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Sustainability Model of ZalaZONE Innovation Ecosystem

Andras Hary[a,*], Csilla Toth[b], Leticia Pekk[c], Virag Meszaros[d]

[a]ZalaZONE Industrial Park Ltd., Zalaegerszeg, Hungary
[b]ZalaZONE Science Park Ltd., Zalaegerszeg, Hungary
[c]ZalaZONE Research and Technology Center, Zalaegerszeg, Hungary
[d]HUMDA Ltd., Budapest, Hungary
andras.hary@apnb.hu

Nowadays, sustainability plays an increasingly important role in the development and operation of innovation ecosystems. The subject of the investigation is the ZalaZONE Park - innovation ecosystem (not an ecosystem from a biological point of view, but rather an economic aspect), where the proximity of the ZalaZONE test track justifies making the operating system more sustainable. The main goal of the study is to develop a scientifically based, sustainable system model for the environmental, economic, and social balance of innovation ecosystem processes. This requires a combination of technological openness and sensitivity, the ability to respond quickly, the appropriate basic energy concept, and the objective-oriented system-level combination of these. The authors take the sustainability issues of innovation ecosystems one by one and then examine the questions of the development of the model through the importance and actuality of megatrends, keeping in mind the area of "zero emissions". As a result of the research, a sustainable energy basic model concept was created, which takes into account the complex factors on the basis of which the ZalaZONE park operates. This is important because the model examines the Park from an environmental point of view in a novel approach, highlighting the importance of moving towards zero emissions, as well as its impact on economic and social aspects.

1. Introduction

Given the growing trends in automated driving and driving assistant technologies, both manufacturers and developers are facing the challenge of limited vehicle testing and validation capabilities. European testing facilities are partly able to meet complex needs for self-driving and automated mobility solutions. That is why it was necessary to create the ZalaZONE vehicle industry test track, which is an object spread over nearly 270 hectares, where vehicle industry-related R&D institutions, OEMs, and other universities, research institutes, and industry actors carry out activities, whether it is testing or validation. The ZalaZONE Park - which is meant to accommodate the competencies built around the test track - is an identity located in the immediate vicinity of the test track and spread over an additional 230 ha. Its main purpose is to operate an innovation ecosystem. The park is home to R&D institutions in on-road and off-road test environments, and in order to diversify capacities, EMC and climate chambers are also available, as well as additional free areas for those intending to settle in. The park operates according to the Triple Helix approach with the presence of industry, state, universities/research institutes. This should be highlighted because the park management tries to contribute to the development of cooperation by supporting joint project initiatives between different types of actors, contributing to the promotion of sustainability. Other important connections:
the new technologies to be developed and tested here must fit the new technological trends, which are influenced by sustainability aspects anyway. In addition, issues of sustainability are approached at the level of the entire innovation ecosystem. As part of these strategic efforts, the so-called "energy ecosystem concept" was developed. This concept is based on specific projects under the umbrella of a system-oriented program. This scientific work deals with a scientific system model approach and the basic formula of the consistent system. This gives the work its scientific novelty.
Since continuous development and new technologies have an increasing influence on the ongoing processes, a fundamental question is how they support and promote the sustainability of innovation ecosystems. In this

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regard, the key question is what is the system model that works towards zero emissions and energy minimization. Time is an important factor when creating the model, as sustainability goals can change frequently, which requires sufficient flexibility from the system.
The main research question of the study: Can a suitable system model be developed that provides a framework for the entire ecosystem program? Can a suitable system model be developed to help the implementation of the program? The hypothesis examines this, and the authors try to develop and project the model onto the ZalaZONE Park system. The aim of the research is to determine and investigate the correct system approach, architecture, and elements of the system model. Then, the authors define further research directions that will further develop the model. The basis of the development of the scientific methodology is the examination of the environmental aspect of sustainability. On the input side of the model are the environmental energy sources and energy carriers, and on the output side are the users who benefit from the benefits offered by the model. The model is actively influenced by the storage of energy sources and weather phenomena. However, time is also an important factor since, in the rapidly changing technological environment, technological innovation must be able to be adapted while keeping costs unchanged or even reducing them.
The literature review reflects the relationship between innovation ecosystems and aspects of sustainability and shows that a close relationship can be observed between the two concepts. Several authors have already investigated the question raised, but in this study, the authors also review the importance of technology in the field of innovation.

2. Literature overview

2.1 Innovation ecosystems

Innovation is seen as a key source of significant wealth creation within the economy. As high-tech industries have higher growth potential, the best way to stimulate job creation and economic growth is to facilitate a more efficient transfer of innovation from the research economy to the commercial sector. The classical definition of innovation, which is considered as the outcome of a process, is based on two basic characteristics: a degree of novelty of change and a degree of utility of the change or the success of the application of novelty. In recent years, there has been increased interest in the concept of 'ecosystems' as a way of describing the competitive environment. The term has entered the vocabulary not only of technology companies but also of certain sectors and the development of a region. The concept of innovation ecosystems has evolved with innovation systems. According to Still et al. (2014), innovation ecosystems are usually viewed as entities composed of organisations and the relationships between them are defined as human networks that generate extraordinary creativity and output on a sustainable basis and are composed of interdependent firms that form symbiotic relationships to create and deliver products and services. The term 'ecosystem' itself has a variety of meanings, and two general views can be distinguished in the literature: ecosystem as a relationship and ecosystem as a structure. Ecosystem as a relationship can be defined in terms of the typical networked interactions and platform relationships. Ecosystem as structure refers to ecosystems as configurations of activities characterised by value propositions. The two perspectives of ecosystem as relationship and ecosystem as structure are conceptually different from each other but mutually consistent (Adner, 2017). According to Adner (2017), the components of an ecosystem are alignment structure, multilateralism, a set of partners, and a central value proposition. Innovation ecosystems can also be distinguished from the technological domains. Gawer (2014) has already written about different technology platforms, such as industrial ecosystems, which are usually organised around a technology architecture linked to an industry but are not necessarily localised. However, innovation ecosystems linked to a specific geographical location are a special type of ecosystem that should be considered separately. Alam et al. (2022), on the other hand, approach the definition of innovation ecosystems from an open innovation perspective. The authors conceptualise an innovation ecosystem as a loosely interconnected network of interdependent firms whose functional purpose is the joint creation of capabilities around technologies, knowledge, or skills needed to innovate products and services. In other words, an open innovation ecosystem can be defined as an ecosystem in which the primary goal of partner firms is open innovation.
According to Boyer et al. (2021), three main characteristics of innovation ecosystems contribute to sustainability: diversity and heterogeneity of agents, complexity of relationships, and new forms of organisation. The main idea of the authors is that ecosystem sustainability is the result of firms' adaptability. In fact, the innovation ecosystem provides mechanisms that allow actors to adapt their organisational behaviour and strategy to market and technological challenges and changes. The sustainability of the innovation ecosystem results from both the continuous growth of value creation and the firm's ability to adapt to market and technological changes (Boyer 2020).
Hamon et al. (2022) point out that the development of the literature on science parks has gone through three phases. Initially (2000-2010), it focused on geographical expansion, particularly in East Asia. From 2011, it diversified into new topics like open innovation and sustainability, reflecting evolving innovation concepts.

Recently, sustainability research, notably since 2015, has gained prominence in science park studies. Laguna and Durán-Romero (2017) conducted a qualitative analysis in Spain, which concluded that STPs "have a high sustainable knowledge potential and proactive attitude, are engaged on environmental issues, although there is still room for improvement in sustainability. Yamamoto and Dos Reis Coutinho (2019) also found that STPs in Brazilian territories have focused on balancing economic and environmental issues. Sustainable development was defined in the 1987 Brundtland report, which called it "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". Sustainable development enhances life quality and the natural environment without destroying the livelihoods of future generations. This requires three dimensions that must be balanced: economic sustainability, environmental sustainability and social sustainability. In a sustainable system, ecosystem service projects can correct market failures when the institutional framework supports sustainability. Without such support, local adjustments have minimal impact. Sustainable systems maintain high ecosystem value with reduced discounting of future values, driving the transition to a sustainable economy. (Szlávik, 2019)

2.2 Role of technology in sustainability efforts

The megatrends address or rely on four factors that are sources of ongoing interactions: economic, socio-political, ecological and technological. Identifying megatrends is not a simple task. From the perspective of technology, an attempt has been made by Bash et al. (2023) to identify the interrelationships between ecological, economic, technological and sociopolitical fields. These four factors are linked to and influence each other across multiple megatrends and trends, which are individually complex.

Mega-trends will continue to rapidly transform our world for many years to come, and their impact is felt globally. Their interaction with each other has accelerated their spread.

A significant challenge is climate change, with rising global temperatures and more frequent extreme weather events. Addressing this requires shifting to sustainability, with countries regulating renewable energy and companies adapting processes. Targeted technological solutions are being continuously developed to combat the climate crisis. (PwC, 2022). A very comprehensive overview by Bash et al. (2023) processes the major challenges, technology applications, emerging technologies and global megatrends. A methodology was also given by the authors to better identify the different categories.

One such megatrend is sustainability, which responds to the challenges of climate change. As a megatrend, it follows the S-curve and involves several technologies while maintaining a constant movement. The technologies follow the so-called Gartner hype curve. The importance of technologies, even in the field of sustainability, is that they help to characterise the evolution of the megatrend, as the state of development of technologies can be characterised (Bash et al., 2023). Some technologies, such as solar, wind, hydro and biomass, are gaining attention as they help to reduce the environmental problems caused by the intensive use of fossil resources (EL-Shimy and Sayed, 2018). Mitigating climate change will require a major transformation of the global energy system. However, energy demand and supply systems are themselves sensitive to the effects of climate change, as wind speeds can vary to a greater or lesser extent in response to climate change, and this can have a significant impact on energy supply (Cronin et al., 2018). Therefore, increasing the reliability of renewable energy sources and optimising energy efficiency are of paramount importance. To ensure reliability, energy storage technologies and adequate infrastructure are essential (EL-Shimy and Sayed, 2018). Technological advances such as IoT (Internet of Things) or AI (Artificial Intelligence) help to track better, manage and integrate renewable energy resources into energy supply systems. Science parks, where technology-based companies and research institutes are located, provide companies with the opportunity to focus on their core business and reap the benefits of innovation. One survey found that sustainability is important when companies choose science parks, while cost remains a key factor (Ng et al., 2022). One of the trends in promoting sustainability is the circular economic model, which was examined by Montanari et al. (2023) for plastic waste management. The model can even act as a principle in the development processes of science parks (such as planning, material selection, production, etc.). To assess the efficiency of sustainability, it can be important to have an evaluation procedure for ranking energy sources based on sustainability.

3. Research questions and approach

3.1 Reasons for the research

As was introduced in the recent chapters, energy and sustainability have become more and more competitive factors not only for companies but also for geographically focused innovation ecosystems like the ZalaZONE park. Keeping this in mind and considering its strategic aspects, the need to strive for a green park concept is a more and more significant trend all over the world. From this perspective, such innovation ecosystems, as a system framework, should serve as a cooperative platform for the related initiatives to support projects for sustainability. The features of the park environments (like many small actors, SMEs but also some larger factories, research units, etc.) used to offer diverse environments for green and new technologies and for their users. All these pointed out the opportunity for the establishment of an innovative sustainability approach as a system model of an “energetics test ecosystem”.

3.2 Research questions and objectives

One of the first founding questions of realising the sustainability concept and the related program described above is, what is the right system model to be used? The role of the system model is twofold. First of all, it gives a framework for the whole energetics ecosystem program (managerial aspects, scientific establishment, and society integration). Secondly, it helps with the execution and configuration of the program (simulation opportunities, scaling, project integration, and deployment approach).
The relevant research objectives to be addressed by this paper are: Ad 1: what is the proper system approach? Ad 2: what is the system model architecture? Ad 3: what are the system model elements? Ad 4: what are the next research steps to determine system element relations and further work out the model?

3.3 Method

Based on the references of the related literature findings, the relevant aspects of the ZalaZONE innovation ecosystem have been summarised. This way, the discussion of the research question originated from an empirical case of ZalaZONE, but the derived model framework is approached as a general system model. The proposed model is based on the classic system theory but adapted to the specifics of an innovation ecosystem energetics perspective. This way, following the methodology of conclusive research reasoning, the top-down description was carried out: system approach, system architecture, and model elements. As this paper gives the actual status of a longer-term running research program, the following research steps and key topics of further analysis also had been defined at the end.

4. Actual status of research and discussion

4.1 Originating case: the ZalaZONE energetics program

The ZalaZONE innovation ecosystem energetics program concept's key ambitions are:
- Contribution to a more competitive innovation ecosystem (financial advantage – less energy cost)
- Contribution to the environment (green approach – less emission and environmental responsibility)
- Contribution to society (an energetics technology and solutions testing knowledge base)

The mission is to establish a program through the implementation of a role model project of "energy neutral" energy solutions and circular economy and its dissemination to reach adaptable outcomes. This way, there are three basic elements of the approach: developing a complex, environmentally conscious, low-emission smart energy distribution system using smart technologies.; Increase the share of locally produced energy by compensating for the impacts of renewable energy sources on the electricity grid.; combined use of the latest technologies. The main features of the program serve as a conceptual basis for the scientific system model:
- Park energy supply should rely as little as possible on external, emission-free sources,
- The park as an energy innovation living lab should present showcases for future energy solutions,
- The energy system cooperates in an integrated way with its surroundings.

4.2 System approach

When approaching a system in a scientific way, it is usual to make the first positioning in view of the traditional classic system approach of Berttalanffy. This helps to set principles for the related research to determine the basics for the own theories. Taking the original definition, the system is a set of interconnected elements, which must be treated as a unified whole because its behaviour depends not only on the individual characteristics of the elements but also on the nature of the relationships between them. In conclusion, any system has emergent properties which only occur only when the elements really interact with each other.
As a consequence of a sustainability and energetics ecosystem approach:
- Define the system scope (or its logic with concentric system boundaries),
- Define the system-level properties (more than those on the system elements level),
- Define key elements and their relations.

As part of the classic system theory, the system-level classification of Boulding (1956) used to be questioned by several researchers, but its key message is that the nature of the system should be clearly agreed upon (e.g., static structure, dynamic system, control system, open system, genetic-societal system, self-aware animals, self-aware humans, social systems).
As a consequence of a sustainability and energetics ecosystem approach:
- An innovation ecosystem is surely a local social-economic system but still includes features related to complex systems),

- A so-called “sub-layer” of the complete innovation ecosystem, like energetics and sustainability ecosystem, should also be approached like a socioeconomic system,
- Still, in order to start modelling energetics and sustainability, the ecosystem could be built up bottom-up, started as static, then dynamic, through control, then up to the social-economic system model.

4.3 System architecture

Without going into the details in the current paper due to its limitations, it is important to highlight the constraints of the regular system theory approach when modelling systems which are not purely “technical”-oriented systems. Analysis of large and comprehensive systems with sophisticated relations (like a social-economic type system) requires a different research perspective. Complexity theory (Sherman and Shultz, 2000) can be a way that might help better understanding of such systems and might give cornerstones to define the system architecture. Most probably, this approach will be used to develop further the system model of the ZalaZONE energetics test ecosystem, but the purpose of the current paper is to show the actual status of the research, which is stuck to the usual system theory.
As a consequence of a sustainability and energetics ecosystem architecture:

- Define the system scope and boundary (technical vs. social-economic system scope),
- Define input and output areas, define corresponding functions (external influences, buffer functions),
- Clarify target functions (economic sustainability as minimum point/optimum),
- Set static vs. dynamic nature (considering time as a variable factor to simulate dynamic behaviour),
- Determine the main rules of the internal algorithm (connection of input and output elements).

4.4 System model elements

The base model framework with the key model elements, as a preliminary result of the research, is shown in Figure 1.

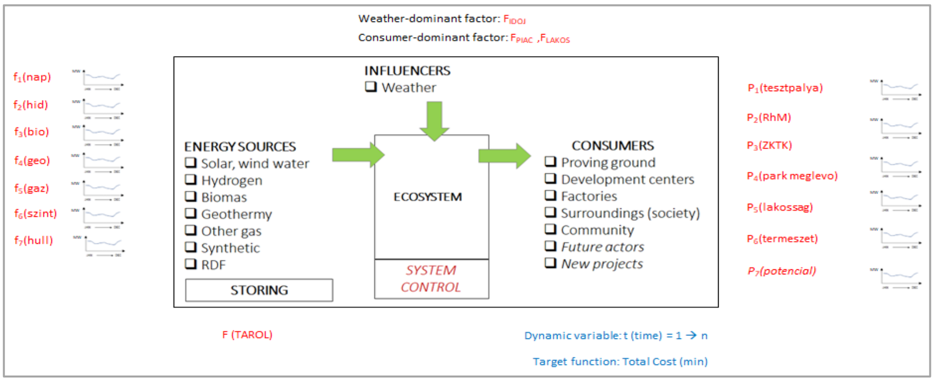

Figure 1: Actual system framework of the ZalaZONE sustainability & energetics test ecosystem

The current system model is based on the classic input-output approach. By definition, the inputs are related to various energy sources (complex system nature) and the output side is related to the consumer side (representing also the social sustainability aspect). The “black box” of the ecosystem is interfered with by influencing factors and can be positively impacted by an energy-storing element. The economic target function adds the economic sustainability aspect while involving the time factor to ensure the dynamic of the model.
This model content is the basic technical level, and it will serve as the base for technical-related projects and research (Annaswamy, 2013). Having this model framework as a rough concept, further aspects of the ecosystem should be added in the next research steps. Scoping will enable the model to ensure scaling opportunities from the project level up to the whole ecosystem level. As a consequence of a sustainability and energetics ecosystem model element, variables on the input and output side are defined, related functions (influencing variables, buffer unit, target function, dynamic factor).

5. Conclusions

The paper introduced the relevant aspects of innovation ecosystems, technology developments, system approaches and theories. The ZalaZONE innovation ecosystem and its special layer “sustainability & energetics test ecosystem” served as an empiric case for originating the research questions. Based on the established program and initiative, considering its goals and ambitions, the need for a scientifically established system model was given. The findings of related research also proved the complex perspective needed for sustainability. Based on the analysis of the literature and concluding the outcomes of the system description methodology, a system model framework was outlined for sustainability and energetics ecosystems. The current paper gave an actual status of the concerned running research results and presented the actual findings. The early system approach used follows the concept of the classic system theory, but having understood the need for a most comprehensive system approach during further research. The actual system model builds on the usual input-transformation-output model, indicating certain variable factors. The presented actual model can serve as the basis for further research work from a technical aspects point of view (technical detailing and parameters/functions definition), from the system as a whole point of view (scoping, adding further elements and aspects of the ecosystem). Additionally, after having the system model elements in place, the relevant functions and system model equations are ready to determine. Both the system architecture and the system elements can be further detailed and worked out in the next steps of the related research program run by the authors.

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