Dziura M., Jaki A., Rojek T. Sustainable management and the prospects for innovation and technological development in Poland . *Zovnishnja torgivlja: ekonomika, finansy, pravo*. 2022. № 2. S. 38-51. Serija. Ekonomichni nauky. https://doi.org/10.31617/3.2022(121)04

UDC 005;330.341.1(438)=111

DOI: 10.31617/3.2022(121)04

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SUSTAINABLE MANAGEMENT AND THE PROSPECTS FOR INNOVATION AND TECHNOLOGICAL DEVELOPMENT IN POLAND

Introduction. *Science and technology policy should be the most dynamic policy domains in Poland. The strong political interest in science and technology reflects a wide recognition of the relevance of scientific research and technological development in relation to industrial competitiveness and societal problems. In preparing for the challenges our country faces in the 21st Century, research and development are regarded as vital, whether they concern aging, transportation and mobility issues or sustainable development.*

Analysis of recent researches and publications *has shown that the published up to date papers aren't systematic and can't claim to be a complete analysis in the chosen field.*

The aim *of the article is to present a recent prospective technological study aimed at reconciling technological development with the long-term goal of achieving sustainable development.*

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СТАЛИЙ МЕНЕДЖМЕНТ ТА ПЕРСПЕКТИВИ ІННОВАЦІЙНО-ТЕХНОЛОГІЧНОГО РОЗВИТКУ В ПОЛЬЩІ

Вступ. *Науково-технічна політика має бути найдинамічнішим напрямом політики в Польщі. Сильний політичний інтерес до науки і техніки відображає широке визнання актуальності наукових досліджень і технологічного розвитку стосовно конкурентоспроможності промисловості та суспільних проблем. Готуючись до викликів, з якими стикається наша країна в XXI ст., дослідження та розробки є життєво важливими, незалежно від того, чи стосуються вони старіння, транспорту та мобільності чи сталого розвитку.*

Аналіз останніх досліджень і публікацій *показав, що сучасні статті не є систематичними і не можуть претендувати на повний аналіз в обраній галузі.*

Метою *статті є представлення нещодавнього перспективного технологічного дослідження, яке безпосередньо спрямоване на узгодження технологічного розвитку з довгостроковою метою досягнення сталого розвитку.*

The authors contribute equally.
The authors of the manuscript did not receive direct funding in the preparation of the manuscript.

Methods. *General scientific methods such as the systematic approach, theoretical generalization and comparison, analysis and synthesis have been used in the research.*

Results. *The aim of the long-term strategies for sustainable development of the state is to provide information and analysis necessary to maintain the leading position in the field of technological development and innovation in the foreseeable future. Currently, a significant method of supporting this activity is technology foresight. In Poland technology foresight activities play an important role in targeting science and technology towards present and future societal needs. Technology foresight is regarded as the most upstream element of the identification of prospects for innovation and technological development. It provides inputs for the formulation of technology policies and strategies that guide the development of the technological infrastructure. In addition, technology foresight provides support to innovation, and incentives and assistance to enterprises in the domain of technology management and technology transfer, leading to enhanced competitiveness and growth. The technology foresight initiative also provides suitable methodologies to promote sustainable and innovative development, fostering economic, environmental and social benefits at national and regional levels. Its outcomes are policies and programs that deal with innovation, industrial growth and competitiveness.*

Conclusions. *The main conclusion of the technology foresight study (especially in their ecological aspects) is that technology offers opportunities for sustainable development. But alignment of technological developments with sustainability is necessary. The secondary effects like shifting the burden from environment to space should be counteract. Also, more attention is needed for system innovations. The government is an important player on different levels (regulation, stakeholder) and should start the dialogue with relevant parties. The system approach and societal needs offer a useful conceptual framework to bring parties together. The technology foresight study could form a basis for this dialogue.*

Keywords: sustainable development, foresight research, innovation and technological development.

Методи. *У дослідженні використано системний підхід, теоретичне узагальнення та методи порівняння, аналізу й синтезу.*

Результати. *Метою довгострокових стратегій сталого розвитку держави є надання інформації та аналізу, необхідного для збереження лідируючих позицій у сфері технологічного розвитку та інновацій для огляду майбутньому. У Польщі діяльність технологічного передбачення відіграє важливу роль у орієнтації науки та техніки на сучасні й майбутні потреби суспільства. Технологічний форсайт розглядається як основний елемент визначення перспектив інновацій і технологічного розвитку. Він надає дані для формулювання технологічної політики та стратегій, які керують розвитком технологічної інфраструктури. Крім того, технологічне передбачення забезпечує підтримку інновацій, а також стимули та допомогу підприємствам у сфері управління технологіями та передачі технологій, що веде до підвищення конкурентоспроможності та зростання. Ініціатива технологічного форсайту також забезпечує відповідні методології для сприяння сталому та інноваційному розвитку, сприяючи економічній, екологічній та соціальній вигоді на національному та регіональному рівнях. Його результатами є політика та програми, які стосуються інновацій, промислового зростання та конкурентоспроможності.*

Висновки. *Основний висновок дослідження технологічного форсайту (особливо в їх екологічних аспектах) полягає в тому, що технологія відкриває можливості для сталого розвитку. Але узгодження технологічних розробок зі стійкістю необхідно. Варто протидіяти вторинним ефектам, зокрема перенесення тягаря з навколишнього середовища на простір. Також більше уваги потрібно приділяти системним інноваціям. Уряд є важливим гравцем на різних рівнях і має розпочати діалог з відповідними сторонами. Системний підхід і потреби суспільства пропонують корисну концептуальну основу для об'єднання сторін. Технологічне передбачення може стати основою для цього діалогу.*

Ключові слова: сталий розвиток, форсайт-дослідження, інновації та технологічний розвиток.

JEL Classification: O33, P50

Conflict of interest. The authors certify that they have no financial or non-financial interest in the subject matter or materials discussed in this manuscript; the authors have no association with state bodies, any organizations or commercial entities having a financial interest in or financial conflict with the subject matter or research presented in the manuscript.

Introduction. Science and technology policy should be of the most dynamic policy domains in Poland. The strong political interest in science and technology reflects a wide recognition of the relevance of scientific research and technological development in relation to industrial competetiveness and societal problems. In preparing for the challenges our country faces in the 21st Century, research and development are regarded as vital, whether they concern ageing, transportation and mobility issues or sustainable development [39].

Analysis of recent research and publications. *Technology Foresight in Poland – theoretical background.* Although the importance of science and technology is recognized, it is far from evident that scientific research and technological development are attuned to societal needs [5, 9, 13]. Traditionally, science and technology policy in most industrialized countries focused mainly on the supply side of the innovation process, hardly taking the societal needs into account. However, during the last years, stimulated forcefully by the government reports on technology foresight, the focus of Polish science and technology policy is to strengthen the interaction between the supply of and demand for knowledge [5, 27]. The Polish government has attempted to gain an understanding of the possibility's technology presents to reduce current technological problems. Evidently there are a large number of technological options that could contribute to economic growth and ecological sustainability. However, encouraging technological development is no guarantee of environmental improvement. For example, new technology can lead to new forms of pollution [1, 36]. In other words: technology implies threats as well as opportunities. A policy on technology from the viewpoint of sustainable development should serve to strengthen the opportunities where possible and mitigate any threats [3, 22, 24].

The representatives of the Polish ministries commissioned all organizations to perform a technology foresight study that was explicitly meant to re-align technological development with the long-term goal of achieving sustainable development. The objective of this foresight was to find handles for policy aiming to selectively stimulate technological systems, with the intention of increasing the environmental efficiency of products, processes and activities [5, 27].

The concept of «environmental efficiency» is a key concept in Polish environmental policy. It refers to a societal development in which economic growth, an increase in competitive strengths and employment goes hand in hand with a decrease in the pressure on the environment and the use of non-renewable raw materials. Technological development is regarded as one of the key elements in realizing radical improvements in environmental efficiency [23].

This environment-oriented foresight studies focuses on a period of 10 years for the purpose of including more radical innovations within the scope of study [2, 16, 19, 20, 23, 38]. One important notion is that it is meaningful to obtain an understanding of the environmental effects of new technological systems in advance of the implementation. The opportunity to intervene early on in the development trajectory may have greater effect on the eventual technology. Also, it seems better to identify potential undesired side effects of new technologies, in order to prevent them from occurring.

The article presents a recent prospective technological study aimed at reconciling technological development with the long-term goal of achieving sustainable development.

Material and methods. *A systems approach.* An important new element in this technology foresight study is that we did not focus on separate technologies, but took a systems approach to technological development. Also, we combined a broadly-based inventory of the technological supply with an analysis of dynamism in society's demand [9, 11, 15].

This technological foresight study takes a very wide field into consideration. It is impossible to describe the technological developments in detail. And more importantly, a detailed analysis of technological components would overlook the relation between these components: it is only in combination that they perform their specific function (transportation, communication) [36, 39]. Therefore, the study focuses on the identification and analysis of developments at system level. The notion of «technological system» was introduced for the combination of technical means and the human skills and knowledge to make these means perform a specific, societal function.

The study focuses on technological systems which might possibly be used in Poland over the next 10 years [28]. When assessing the environmental relevance of these systems we made a distinction in terms of the sphere of application for which they are developed. We chose a breakdown into societal functions. This, far more than a classification into branches of industry, provided us with the opportunity to do justice to the social dynamism over the next few decades. These functions will not change quickly; the way in which these functions are fulfilled will.

The term «societal function» is seen in the broad sense. It covers the function fulfilment for the end consumer, as well as for the industrial suppliers. The different functions are based on Michael Porter's often-used categories of economic goods and services [3, 6, 14, 32, 37]. In analogy with Porter's classification, a distinction is made between:

- generic functions that feed all the other functions, such as the supply of energy and (raw) materials.
- intermediate functions that create the essential conditions for all other functions, such as movement (transport and infrastructure), communication and business services.
- end-use functions that fulfil the needs of the consumer, namely: nourishment; housing, care and recreation.

If we focus on innovation processes at the system level, we should distinguish between innovation taken one step at a time and radical innovation. Step-by-step innovation is based on existing systems; radical innovation often focuses on new systems to replace existing ones. We make a distinction here between three ideal kinds of innovation: optimization, redesign and function innovation of technological systems [1, 25, 29].

Optimization focuses on improving existing products, processes or infrastructure. The main concern here is to modify systems which already have a commercial use. In this type of improvement, the system concept is not essentially modified but the efficiency of the system is increased by making slight modifications only.

In the second kind of innovation, redesign, the actual design of existing products, processes or infrastructure is partly changed. Specific features of the system are changed, for instance by choosing to use materials that can be made suitable for reuse in the disposal stage. In redesign, the system concept remains largely unchanged [12].

More far-reaching improvements can be achieved by departing from the system concept and by developing new systems which perform the same function better. This can result in a radical change as to how the function is fulfilled. This kind of innovation is called function-oriented innovation or in short: *function innovation*.

Optimization, redesign and function innovation are indicative of ideal types within a continuum. The degree of freedom in this continuum becomes progressively higher. Whereas for optimization the system concept is in essence still a given factor, for function innovation only the system's function is important. In many cases, function innovation is linked with shifts in the associated socio-economic system. This is because new parties enter the market and established market positions come under pressure. In addition to the required R&D effort, it is because of this socio-economic dimension that function innovations need considerably more time to be realized than optimization of existing systems [29, 31].

This distinction also shows that the difference between these different kinds of innovation is important from the viewpoint of the environment. Improving existing systems can lead to substantial improvements in efficiency, but at some point, the existing concept becomes fully developed and the ceiling will have been reached in terms of environmental efficiency. Only by changing the design, or by introducing a completely new system concept it would become possible to break through this ceiling. In the long run a greater leap in efficiency may be expected from the development of new systems than from optimizing existing ones. How great that leap will be obviously depends on the system and the function. It only gives a general indication in this respect.

In terms of methodology, two ways were followed in the environmental technology foresight systems:

- mapping out the technological developments that could lead to a significant change in environmental impact in the next 10 years (positive, or negative).
- investigating the main societal driving forces which are decisive for the resulting developments [25, 29, 30].

First an overview was compiled of all the currently known technological developments which over the next 10 years could lead to a substantial reduction in today's environmental problems or, conversely, to the advent of new environmental problems. This overview was based on the findings of numerous technology foresight studies describing future trends and expectations in a wide variety of technological fields.

Subsequently, a systematic assessment was made of the potential consequences of adopting new or upgraded technological systems in terms of changes in environmental efficiency (both positive and negative). Extent of changes in the consumption of energy, scarce raw materials and in the release of emissions and waste were analyzed when making this assessment. Also, the use of space was taken into account. All changes were assessed on the basis of unit of output (product or service), implying that any potential developments in production volume or amount of consumption were not taken into account. Nor were behavioral changes, which could either increase or neutralize the environmental pay-off of improvements in environmental efficiency taken into consideration when carrying out this assessment [3, 23, 35, 40].

The second route consisted of a scenario analysis of the main societal driving forces and obstacles that are decisive for the rate and direction of technological development, and thus determine how fast new technological systems penetrate the market. On the one hand, the specific features of the systems themselves, such as the technological barriers that need to be overcome before a system becomes ripe for the market, were taken into consideration. On the other hand, the driving forces and obstacles of a cultural, social and economic nature were also analyzed. Among other things this relates to the pace of economic growth, the interaction between the societal demand and the technological supply, society's acceptance of technological innovation and the price we are prepared to pay for resolving collective problems. These analyses were based on future scenarios drawn up by the Polish Ministry of Economy and the Ministry of the Environment (see *Table 1*). The resulting information on driving forces and obstacles was used to identify handles for policy.

Table 1

Relevant differences between the potential scenarios for Poland

Balanced growth	European Renaissance	Global shift
· dominant market perspective is balanced perspective · open market correction	· dominant market perspective is co-ordination perspective · forming of trade blocs	· dominant market perspective is open market perspective · trade liberalisation
· strong economic growth · strong growth in labour and capital resources productivity and material productivity	· strong economic growth · strong growth in material productivity and extra stimuli for economic infrastructure	· economic growth lags behind · growth in labour and capital resources productivity
· ample willingness to change · substantial R&D · strong technological · dynamism	· less call for innovation · substantial R&D · less strong technological · dynamism	· conservative, more of the same · little R&D · innovation coming to a halt, duplication
· global awareness of the · environment · high level of energy saving	· European awareness of the environment · energy saving	· local awareness of the · environment · very little saving of energy

Source: based on Weterings *et al,* (1997).

Results. *Clusters of technological systems.* The inventory of the technological systems that could lead to a substantial change of the environmental impact over the next 10 years resulted in a technological system. These systems can be categorized in five major clusters:

- energy systems, including systems based on coal gasification, solar energy, wind energy, biomass, hydrogen, nuclear fusion, nuclear fission and innovations in energy distribution (for both local and mobile supplies).
- new (raw) materials, particularly biological raw materials, composites and new colour systems.
- production systems, geared towards optimizing industrial production (including the metal industry, synthetic materials production industry, food processing industry) and agricultural production.
- information and communication systems, relating mainly to the application of information and communication technology in the industrial and service sectors, as well as in the domestic environment.
- transport systems, a cluster of innovative systems for the transportation of people and goods (e.g. super-aircraft, new trains, hybrid transport and underground pipeline transport). In these innovations, the introduction of new or improved modalities is inevitably coupled with changes in the transport infrastructure [5, 28, 41]

Innovation, technological development and environmental efficiency. Innovation and technological development lead predominantly to an improvement in the environmental efficiency of products, processes and activities. Some technological systems can be expected to result in an improvement in environmental efficiency. From these we can expect a positive contribution in the form of:

- substitution: substitution of oil, gas and coal by renewable energy sources, including the utilization of energy systems based on biomass, solar and wind energy.
- energy saving: a reduction in energy consumption per unit of output that can be expected in the majority of industrial production systems.
- a reduction in combustion emissions (CO2, SOx and NOx) and (waste) clinkers inherent in the utilization of oil, gas and coal.
- dematerialization: a reduction in the input of scarce materials (metals, groundwater and tap water) per unit of output that can be expected from industrial production systems on the basis of closing the cycle.
- waste reduction: a reduction of hazardous and non-hazardous waste per unit of output, particularly through using the majority of the production systems investigated.

Considerable saving on energy consumption and the use of materials, as well as a substantial reduction in emissions and waste can be achieved by optimizing the technological systems of today. About 50% of all systems are in this category. Even larger efficiency improvements can be realized either by radically changing the design of contemporary technological systems or by developing new systems to take over the functions of existing systems in a completely new way. Only few identified systems are in this category.

Negative effects of innovation and technological development. The findings of the technology foresight also stress that technological innovation is no guarantee of environmental improvement. This is evident in these technological systems. In addition to the positive effects, one can also be expected a negative impact in adverse effects on the environmental efficiency of products, processes and activities. They relate mainly to:

- a potential increase in the consumption of oil, gas and/or coal and the resulting combustion emissions and (waste) clinkers, for instance through the introduction of supersonic aircraft.
- a potential increase in waste and the utilization of scarce raw materials (especially metals) which could result from implementing the information and communication systems investigated.
- a potential increase of emissions linked with intensive farming (mainly manure and crop protection agents) resulting from the cultivation of agricultural crops to be used as biological raw material for the energy supply and agricultural chemistry, etc.
- the possible generation of new, complex waste streams which are at present difficult to process, for instance from using metallic-matrix-composites and nuclear fission [5, 16, 19, 23, 30].

It is important that the detection of these potential effects in this technology foresight study is followed up by more specific initiatives focusing on identifying preventive solutions in the design stage.

In addition to these adverse consequences, a number of technological systems could shift existing environmental problems onto the use of space. It concerns particularly those systems for the functions of supplying energy and (raw) materials and the function of movement. One concrete example in this respect is the substitution of oil by biomass in energy supply and in the chemical industry. Clearly, the production of agricultural crops demands that physical space is available. Another example is in the field of transportation. Some of the new systems for the environmentally-efficient transport of persons and goods require the construction of infrastructural facilities and, hence, additional physical space. Throughout Europe, but particularly in Poland, physical space of good quality is rapidly becoming a scarce resource. It is urgent that these shifts onto physical space be investigated further [3, 11, 16, 23].

Opportunities and threats. The observation, that is the majority of environmentally-relevant systems, examined here, contribute in a positive sense towards environmental efficiency and may not lead to the expectation, that technological innovation will lead, in due course, to the automatic solving of all environmental problems. Such a conclusion would overlook any possible adverse effects of several technological systems. Moreover, it does not go without saying that the environmentally efficient systems will automatically break though into society [17, 19].

How quickly a new system reaches the market expansion stage, and how extensive that expansion is before the market reaches saturation point, depends on a number of driving forces and obstacles which accelerate or hinder market development. Such driving forces and obstacles are found in the characteristics of:

- the technological system itself (technical features, unwelcome characteristics).
- the market parties that develop and market the system (the supply side).
- the market parties that can use the system (the demand side).
- current governmental policy (infrastructure, regulations) [24].

It is the actual characteristics of a technological system that conceal the scientific and technological obstacles or thresholds, that will need to be overcome before the system can be realized. The size of these obstacles determines how much money will be required for research and development in order to get a new system ready for commercial production. It is obvious that research and development will still continue, leading to updated variations of the system (which also will be marketed eventually) [25].

How quickly a new system reaches the expansion stage, and how extensive that expansion is before the market reaches saturation point, depends on driving forces and obstacles of a cultural, social and economic nature. Among other things this relates to the economic dynamism: the rate of economic growth, the level of prosperity and the interaction between demand pull and technology push. The social and cultural dynamism of society is expressed in society's acceptance of technological innovation and the price people are prepared to pay to resolve societal problems [7, 10].

For each of the five clusters of technological systems mentioned above, an analysis was made of the main societal trends and driving forces stimulating or hampering the process of innovation and diffusion. When assessing the technological environmentally-relevant systems in three contrasting future scenarios we can observe that the development and use of environmentally-relevant technological systems was just as dependent on societal trends (the demand side) as on the continued augmentation of knowledge (the supply side).

Especially the price of energy and the willingness of society to change its habits are apparently of crucial significance. The price of oil, gas and coal is evidently the main obstacle standing in the way of environmentally-efficient technological systems. This applies not only with regard to innovations in the field of energy supplies, but also to innovations in industrial production systems and transport systems.

The government is brought into contact with new technological systems at an early stage via standardization, product regulations and other instruments which set a framework for the workings of market mechanisms. In addition to this regulatory role, the government also fulfils a role in developing both the supply (R&D investments, subsidies) and the demand (price measures, subsidies, the government as a demand party) [31, 33].

As we found in Polish foresight (and the other studies), the price of fossil energy carriers is evidently by far the most significant obstacle to the development and breakthrough of environmentally-efficient technological systems. This applies not only with regard to innovations in the energy supply, but also to innovations in industrial production systems and transport systems. In theory, a price increase on fossil energy carriers (e.g. by introducing an energy tax) would make a positive contribution to environment-oriented technological innovation. In connection with energy systems, industrial production systems and transport systems, we recommend investigating which forms are conceivable and what potential consequences can be expected from government measures which focus on lowering this price barrier.

However, it is not only the energy price that offers a handle for the selective stimulation of environmentally-efficient systems. The most important driving forces for the breakthrough of environmentally-efficient systems are: a high level of economic dynamism (supply) and an articulated societal demand for (environmentally) efficient systems (demand). This environment-oriented technology foresight study shows that the government could additionally promote the breakthrough of more environmentally-efficient systems by:

1. Encouraging the supply dynamism of technology development, for instance by initiating dialogues with the parties involved, stimulation of combined public and private R&D investments and by facilitating knowledge transfer between companies.
2. Encouraging a selective articulation of the demand, for instance by the government taking action as the pro-active party on the market, and by introducing price measures which selectively lower the threshold for introducing new systems.
3. Direct government control, geared towards intervening in the development of technological systems which could lead to adverse environmental effects, for instance by means of environmental regulations which impose more stringent requirements on existing systems, plus a selective policy on the introduction of new systems [12, 33, 37, 39].

Although it might be tempting to focus on selective incentives policy, it is important not to limit those incentives to too great an extent to a few technological options. A substantial contribution towards the aim of achieving sustainable development can especially be expected from a policy that stimulates the supply dynamism and the demand articulation, in combination with monitoring both the direction and pace of environmentally-relevant technological innovation.

An important policy issue is also how to cope with the substantial lack of knowledge regarding the economical, societal and environmental impact of new technologies. It is impossible to identify and assess all relevant developments over a period of 10 years from now, the time horizon of this foresight study [14, 15].

Indeed, the result of this technology foresight draws attention to the considerable lack of knowledge on the impact of new technologies. Especially in the field of information and communication technology, the speed of technological development is so fast that all the potential uses are yet unknown. This is more important, since the continuing penetration of information and communication technology is a significant trend in all future scenarios. These ICT systems may contribute to substantial changes in all social functions. The further growth of products and services based on information and communication technology is expected to expand enormously. Considerable impact is expected on industrial production and business services. The added value of the provision of services vis-à-vis physical production gradually becomes more important. The office environment shrinks to the dimension of the individual: all white-collar workers are provided with portable data and communication equipment. In addition, a large growth in the market for virtual amusement can be expected. Citizens are entertained by new services such as virtual travel in both time and space, experiencing these new opportunities as a substitute for the need for physical movement. An extra stimulus to develop information and communication systems may arise from investments in a European traffic and transport infrastructure.

So far, research into information and communication technology applications has been mainly supply driven. Little can be said as to how the information and communication technology revolution will influence other functions over the next few decades, or the associated substitution effects. The direct impact of the revolutionary growth of information and communication technologies on the environment is also undisputed. On the one hand we may expect that the penetration of information and communication technology will lead to an increase in the use of energy and scarce raw materials in connection with the production and use of information and communication technology hardware. On the other hand, miniaturization will raise the energy and material efficiency of the equipment. While some people expect that information and communication systems will reverse the current growth in the use of paper and transport movements, others point out that the opposite is quite conceivable.

The lack of insight into the potential environmental effects of information and communication systems has become acute since it is widely expected that these systems will penetrate strongly into society over the next few decades. A more in-depth predictable study of the potential impact of information and communication systems on the environment in different applications is needed. Such a study should provide a greater understanding of the conditions that underlie these effects, as well as insight into any preventive measures that can be taken.

The findings of the environmental technology foresight have given new impulses to policy development in Poland. For instance, in the governmental studies on environment and economy, several technological systems were described as «inspiring imaginary projects». In the recent Polish strategies, the systems approach has found a profound place in the policy on environmental technology. The findings also gave rise to enhance the budget for an existing research programme on economy, ecology and technology. New policy instruments, such as task forces and a first mover facility were announced. Also, a decision has been taken for a study to explore the possibilities of ICT for a sustainable economy. The basic notion of these policy instruments is that changes in technological systems go hand in hand with changes in socio-economic systems. The instruments are used to create incentives in the socio-economic system that support the actual implementation of new technological systems [5, 28].

A direct follow-up of the studies (foresight and strategies) were more detailed studies, with the objective to define more specific policy action plans for technological systems. Dialogue is a key characteristic in the follow-up. The results form a basis on which a dialogue between key actors from both research and industry can be started. The objective is to establish a shared vision of how to direct the technological development towards a sustainable economy. Dialogue is to be started with policy makers from all relevant Polish ministries and with key actors from relevant Polish research organizations and stakeholders from industry [28].

This last element, the active participation of relevant stakeholders, is directly related to the experiences with technology foresight and technology policy in Poland. Polish policy makers pay more and more attention to the innovation system itself: the institutions, the level and dynamic nature of their cooperation, their positioning in (inter)national networks. New networks are identified, combining relevant research organizations, industries and stakeholders, in order to identify and develop new options in collaboration. The most recent example is the start and continuation of the National Development Strategy (NSR) [28]. This initiative has the objective to bring together different stakeholders around sustainable technological development. Here also technological systems are the focus. The NSR, together with the relevant actors, identifies new sustainable technological systems. The NSR also stimulates and facilitates research around the driving forces and barriers relevant to technological and institutional breakthroughs [28].

Conclusion. The main conclusion of the technology foresight study (especially in their ecological aspects) is that technology offers opportunities for sustainable development. But alignment of technological developments with sustainability is necessary. Secondary effects like shifting the burden from environment to space should be countered. Also, more attention is needed for system innovations. The government is an important player on different levels (regulation, stakeholder) and should start the dialogue with relevant parties. The system approach and societal needs offer a useful conceptual framework to bring parties together. The technology foresight study could form a basis for this dialogue.

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The article has been received by the editors on 14.02.2022.
The article has been accepted for publication on 01.03.2022.
Online publication 22.04.2022.