project of which she is the manager. Finally, one of the PhD candidates also emphasized that participation in InnoEnergy may not have resulted in the commercialization of research, but it certainly expanded their horizons and understanding of the need for a business approach in such work.

To the fourth question 'What was the main difficulty you met, whatever the nature of it?', there were also many answers on different levels, such as, for example, time management, overtasking, and personal challenges. Among those connected with undertaking a PhD, the candidates listed securing financial support (i.e., for new equipment and appliances) and accurately locating the findings of their PhD theses within the realities of the market at its current state. Only one person mentioned the COVID-19 restrictions and their impact on daily life.

Section II: Capacity for Innovation

In this section, PhD candidates sought to answer whether their work has a capacity for innovation, and what kind. All PhD candidates saw potential for innovation in their research or knowledge. Some of them have elaborated prototypes of their devices. Among them are a number who have already launched their start-up, and some who have developed a supply chain for individual components for prototypes but need to raise necessary funds. Others are performing research into increasing levels of technological readiness. The latter group identified areas in which their studies have innovative and business potential.

Section III: Personal Professional Plan

Most PhD candidates have specific goals for their future careers. This is related to the fact that some have jobs, and others want to continue their careers in academic and commercial industries connected to their PhD topics, and thus will be able to further their PhD research after their defence. Among those who have jobs, a number want to climb the career ladder, and others are thinking of opening their own businesses.

Section IV: InnoEnergy PhD School Activities

This section gathered information about the activities in which the PhD candidates participated in 2021, as well as their assessment of those activities. All PhD candidates completed all the provided courses in the EIT InnoEnergy Programme in 2020. In 2021, three of them participated in placements. For these PhD candidates, these were very fruitful. For one of them, the key aspect of this practice was to gain knowledge about running a business, which he succeeded in doing. For the second, the main goals were to verify the ideas of his thesis and to test his simulations in real-life industrial applications, and he also achieved them all. For the third, the experience provided him with the opportunity to build new relationships and increased his self-management skills (prioritization, time management, and focus).

Section V: General Feedback and Suggestions for the Programme

In general, all the feedback was positive. Some of the PhD candidates mentioned that InnoEnergy provided them with possibilities that they would not have access to in any other way, for example, interesting courses relevant to their topic and held professionally even in difficult pandemic circumstances. These activities taught them the business approach to research, which was very helpful when applying for financial support and has had a positive impact on their current as well as undoubtedly their future professional careers. Most of them mentioned the placement as a unique experience which increased their competences significantly, and demonstrated that individuals can make a change if surrounded by passionate people and given the right tools. Many participants pointed out that their soft skills increased, and they developed interpersonally because this programme offered a great opportunity to network with industry leaders, scientific specialists, and other PhD candidates around the world. With a clear conscience, all the candidates recommended the InnoEnergy PhD School programme to anyone interested in studying at the border between science and business, as well as for those who are not afraid of challenges.

The survey presented shows that PhD candidates participating in the InnoEnergy PhD School programme recognize the key value of gaining expertise in conjunction with business education. Their understanding of the entrepreneurial spirit, and thus the need to commercialize their work, enables them as young innovators to advance their careers in ways that they did not foresee before joining the programme. They also appreciate the opportunities they have received through participation. These have included testing their solutions in real-world conditions and presenting their ideas to experienced business players. With the knowledge of how to turn research activities into concrete innovation, some have found their place in the business world. One PhD candidate founded his own start-up. Others, even if they have not created their own start-ups, are involved in commercial activities and continue their research work. At the same time, they have achieved an understanding of the importance of creating disruptive innovation in the age of energy transition. The soft skills noted by the PhD candidates, their development emphasized by the EIT throughout the programme, have been helpful in realizing the chosen directions of development. Collaboration between research and private companies has offered great opportunity in terms of knowledge transfer and development of cross-sector skills and competence. In many cases, after international experiences by PhD candidates, collaboration continues. This is also a great return for the network, as PhD candidates exchanging knowledge and experience have a significant impact on the financial stability of the European community [90].

Attention should also be given to PhD candidates who have remained at the university. Several of these have become project managers or task managers through participating in projects, or are passing on to students the knowledge they themselves have gained. In addition, all continue to develop the research they began during their PhD studies. It is also worth noting that the PhD candidates who are employed at the universities continue the mission of InnoEnergy. This means that they do not simply focus on teaching or traditional research work, but continue to seek opportunities and pathways for growth through participation in training, including soft skills. They participate in tutoring and mentor training and become leaders of small teams themselves. Participation in the programme has sparked PhD candidates' interest in the possibility of European scholarships, which they apply for with greater confidence that they will succeed on the international stage. They also seek national funds to conduct international staff exchanges and gain new experience, which results in joint research. The PhD InnoEnergy School has also strengthened cooperation between AGH University of Science and Technology faculties in Krakow. The result has been the formation of new working groups and the preparation of joint papers, and in the future perhaps also projects. This makes the approach to science more interdisciplinary and broadens horizons [90].

Finally, taking into account the challenges faced by Poland in the fields of mining and energy, the project also implements the strategic goals of other EIT networks, including Raw Materials, extending the reach of its impact. This primarily relates to two strategic goals of EIT Raw Materials, i.e., the designing of solutions and the closing of material loops. This means the project implements the agenda of building the diversity and strength of the InnoEnergy network across the value chain. Once a partnership has been established, incorporating a wide range of stakeholders, it integrates all the actors who rely on natural resources, including start-ups and local communities. The Consortium, representing ESEE (east and southeast Europe) and RIS (Regional Innovation Scheme) countries, fills a gap related to the KTI (knowledge triangle integration) goals [90].

## 7. Conclusions

The European initiative presented in this article, implemented in cooperation with AGH University of Science and Technology in Krakow, among other institutions, is a practical example of a tool that supports education by enriching it with entrepreneurship, innovation, and business education (EIB) and that can help the future generation mitigate the effects of the energy transition. Through the implementation of courses, workshops and international mobilities, PhD candidates have been equipped with the right competencies to become experts and entrepreneurs. Programme participants find it easier to implement innovative solutions in their workplaces, start their own businesses, and transfer knowledge. This confirms the hypothesis that an appropriate pedagogical approach and personnel training outside the traditional model can contribute to tangible benefits in the context of the economic transformations that European countries will face in the coming decades. Universities are likely to play a key role in tackling climate change and will influence the attitudes of young people as they embark on their careers, so their role should not be limited to imparting knowledge, but should also equip them with the tools to tackle the problems on an immediate basis. Key to the future will be shaping the mindset of an innovator who is able to offer a powerful range of products and services that can be tailored to meet the most complex business needs.

It should be emphasized the research group was relatively small (see the Section 6.1), which may raise doubts as to the representativeness of the study. However, considering the total number of all survey participants and the participation of Polish PhD candidates, the results are satisfactory and may allow certain conclusions to be drawn and some analysis to be conducted.

This article is the first in a series on educational programs responding to the challenges related to the energy sector and its transformation. Further research will be aimed at verifying the legitimacy of investing in educational programs. The criteria of research interest will be business ideas that respond to real socio-economic problems in the energy sector and are of interest to key market players. In addition, it is planned to conduct a comparative analysis of the results of the InnoEnergy programme in other countries, including Portugal. Portugal is an example of a country that has stopped using coal to generate electricity, so it can be a model for countries like Poland, which is still determined by high-carbon economy.

The study does not in any way pretend to present a theoretical model of how higher education should face the climate crisis. Its task is to recognize the possibilities of using European initiatives in the field of education, and the benefits they bring; e.g., stimulating innovation through an appropriate pedagogical approach, or pointing to the need to strengthen the business imperative in doctoral education. The authors believe that supporting such educational initiatives in the future will provide a basis for changing curricula in higher education, and thus contribute to mitigating the effects of the energy transition. Furthermore, in the context of reinforcing the need for a transition to a green economy (i.e., a fundamental transformation towards more sustainable modes of production and consumption), this kind of initiative should be helpful, because it (i) promotes the development and adoption of innovative and sustainable technologies, (ii) offers information on the growing importance of global environmental challenges, and (iii) provides future decision-makers (in this case, PhD candidates) with knowledge about the business sector and so-called sustainability entrepreneurs who can play a part in bringing about the shift to a green economy.

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