

# Sustainability of Nuclear Power Plants — A Socio-Technical View

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**Abstract:** Nuclear power plants are often characterized and criticized as non-sustainable entities. To explore this characterization and criticism, we move beyond common environmentalist perspectives and study nuclear power plants within the framework of broader sociotechnical system theory. This approach incorporates two distinct interpretations of sustainability: political and economic. We focus on organizational culture, participation, and communication strategies to examine how nuclear power plants perceive sustainability at both the political and business levels. To support our conclusions, we conduct a case study analyzing the initiatives undertaken by the Krško Nuclear Power Plant to implement new sustainability standards.

**Key words:** nuclear power plant, sustainability, socio-technical theories, environmental discourses, organizational culture, participation, communication

## 1. Introduction

Sustainability necessitates a new vision for the environmental, social, and economic development of European societies. It is crucial not only for environmental discourse but also for developmental (business) planning. In both contexts, sustainability entails the emergence of new values, developmental goals, and, most importantly, new types of relationships among key actors, including governments, companies, citizens, local communities, the research centers, and non-governmental organizations [1].

To reach sustainability, nuclear power plants must implement substantial structural changes across three key levels: techno-economic, socio-technical, and political. In the theoretical framework of our discussion, we will explore the characteristics of each of these dimensions.

It is essential to emphasize that achieving sustainability requires radical transformations in industrial procedures and significant shifts in the organizational culture of nuclear power plants, and a renewed attitude toward the surrounding social environment. Therefore, to progress toward sustainability, nuclear power plants must continually pursue innovative technological solutions that enhance safety and reduce nuclear waste on one hand while simultaneously transforming their relationship with the broader society in which they operate [2].

The primary objective of this article is to address three key research questions: 1) “Which dimensions of sustainability are addressed by the principles of the World Association of Nuclear Operators?” 2) “What business approaches and environmental discourses does the nuclear industry employ to tackle the issue of sustainability?” 3) “What changes are necessary at the organizational culture level, in participation patterns, and in communication strategies for a nuclear power plant to be considered a significant actor in promoting sustainability?” To answer these research questions,

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we will focus on the Krško Nuclear Power Plant (KNPP), examining its organizational culture, commitment to sustainability, and the associated strengths and weaknesses.

## 2. Methodology

To explore the sustainability of nuclear power plants, as typical socio-technical systems, we have decided to use qualitative inquiry and qualitative research design. There are five key reasons for that. The first and most important reason is that the relation between managerial practices and sustainability are rarely discussed in Slovenian research community [3, 4]. There are authors who have analyzed social responsibility of KNPP [2], authors who have analyzed nuclear safety management at KNPP [5] and authors who have analyzed nuclear waste management at KNPP [6]. But none of them analyzed KNPP as a social actor and try to envision its strategy towards other actors in sustainably arenas. None of them answered a simple, yet very important question: “What can KNPP do to become a proactive part of sustainable arena and of sustainable community as such?”

The topic we are addressing here is in a way terra incognita for Slovenian science. If we want to make a solid foundation for future in-depth quantitative research, we have to make firm qualitative frame first. Second reason that brought us to quantitative approach is that we are not interested in analysis of broad, analytical information, that can be used for generalizations. We are setting a new approach to the transitional sustainability studies of nuclear power plants, not a broad, generalized view<sup>1</sup>. The third reason

for our decision to stick to quantitative approach is that the area we are focusing on, is changing fast. It is important to take a valid snapshot of current situation to understand the events that are going to take place in future [4]. The fourth reason for qualitative approach is that numerical data cannot cope with the social complexity of the analyzed processes and the relations that are creating new social, economic, and ethical contexts. And the fifth reason is that the discussion has to be able to connect facts and findings from political science, management science and communication science to an understanding of broader techno-economic context KNPP is a part of. And qualitative approach is much more suitable for this kind of scientific research connection than quantitative approach [7].

## 3. Nuclear Power Plants as An Important Social Actor

Nuclear power plants are — as any other type of large energy producers — complex socio-technical systems. And as any other type of complex socio-technical system, their processes have to be analyzed from three key organizational perspectives: techno-economic perspective, socio-technical perspective, and political perspective [8]. That is a must, if we want to have a comprehensive insight in the sustainability transformation of KNPP.

Techno-economic dimension of socio-technical systems includes processes such as energy production, energy transfer, energy infrastructure, dynamics in energy market, energy use, and energy storage. To analyze KNPPs overhaul, or new technical standards that were introduced, or new technological adaptations, or the trends in energy price, we need to employ experts in energy technologies, engineering, and economics. Their knowledge will help track changes

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<sup>1</sup> The facts we are going to come to are the result of specific economic, social, environmental, and historical events Slovenia and KNPP have experienced in past four decades. It can't be simply imitated or mirrored. But the analytical steps we are taking can be used regardless of geographical, political, or developmental properties of a specific nuclear power plant. The connection between comprehensive understanding of nuclear policy and comprehensive understanding of sustainable

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business approaches is important for any country, for any nuclear power plant and for any energy arena.

and find innovative approaches in conducting, maintaining, and financing processes [4].

Socio-technical dimension of socio-technical systems includes an understanding of networks that are crucial for socio-technical system to function as a continuous and constructive part of broader regime(s). It includes an analysis of energy institutions, practices, and connections [10]. To get a full picture of KNPPs socio-technical dimension one has to analyze relations

between employees and management, relations between different structural parts of KNPP, relations between KNPP, GEN Energy and HEP, and relations between KNPP, energy consumers and Municipality of Krško. It is important to connect the knowledge of experts from technical science, managerial science, and political science to cover this area. And the same knowledge is needed to introduce innovation in that dimension.

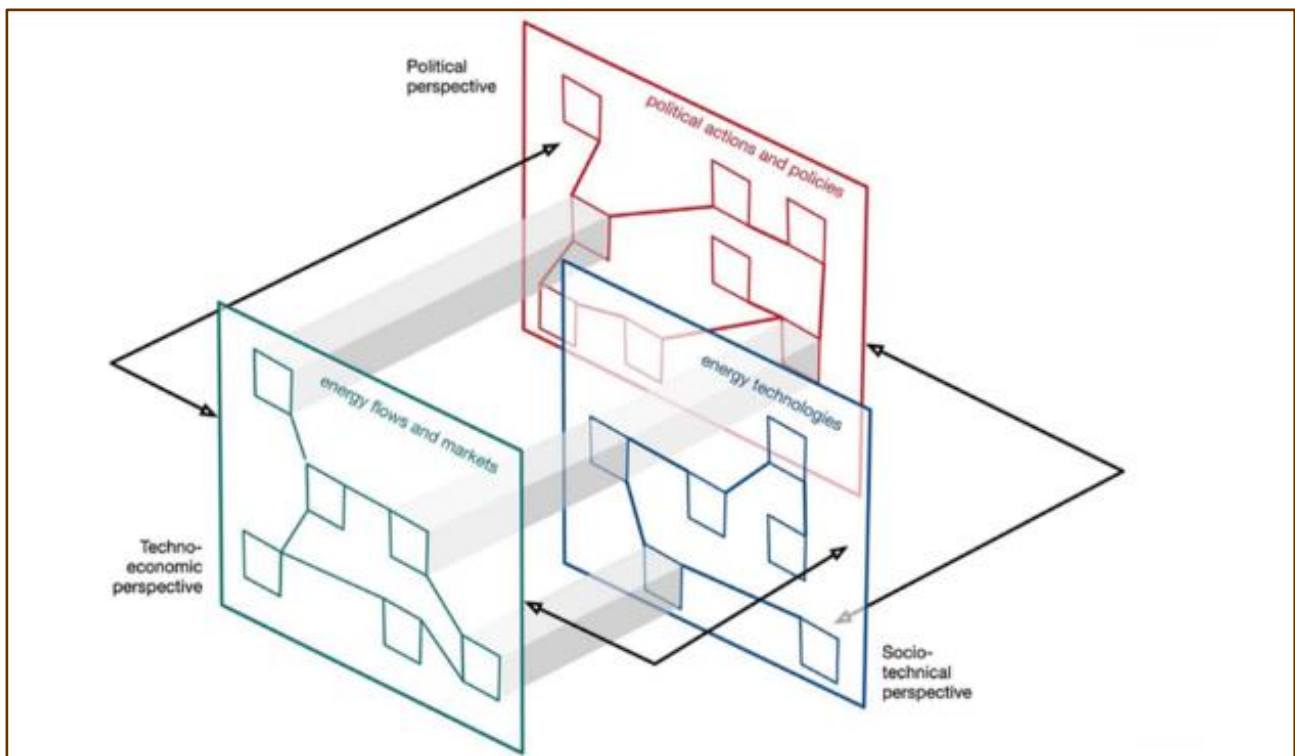


Fig. 1 Cherp (2018, str. 183).

Political dimension of socio-technical systems focuses on a relation between energy producer and its social/political environment. In sustainable society companies are considered to be important social actors and as important social actors they need to communicate and cooperate with other actors on multiple levels of policy making. Innovation at this level is very important, especially because this dimension is constantly overlooked and companies as KNPP are quite conservative in their relation to their environment. To allow the transition from one type of

business approach to sustainability to another KNPP needs to build its insights in new types of governance, new logic of public administration and new types of public pressure. And to do that it needs insightful know-how of political science when making a strategy, and know-how of communication science when preparing for its promotion [1, 9].

### 3.1 Zoom in: Political Dimension of KNPP and Tree Key Areas of Our Focus

We are going to address three key areas of KNPP

political dimension here. Those areas are: organizational culture, participation processes and the advance in communication processes [11].

### 3.1.1 New Organizational Culture and the Urgent Need For Reflexivity

Organizational culture defines a certain collective mindset, common behaviors, and practices which priorities environmental responsibility [12]. It changes with a change of society, business practice and an understanding of sustainability. Comparing Triple Bottom Line approach to sustainability and Truly Sustainable Business approach to sustainability, we can argue that there is not a big difference in values of Triple Bottom Line approach and values of Truly Sustainable Business approach. Both approaches take respect, legitimacy, responsibility, justice, and accountability as a standing stone of their organizational culture.

The main difference between organizational culture of Triple Bottom Line approach and organizational culture of Truly Sustainable Business approach is in companies' ability to be opened and reflexive in relation to its social environment. Triple Bottom Line approach was first model of business sustainability which understood companies as a proactive parts of society transitions. But it has focused on economy and Business practices. Truly Sustainable Business approach took it a step further. It expended their focus from business to social/political arenas.

Truly Sustainable Business approach takes reflexivity as a fundamental, unavoidable feature of sustainability management. It demands that companies are able to critically evaluate relations within different sustainability arenas, to break down specific complex situations, and to understand interests of other actors [13]. It takes reflexivity as a starting point to realize joint-reflective practices, to pass the notion of respect, legitimacy, responsibility, justice, and accountability to a broader environment and to make a company an

important factor in a process of social governance. This ability is just as important in sustainable problem structuring, as in development of a transition agenda, establishment and implementation of transition experiments, mobilization of transition networks and preparation of adjustments. Companies that manage to have intensive reflexive communicative policies understand interests of other actors and can find common ground in a discussion with them and solutions that are consensual, not based on their political or financial strength. If the company still rests on principles of Triple Bottom Line approach, it focuses just on state policies and is interested only in its key technical and economic endeavors — while its connection and reflexivity are quite underdeveloped. That means it is not adopted to the most important trends in society and is not ready to co-create it, so it is falling behind in its own development and in its relationship with the surrounding society. To get a good estimation of company's ability to be truly reflexive, one should focus on its values, interactions with employees on one hand and with actors on the other and communication patterns [3].

### 3.1.2 New relations and the need for new types of participation

Participation builds a direct relation between socio-technical systems such as nuclear power plants and their environment. It promotes social learning and deliberation. Companies' ability to participate in governance processes, and to be a constructive part of social networks are very important properties as it is a key prerequisite for its reflexivity. Most important types of participation in governance are: public consultation, deliberation assemblies, referendum, and different types of formal and informal alliances [14].

It is important to distinguish between formal and non-formal sustainability arenas, as there are many differences between them. The aim of the first type of arena is governance and the aim of second type of

arenas is to form common interest, with many different actors.

The need for companies such as KNPP to increase their efforts and to get involved in both types of arenas is very important. The participation will allow them to understand not only actors and their personal *Raison d'être*, but networks that are forming between actors and the power these networks are exerting on government and decision makers. It is needed to turn from confrontational to consensus dialogue, and from an argument of hard power to an argument of soft power [15].

### 3.1.3 New Types of Corporative Communication

A successful communication is fundamental for any economic or social interaction between company on one hand and its social environment on the other. Without a considerable energy and attention put into the communication upgrade companies transition from Triple Bottom Line approach to Truly Sustainable Business approach is nonfunctional and meaningless [16].

Unlike their counterparts in oil and gas industry, who are traditionally hard investors in communication processes, public discussions, and comprehensive cooperation with wide array of actors from research and non-governmental sector, nuclear power plants are traditionally quite introverted.

Their aim is to promote security of their systems, amount of energy they produce and low carbon-dioxide footprint. So, they use primarily technical language and are dominantly focused on energy arena. They use classical, one sided and informational corporative communication [17].

Sustainability communication needs to be two-sided and complex enough to create a knowledge generation, social learning, collaboration in developing solutions for sustainability problems. It has to ensure the generation of common frame, shared concepts, and quality of discourse. One-dimensional, sender-oriented

communication does not suffice [18]. So, to get from Triple Bottom Line approach to Truly Sustainable Business approach the company has to build up its communication team, secure its balance between social, communicational, and technical expertise and allow new types of communication tools to be implemented [3].

## 4. Sustainability as a Prevalent Political and Business Approach to Development

Sustainability is a guiding principle of green transformation. It can be said that it is a kind of developmental beacon or an instructive principle that demands a significant reduction of human footprint in our natural habitats and consequently a change of our social, political, and economic development. It has a decisive influence on the relations between actors, institutions, practices, connections, networks, and technologies. It connects energy systems to economy, political processes, social structures, and the research centers in a new, quite fundamentally novel way [19].

To understand sustainability as a concept, it is important to stress out that one can observe it on business and on political level. Both levels are equally important for our discussion. And both are tightly connected to evolution of environmental, social, and political systems, to new technical solutions and new environmental challenges societies face.

### 4.1 Changing Nature of Sustainability in Business

The first attempt to include sustainability as a principle to business practice is called Refined Stakeholder Value approach. The theory supporting this approach advocate one-dimensional, one-sided and sender orientated relations between company and its environment<sup>2</sup>. Companies tried to prevent possible accusations of environmental negligence and pollution. So, they put sustainability as a value in their

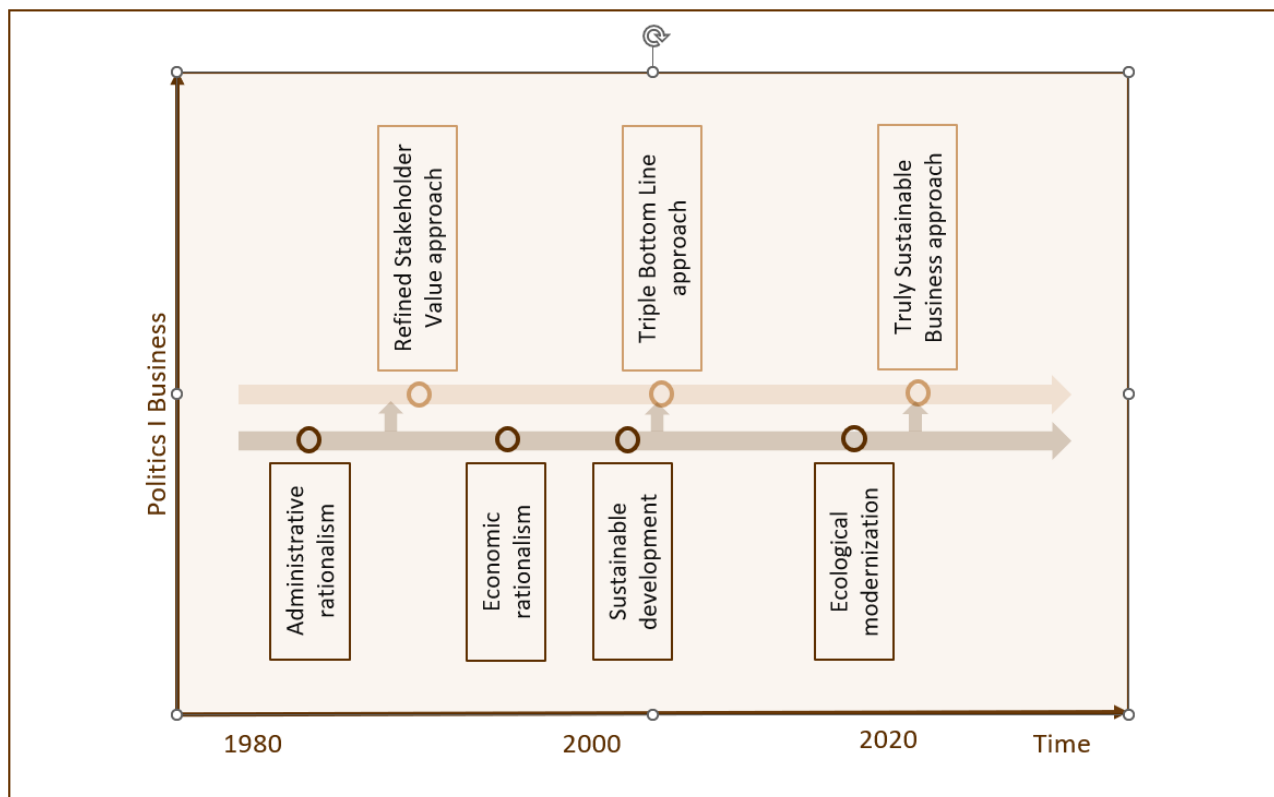
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<sup>2</sup> It addressed only socio-technical dimension of socio-technical systems.

promotional activities and public relations. But their actions were limited to their market appearance. They did not make a considerable reorganization of their industrial processes or their inner organization.

The approach actors took a decade later when sustainable development became a dominant political construct - is called The Triple Bottom Line approach. It demanded a change of developmental paradigm and a move from economic perspective to a much wider social perspective. Analyzed through the lens of sociotechnical theory techno-economic dimension was added to an existing socio-technical dimension. So, it was not enough to change marketing approaches, as it

was the case in Refined Stakeholder Value approach. Changes had to be put to the strategies, measured, processed, and made public. The repetitiveness and continuity of these processes became important, as the climate change became apparent and pressures put on companies become constant and uncomprehending. But as sustainability reporting stayed one-sided and sender orientated and it didn't allow and serious discussion or cooperation it was often understood as mere greenwashing. An activity that fulfils legal obligations companies have but does not change a way they act or think [20].



**Fig. 1** The evolution of sustainability on political and business level [3].

The approach actors are taking to secure sustainability now is called Truly Sustainable Business approach. It was developed at the same time as an environmental discourse of ecological modernization and had to adopt to new type of governance and new type of transition management.

New type of governance included changed political structures, changed decision-making procedures, changed rules, and changed ways of participation. It demanded new policy arenas, new relations and new responsibilities. Transition managers realized that they were caught up in a cycle of problem-definition,

intervention, and response. So, they had to be reflexive and proactive. The communication in Truly Sustainable Business approach became horizontal, two-sided, and deliberative. Its mission was to broaden companies' understanding of other actors, their values, roles, and strategies [21].

#### *4.2 Changing Nature of Sustainability in Politics*

The most important conceptual understandings of sustainability in politics are called environmental discourses. Just as business sustainability approaches create a path for business reorganization, so the environmental discourses create a path for broader social reorganization. They influence governments priorities, decision making processes, political arenas, relations between actors and different ways of cooperation and participation [22].

First environmental discourses were developed in 70-ies with Club of Rome and its famous report called "Limits of growth". Politics and policy making got through eight different environmental discourses since then [23]. We are going to focus on the four: environmental discourse of administrative rationalism, environmental discourse of economic rationalism, environmental discourse of sustainable development and environmental discourse of environmental modernization.

Administrative rationalism and economic rationalism are important ecological discourses as they were developed and implemented at the same time as Refined Stakeholder Value approach. Administrative rationalism built on the essential presumption that public is not an actor in sustainability transitions. Its proponents were convinced that citizens are not interested (or capable!) to grasp problems transition to sustainability pose. And that it is enough, if the state leads a discussion between democratically elected government, bureaucracy and a council of experts [24]. The result of such an attitude, was that the

sustainability arenas were closed and that communities and nongovernmental organizations were entirely alienated from the discussion. Economic rationalism that has developed a decade after administrative rationalism built on the basis of neoclassical school of economic. It understood companies as most important social actors, so it demanded companies to act as true social leaders and the state act as a kind of nightwatchman. This is why economic rationalism used financial incentives as a key tool to secure sustainability.

Sustainable development is especially important environmental discourse because it was developed at the same time as Triple Bottom Line approach. It demanded that the discourse of sustainability becomes international and that the states address it as a priority. As John Elkington, as one of most influential theorists of this age, put companies at a "driving seat". Companies take aim for sustainability as their fundamental mission. That they have to be proactive in addressing civil society, nongovernmental organizations, and the state. And that they need to develop a system of annual reporting that includes their economic, social, and environmental footprint. All these views made it revolutionary in a way, or at least very progressive [19].

Environmental development as fourth and final ecological discourse, that is going to be analyzed here, is important as it is a conceptual backbone of Truly Sustainable Business approach. And it demands that with transition to sustainability companies are responsible actors, that they are proactive and do report annually, but the states are those actors that take central role. As most powerful and most inclusive actors they have to connect government, state agencies, companies, universities, nongovernmental institutions, regions, and municipalities as a responsible stakeholder in open, reflexive and deliberational manner. They have to

stimulate connectivity and development of alliances at local, regional, and national levels [3].

## 5. Discussion: Can Our Fundamental Assumptions Be Confirmed?

Up to this point we have focused on sociotechnical theory and on consequences of sustainability in business and politics. Now we can use this frame to assess facts observed analyzing KNPPs organizational culture, participation patterns and communication and to answer research questions.

### 5.1 Is KNPP Following WANOs Principles?

The introduction of WANOs safety principles to KNPP started in 2019 with quality assessment. KNPPs management invited colleagues from other nuclear power plants to make a peer review [25]. And as a consequence of a peer review, they introduced a set of innovations and strategical approaches in their procedural praxes [26]. Improvements they introduced can be acknowledged in techno-economical and on socio-technical dimension. In a new, more inclusive types of inner communication and within a unit and between units, a direct top-down connectivity that leads to increased security, horizontal discussion processes, secures positive relations. New categorizations were also set to measure standards in industrial safety area [27]. And in yearly reporting the structure business report were aligned with the requirements of International Atomic Energy Agency and World Energy Council. KNPP upgraded its information platforms. So, in first two dimensions of socio-technical systems theory (techno-economic and socio-technical) KNPP has lifted its developmental and sustainability to a higher level [4]. It approved inner communication and procedures needed to secure effective facility management, perfected operation conditions, upgraded information flow, and nuclear waste management on one hand. And reduced a possibility of human error on the other hand. As a result

of that, KNPP got more than the recognition of WANOs. Based on analysis of KNPPs documents and WANOs report we can say that KNPP is following WANOs principles on a highest level. And that it promotes professionalization, individual responsibility, trust, open and positive communication, and respect, both on systemic level and on individual level.

As a result of advancements in techno-economic and socio-technical dimension Slovenian Nuclear Safety Administration gave KNPP environmental protection permit in 2023 [28].

### 5.2 Which Approach to Sustainability Does NKPP Use at the Moment?

Based on the study of KNPPs organizational culture, communication principles and participation horizons we can say that our opening assumption was proven right. KNPP acts in accordance with key principles of Triple Bottom Line approach and environmental discourse of sustainable development [29].

If we focus our attention on organizational culture, we can see that KNPP builds on values such as expertise, responsibility, trust, respect, and improved horizontal communication on organizational level and on personal level. It includes reflexivity and two-sided communication.

But it did so only in inner communication, that is in communication between management and employees, and employees themselves. Not in relation to its immediate and wider environment [30]. To get from the Triple Bottom Line approach to Truly Sustainable approach the company has to be able to be reflexive on all levels, both on the inside communication and in the communication with its social environment. KNPP participation consists of classical discussion with government and with other companies from energy sector [31]. Its management is in constant conversation with state institutions such as Ministry for energy, climate and environment, Slovenian Nuclear Safety Administration and Governments National Nuclear



Program, with its owners (GEN Energy and HEP), and also, with the municipality of Krško. Jet all these business and political actors are reactionary and conservative [32]. They do not promote necessary innovation in political dimension of KNPP<sup>3</sup>.

As a result, KNPP use inner communication in a way that is complex and multilevel. It supports new decision-making philosophy (promoted by WANO) on all levels. Therefore, it combines communication as a knowledge generator, communication as social learning tool, and communication as a foundation for proactive collaboration in developing solutions. So, one could say that KNPP is following the highest levels of communication here. In addressing external audience, KNPP focusses only on information and fact presentation. It reports facts such as radioactivity measurements, measurements of the temperature of river Sava, and information about nuclear waste. And it does so in a manner mostly suitable for people with considerable expertise and knowledge [10].

### *5.3 What Needs to be Changed in KNPP to Advance From Triple Bottom Line Approach to Truly Sustainable Business Approach?*

To make a transition from Triple Bottom Line approach to Truly Sustainable Business approach on one side and from environmental discourse of sustainable development to environmental discourse of ecological modernization the focus must widen from techno-economic and socio-technical dimension to all three dimensions of socio-technical theory. Nuclear power plant, as KNPP, has to become a part of existing arenas and co-creator of new arenas. Its relation to other actors must be reflexive [8], as it needs to become an actor who wants to be a part of sustainable political arenas. Not only of energy arena.

If nuclear power plant wants to become a part of sustainability, they have to act as a part of an environmental discourse. And to be a part of environmental discourse it has to open up and put a communication to a higher, more proactive and two-way level. And it has to discuss energy policy in general. But not only energy policy. It has to be a part of discussion on the future of Slovenian industry, on future of Slovenian infrastructural connectivity, and on development of Slovenian urban and rural areas. As we have shown in our analysis of KNPP, a nuclear power plant needs to be able to be a part of a wider deliberative discussion and deliberative decision making too. It needs to be able to use reflexive argumentative techniques and to cocreate key social arenas. It has to create new partnerships (with different social actors), add new actors to the discussion, and to be in touch with other players. It is important that KNPP supports efforts of municipalities, such as Municipality of Krško to address the future of sustainability in democratic and inclusive manner [1].

KNPPs communication is among the best in the nuclear industry. Yet it will have to radically upgrade it both in its goals and in its techniques. The traditional goal of KNPPs communication is informing the public about the energy production, companies financial results, and environmental footprint. To get from Triple Bottom Line approach to Truly Sustainable Business approach that will need to be supplemented with two additional essential goals: 1) to make firm alliances within a broader society, and 2) to get outside information to the company.

## **6. Conclusion: Urgent Steps Needed to Make KNPPs Comprehensively Sustainable!**

Our analysis of KNPP indicates that significant progress toward achieving sustainability has been made, particularly in the techno-economic and socio-technical dimensions. KNPP aims to serve as a

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<sup>3</sup> That is why KNPP has to be proactive not to miss the changes of political arenas, developmental culture and broader social culture of sustainability that is going to grow exponentially in next 30 years.

globally recognized example of nuclear safety and operational excellence.

To facilitate a meaningful transition from the Triple Bottom Line approach to a Truly Sustainable Business model, it is crucial for KNPP to invest considerable attention in fostering innovation within its political dimension. Achieving a comparable level of excellence in this area, similar to that attained in the techno-economic and socio-technical dimensions, requires KNPP to operate as a progressive, reflexive, and self-initiating entity. This entails a deep understanding of how communities function at local, regional, and national levels [33].

Furthermore, KNPP must enhance its communication strategies with various stakeholders, both directly and indirectly. Effective public engagement necessitates that communications are not only precise, scientific, and comprehensible but also interesting, engaging, and motivational. It is vital for

KNPP to perceive its audience as responsible citizens — recognizing their beliefs, concerns, and cultural contexts — rather than viewing them simply as uninformed consumers with a singular focus.

To mitigate the spread of unfounded fears — fears that could generate significant opposition to nuclear energy and sway the decision-making processes of large segments of the population — nuclear power plants as KNPP must leverage communication as a tool for knowledge generation, social learning, and the foundation for proactive collaboration in developing solutions to sustainability challenges. It is insufficient for KNPP to merely react to the actions of nuclear energy opponents or to respond to the fluctuating interests of the media. Instead, the plant must establish proactive, continuous, and direct engagement with the public, and this initiative must commence without delay.

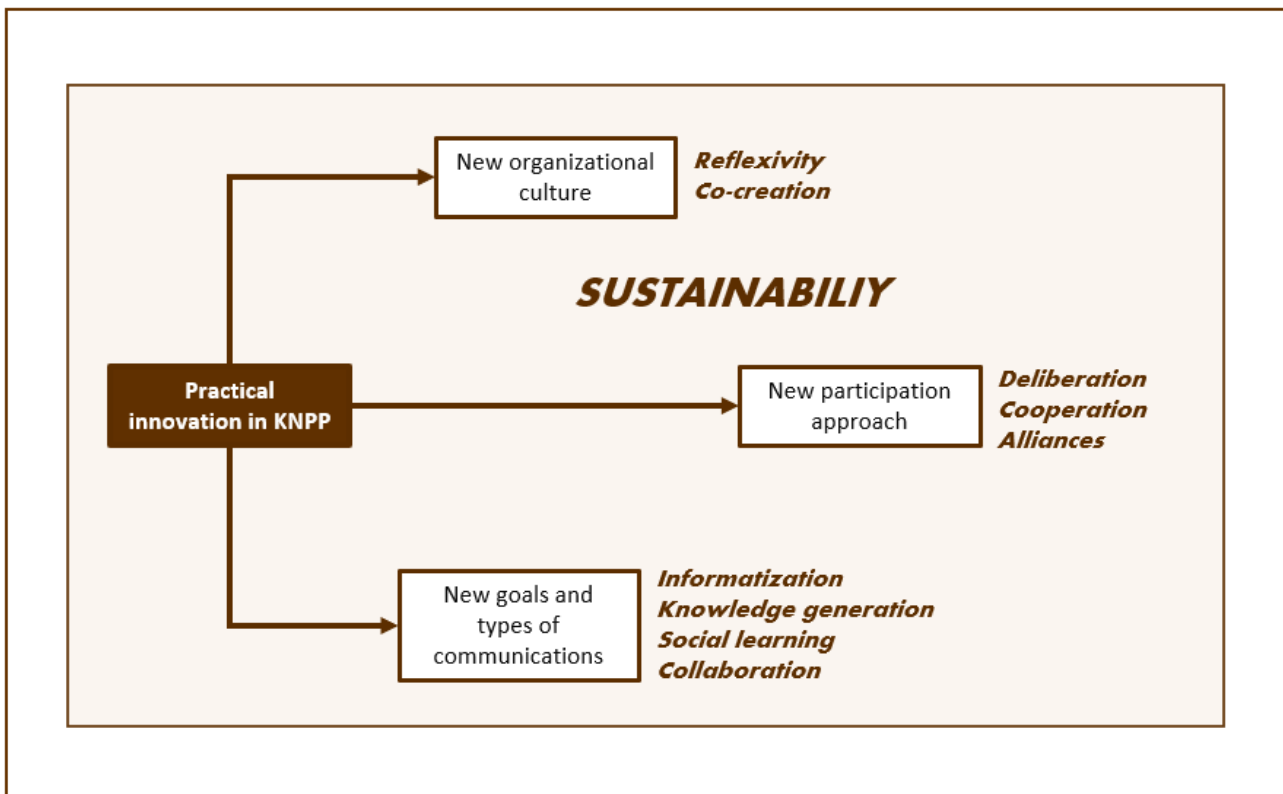


Fig. 3 Three essential levels of innovation in political dimension of KNPP [3].

To achieve this, KNPP needs to gain a thorough understanding of the public's needs, as well as the perspectives of both supporters and opponents of nuclear energy, alongside the rationale and dynamics of the political landscape.

Consequently, KNPP should prepare a comprehensive communication strategy that allocates appropriate resources and personnel focused on engaging with stakeholders and networks. This strategy should extend beyond the insights offered by the Triple Bottom Line approach to encompass a Truly Sustainable Business model [34].

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