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METHODOLOGY FOR SELECTING A SOURCE OF ELECTRICAL ENERGY SUITABLE FOR THE SITE

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Abstract

To ensure a reliable supply of electricity in a given territory, it is necessary to choose the source that is most suitable in all aspects, i.e. the availability of resources, technology, costs and personnel requirements. Since the requirements are incommensurable, a multi-criteria approach is chosen. Used procedure is described in detail. To ensure the development and safety of the State, each State needs raw materials, energy, transport, industry, agriculture and services to ensure the basic functions of the State. In the article, we focus on energy production, which is the basis for the extraction of raw materials, industry, transport, the operation of critical infrastructures and services that ensure the protection of the lives and health of the population, the protection of property and the protection of the environment.

Keywords: Power sources; availability; risks; safety; multi-criteria approach.

1. Introduction

The first UNDP *Human Development Report* stated that, ‘The basic objective of development is to create an enabling environment for people to enjoy long, healthy, and creative lives’, and defined human development as ‘a process of enlarging people’s choices' [63]. Human development focuses on improving the lives people lead rather than assuming that economic growth will lead, automatically, to greater wellbeing for all. Income growth is seen as a means to development, rather than an end in itself [71].

To ensure the development and safety of the State, each State needs raw materials, energy, transport, industry, agriculture and services to ensure the basic functions of the State.

Safety and security represent many things, including a stable income, consistent housing, clothing, and food supplies as part of the predictability of daily life, protection from crime, and psychological security [58]. Based on current knowledge and experience, it is a fact that the quality of life, health and safety of each person depends on the quality of the human community to which they belong. A number of studies, notably the World Bank’s Voices of the Poor report [33], show that safety, security and justice are major concerns for citizens. From the reasons of fulfilment of targets of humans (human security and development) that may be only realised if human communities are in safe territory [34], [52]. Safety and security represent many things, including a stable income, consistent housing, clothing, and food supplies as part of the predictability of daily life, protection from crime, and psychological security [66]. Ensuring the safe human system is not easy [26], because the human system is a system of systems [48], i.e. system of several mutually interconnected systems of a different nature. Consequences of interconnections (interfaces) are mutual dependences, the character of which is physical, cyber, territorial and organisational [51]. As a consequence of growing globalisation the new sources of disasters take on force, they also cause complex facility failures. [22], [27].

A Million Voices report, on findings from the post-2015 development agenda consultation process, highlights security and justice as key elements missing from the Millennium Development Goals (MDGs) [70]. There is a growing body of evidence demonstrating that shortfalls in safety, security and justice contribute to both poverty and underdevelopment [19]. Conversely, the presence of safety, security and justice can contribute to development outcomes including virtuous cycles of security and development, 'with high levels of security leading to development and development further promoting security' [63]. There is a strong association between justice and development, in the sense that prosperous countries generally have more complex legal systems and deliver a higher quality of security and justice services to citizens [5]. However, while evidence suggests that safety, security and justice are associated with development, establishing direct causality is complex [55], [56]. Safety, security and justice are seen as moral rights and intrinsic to development [3].

Mitigating climate change and the clean energy transition

The safe community is now at time of globalisation very dependent on a safety level of complex facilities ensuring the territory by basic service necessary for human live, e.g. the electric energy on which there are dependent supplies of good quality drinking water, utility water, information distribution etc. [47].

Energy production for each State must be sufficient in terms of need and must be cost-effective and it must not damage public assets, so as not to harm the public good. This can be achieved through an appropriate combination of cost, quality, time, flexibility and innovation [23]. Daas et al. [6] developed a Decision Support System (DSS) for designing business models. A Decision Support System (DSS) consists of a design process that follows different design methods. Its application ensures compliance with legislative requirements.

The Paris Agreement duly reflects the latest scientific understanding of systemic global warming risks. Limiting the anthropogenic temperature anomaly to 1.5–2 °C is possible, yet requires transformational change across the board of modernity [1]. After some 20 years of negotiations under the auspices of the United Nations Framework Convention on Climate Change (UNFCCC), a historic, binding climate agreement was reached in Paris. At the twenty-first Conference of the Parties (COP21), 195 nations committed to "holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change" [59]. The release of carbon dioxide (CO_2) and other greenhouse gases (GHGs) due to human activity is increasing global average surface air temperatures, disrupting weather patterns, and acidifying the ocean. Left unchecked, the continued growth of GHG emissions could cause global average temperatures to increase by another 4 °C or more by 2100 and by 1.5 to 2 times as much in many midcontinent and far northern locations [64]. Although our understanding of the impacts of climate change is increasingly and disturbingly clear, there is still debate about the proper course for policy [36].

Mitigating climate change is unavoidably linked to developing affordable low-carbon energy technologies that can be adopted around the world [67]. In the face of the Paris climate agreement, a combined transition to clean energy and acceleration of decarbonization goals will require the refocusing international research and deployment schemes to promote energy R&D (research and development) [30]. Dramatic cost declines in solar and wind technologies, and now energy storage, open the door to a reconceptualization of the roles of research and deployment of electricity production, transmission, and consumption that enable a clean energy transition [31]. The solar photovoltaic industry has undergone a dramatic evolution over the past decade. [76]. While basic research remains a vital element to address a clean energy transition, increasingly an interdisciplinary approach is needed. Deeper integration with policies that build market growth [36] and cutting-edge business models will enable far faster uptake of critical research programme outputs. Accelerating the development and deployment of energy technologies is a pressing challenge. Doing so will require policy reform that improves the efficacy of public research organizations and strengthens the links between public and private innovators [2]. The clean energy transition requires a co-evolution of innovation, investment, and deployment strategies for emerging energy storage technologies [21].

2. Energy sources and their requirements

In general, energy in a particular locality can currently be provided by the construction of a technical facility, i.e.: hydroelectric power plants; large nuclear power plants; gas-fired power plants; thermal power plants; geothermal power plants; diesel engine systems; wind power plant systems; photovoltaic power plant systems; and small modular reactor (SMR) systems [44].

A basic analysis of the conditions of individual technologies shows that for the implementation of the mentioned technical facilities it is necessary to have at your disposal for:

- hydroelectric power plant - river with a sufficient amount of water throughout the year,
- large nuclear power plant - territory that meets the requirements for location of large nuclear power plant, water source for cooling and available and safe nuclear technology,
- gas-fired power plant - stable and affordable gas supply,
- thermal power plant - stable and affordable supply of coal, wood or others biomass,
- geothermal power plant - a stable and affordable local source of geothermal energy,
- diesel engine system - stable and affordable supply of diesel,
- wind power plant systems - stable and sufficient wind,
- photovoltaic power plant system - stable and sufficient source of solar energy,
- small modular reactor (SMR) system -territory that meets the location requirements for SMR.

Since only SMRs are energy sources that are not yet so well known, we will discuss them in more details in the next chapter.

3. Small modular reactors (SMRs)

Small modular reactors (SMR) have been in development for decades [12], [13], [14], [15], [17], [37], [38], [42], [57], [74]. The International Atomic Energy Agency [17] defines small, medium and large reactors according to output electrical performance; reactors up to 300 MWe are classified as small reactors. They are increasingly used in practice, as they are cheaper and their area of emergency planning is smaller compared to large nuclear power plants [42], [57], [62]. In the Czech Republic, we work on the Energy Well reactor [68], [69] which we want to use as energy sources in technical installations producing the energy for: train and ship drive; operation of processes as reverse osmosis; hydrogen production and hydrogen storage; and mining the minerals in remote regions [8], [32].

The advantages of SMRs are mainly in the low installed performance. This advantage is conditioned by a high degree of inherent safety of the system. Due to the low power, passive cooling and the possibility of connecting to low-voltage networks are often talked about in connection with SMRs. If it were not a passive cooling system, batteries could be used for emergency power instead of diesel generators. Due to the low installed capacity, it is possible to reduce the emergency planning zone and generally reduce the licensing period due to the greater simplicity of the system in comparison with large nuclear power sources [43]. With outputs of less than 60 MW, it would be possible to cool the generator with air [18].

Another advantage is the size of the device. Due to this fact, it is possible to build nuclear facilities that are, compared to conventional nuclear sources, more resistant to earthquakes. At the same time, it is possible to renew older ideas about the operation of a nuclear reactor under the Earth's surface, which would be economically unacceptable in the case of conventional nuclear power plants [8]. Burying the SMRs would increase the safety of the system against windstorms, tornadoes and hurricanes, for example, as well as the possibility of a terrorist attack. At the same time, however, access to the equipment during the shutdown work or accident is noticeably reduced. Burying it under the Earth's surface would also be lucrative for military use, drawing on an extremely small built-up surface. However, for military purposes, the installation process would need to be extremely accelerated. At the same time, underground systems could be less sophisticated, reducing the price of SMRs in direct proportion [43].

Furthermore, the relatively small dimensions of the entire system would not cause much difficulty in transport or in the selection of suitable locations. Possibility of connection where it is not possible to build large power plants for many reasons (logistics, subsoil, cooling, etc.) [43]. According to the IAEA, the advantage is, of course, lower investment risk, improved cash flow or shorter construction time [11]. With smaller component dimensions, the price also decreases due to greater competitiveness among suppliers potentially bidding for contracts [18].

The largest economic indicator for nuclear power plants is LCOE (Levelized Cost of Electricity), which is the ratio of the final price of a nuclear power plant to the installed electrical capacity. From the point of view of SMR optimization, it is, therefore, essential to reduce LCOE [8]. Opinions on the method of reduction vary, one of them is, for example, a decrease in installed capacity, which should also have an impact on greater simplicity of the system, and therefore, lower investment costs [17]. The estimated costs according to [73] are as follows: SMART - construction costs 5000 $/kWe, operation and maintenance 6.1 cents/kWh (which is lower than hydropower), NuScale - construction costs 4000 $/kWe (40 months of construction), fuel costs 5.5 $/MWh.

According to [18], it is reality that in SMRs around 15 systems and components necessary for LOCA disaster resolution are eliminated and, for example, in NuScale units, they are replaced by only one system due to the low electrical power of 50 MWe. As a small facility, SMRs have also benefit in terms of supply chains. The production of smaller pressure vessels gives the opportunity to more companies, including the domestic ones. At the same time, there are no complications in dealing with large manufacturers of heavy components, respectively with their workload. The same approach applies to the production of turbines and generators. A larger group of possible manufacturers encourages a more vigorous competition in a competitive market, and therefore, a possible reduction in acquisition costs. In addition, as already mentioned, smaller equipment is easier to transport, maintain and possibly dispose of. In the case of turbogenerators with lower outputs than 50 MWe, it would be possible to transport the entire equipment on a "separate pallet" and, in addition, it would be possible to cool it with air [18].

The impacts on investment decisions can be summarized in 11 classes, which include, for example, the stability of the electricity grid, public acceptance, technical constraints on location, project risks, national industrial system, time of market launch, competences required for operation, effects on employment, design robustness or political relations [25].

In a 2016 document [39], the OECD argues that the problem still remains that capital costs, operating and maintenance (O&M) costs and fuel costs are not yet known. On the other hand, it confirms the advantages of SMRs, among which it states: increased nuclear safety and implementation of unique passive elements; reducing the number of systems and simplifying the energy conversion; easier financing; better network flexibility, e.g. load monitoring modes; lower transmission system requirements due to lower power outputs; identical SMRs are advantageous in terms of human resource management; easier decommissioning; and the ability to avoid downtime by help of suitable SMR configurations.

At the same time, the report [39] states that the following will be key for customers: GDP and its possible growth; electricity consumption per person; credit rating; self-sufficiency of electricity supply; environmental protection; national membership of the IAEA; electricity price; and specifics of the electrical network (size, voltage, quality, interconnection, load).

For SMR manufacturers, according to [39], it is a matter of ensuring: technology readiness and demonstration possibilities; financial background; and supply chain and public procurement.
At the same time, the report [39] mentions a comparison of the aviation industry with nuclear facilities, which is a frequently used parallel, but it is not as simple as it may seem to others. In particular, the efficient full assembly of SMRs at the factory may not allow the inspectors of supervision office to check all the steps (an on-site inspector could be preferred to optimize the assembly process at the factory) [7]. With regard to the deployment of SMRs, the innovative licensing system should separate the general approval or licensing of production equipment for SMRs, the SMR itself and the site for SMRs [39].

It can be argued that SMRs have reached a certain degree of maturity and are competitive with other energy sources [7]. In addition, large nuclear power plants and SMRs are expected to have the same LCOE of USD 70/MWh (at a reasonable weighted average cost of capital) with a load factor of 85 %, but a slightly different distribution between fixed and variable costs [57]. This leads to the idea that SMRs may have lower investment costs due to factory production, shorter construction times, simpler financing and the like, but higher variable costs due to higher O&M costs per MWh due to the fixed component of O&M costs, lower fuel efficiency, etc. In this example, SMRs are most competitive with load factors of 60-85 %, replacing the coal and large nuclear power plants to this extent [39]. The DoE [7]. states that the safety of SMRs might not be as perfect as it is generally claimed. The main argument concerns passive safety systems and elements that are not infallible. A smaller containment is disadvantageous in terms of the ppm value of hydrogen, which would be enough for an explosive concentration in the containment area. If the reactor were to be buried, earthquake resistance could be increased, but flood safety decreased. At the same time, safety is reduced due to fewer operating staff or in the event that the manufacturer decides to reduce costs [43].

The advantages of SMRs according to DoE [7]. are modularity, the ability to build units in a factory and transport them to the site. It is suitable for small electric markets, places with low logistical support and places with smaller industrial plants. At the same time, it is possible to replace old coal-fired power plants with green sources, which are SMRs. There is also the possibility of connecting SMRs with other sources of electricity, which could increase the stability of the network or the safety of the transmission system. A large part of the SMRs is planned in such a way that there would be no situ betting, but it would be done directly in the factory [43].

In the case of multiple SMRs, this technology could be less safe than in the case of a large nuclear power plant, when the SMR manufacturer fails in one project [43]. However, this presumption is applicable not only to SMRs or large nuclear units, but to series production in general.

The advantage of SMRs in terms of safety is also the so-called integral arrangement, where the reactor and the components of the primary circuit are placed in one pressure vessel [18]. This eliminates the amount of cooling pipe and its dimensionality. Due to this, the sleeves leading out of the TNR are also drastically narrowed, which has a positive impact on the course of the LOCA accident. Heat exchangers are usually seated higher than the core, thereby contributing to the natural circulation of the refrigerant. However, some systems, due to the natural circulation of the refrigerant, completely eliminate the main circulation pumps and the associated possibility of a LOCA accident [18].

Sources of risk were monitored in work [46]. Other factors that are sources of high risk, which is common to a capital-intensive industry, are according to [4], [39], large initial expenses; the uncertainty of the return on initial investment; the danger that the work will not be completed, or changes will be necessary, which will require enormous additional costs for completion; long building and construction time; sensitivity to demand; reliability, availability and load factor of the power plant; electricity price; unstable public support; low acceptance of nuclear power installations with the public (although nuclear technologies used in medicine and food, which are not as secure as energy [46], do not create public disfavor); decisive influence of the regulator; and decommissioning - decommissioning and subsequent decontamination of equipment and surface treatment, which does not yet have a clear procedure, although there is experience [16] and civil procedures [49].

According to the work [4], the advantages of the reduced power plant size, complexity and simplified design offered by SMRs would allow: better control over construction; less risk associated with suppliers; and better control over the cost of equipment design. According to works [8], [18], [32], [35] SMR can be used for: long-range heating; desalination and water purification; advanced oil extraction and oil refining processes; production of hydrogen for the enrichment of liquid fuels and, where appropriate, the use of fuel cells; advanced energy conversion processes such as coal liquefaction and petrochemical production; general process heat for chemical or manufacturing processes; the standby power of a nuclear power plant; data centers; military bases; mining sector; remote island operations; industrial complexes; production and liquefaction of hydrogen; steelworks; oil and gas terminals; large chemical plants; desalination of seawater; and propulsion of ships.

4. Methodology for selection of a suitable source of electrical energy in real site

In any case, it is a question of choosing a technology for which there are conditions in the territory and which is safe, which means reliable and functional and procure quickly, while its demands on safety, operation, human resources and other service systems are such that it will be cost-effective. This means that the benefits for the territory while ensuring a level of safety will be optimal. The optimal solution is obtained by assessing possible variants [45], [49].
According to [49], any suitable solution for meeting the specified goal is considered a variant solution, i.e.:

- various localization of the construction site and traffic route management,
- various technological processes,
- variant type of activity, e.g. choice of import instead of domestic production,
- different implementation timetables,
- substitution of raw materials,
- various solutions for the disposal of waste, emissions, etc.

Variant generation is a creative model of thinking that depends on the criteria of the goal. In a State governed by the rule of law, the objective must be consistent with legislation that promotes the security and development of the State.

The goal in terms of development and cost in any case is to select a technology that will be: safe; tried-and-true; feasible within an acceptable time; easy to maintain, and have reasonable demands on fuel, self-consumption, personnel and finances necessary for safe operation.

In the world, a procedure called "technology assessment", which is codified in each country [50], is used for this purpose. The form of technology evaluation is determined by legislation in each country; the goal is the same, but the form of application varies from country to country [9], [10], [28], [29], [41], [50], [53], [54], [60], [61], [65], [72], [77].

According to [9], [10], [28], [29], [41], [50], [53], [54], [60], [61], [65], [72], [77] the evaluation in question is a comprehensive interdisciplinary expert evaluation of planned technical facilities, which considers both, the possibilities of the investor and the impacts of current and future on the areas of technology, the environment, social, social and economic; in Europe, it began to be used in the early 90s.

The evaluation in question is not directed against technologies; its aim is to detect problems and prevent damage caused by uncritical application and commercialization of new technologies. The results of the evaluation are intended for investors (in the case of public projects for politicians), who ultimately decide to enable the implementation of a technical facility.

When making a decision, based on the evaluation of technology, there is a dilemma:

- correctly appreciate the impacts of the planned technical facility, which cannot be easily predicted until the technical facility is extensively developed and used,
- it is difficult to manage or modify a technical facility once it is widely used.

To do a decision is difficult, because in a particular case:

- it is difficult to estimate the cost of externalities and internalities,
- it is not easy to select indicators to assess the benefits and impacts of the planned technology,
- it is not easy to convert damages and injuries into money,
- there are also ethical barriers.

Based on the above quotes, "technology assessment" is mainly used in the following areas: information technology; hydrogen technologies; nuclear technology; molecular nanotechnology; pharmacology; organ transplantation; genetic technology; artificial intelligence; internet, etc.

On the basis of the OTA (Office for Technology Assessment) documents collected in the database [41], the specific assessment is carried out in two steps. First, a screening of possible variants is carried out, i.e. an evaluation of essential factors to exclude major unsatisfactory variants, and a detailed evaluation is carried out for the remaining variants, which forms the basis for the decision of the investor (or politicians, in the case of public projects).

Based on the documents cited above, an evaluation based on the following criteria shall be used for screening:

- Is the operation of the technology tested?
- Is the power supply safe, i.e. reliable and functional for life?
- Is the technology available to the investor?
- Is the performance of the technology stable in the long term?
- Can the technology be implemented quickly?
- Is the cost of applying the technology acceptable?
- Can a source with this technology quickly (less than 1 year) meet the needs of the investor for the entire duration of operation of the building for which it is being built?

The comparison of suitable variants of technologies determined by screening for an investor or supplier of an electricity source in the monitored case for understandable reasons (it is to ensure the needs of a company) does not include or only to a limited extent includes the needs for the territory in which the energy source is located and put into operation (e.g. public welfare, employment, services in the territory, etc.). Table 1 shall be used for the detailed evaluation of variants. The optimal solution is a variant that:

- has the most benefits,
- does not have too large specific requirements for operation,
- according to [20] losses caused by accidents or failures will not reduce the expected annual return below value 0.7 x total useful income / lifetime.

Since nothing is absolute, no technology meets the requirements absolutely.
Since this is a complex decision-making problem in which it is necessary to consider criteria from many areas that are often incommensurable, it is necessary to apply a multi-criteria evaluation [45], [20] based on the philosophy put into practice in the work [40].

For the selection of source of electricity production, in accordance with the knowledge [6], [20], [24], [45], [50], [75], we have constructed a decision support system for evaluating the contributions of individual criteria to the integral safety of the technical facility (energy source) and its surroundings; Table 1. We have created the criteria on the basis of the knowledge gained from the critical analysis of [20], [24], [41], [45], [50], [61], [72], [75], [77] so that "the higher the value of the valuation, the higher the contribution to integral safety" is paid. The evaluation of the criteria is carried out by assigning points as follows:
0 point - the criterion is met at less than 5 %, i.e. it does not contribute to ensuring the integral safety,
1 point - the criterion is met at 5- 25 %, i.e. it contributes little to ensuring the integral safety,
2 points - the criterion is met at 25 – 45 %, i.e. only moderately contributes to ensuring the integral safety,
3 points - the criterion is met at 45 – 70 %, i.e. it contributes highly to ensuring the integral safety,
4 points - the criterion is met at 70 – 95 %, i.e. it contributes very highly to ensuring the integral safety,
5 points - the criterion is met at more than 95%, i.e. it contributes extremely highly to ensuring the integral safety.

Since we use incommensurable items in the evaluation, we use the auxiliary scale, shown in Table 2, to ensure commensurability [45].

Criterion	**Evaluation**	**Note**
Safety of technology		
The rate in whichtechnologyhasinherentsafety.		
The rate in which technology is a clean source of energy.		
The rate in which the technology is able to ensure a stable supply of electricity. This means that it is still operational and does not depend on frequent specific deliveries or specific external conditions.		
The rate in which the technology has the ability to operate without trouble.		
The rate in which the technology does not require frequent repairs.		
The rate in which the demands of the technology operation do not require qualified operator intervention.		
The rate in which the impacts of the operation of the technology on employees are acceptable.		
The rate in which the impacts of the operation of the technology on the surrounding environment are acceptable.		
Material demands on the feasibility of technology in a certain place		
The rate in which technology includes measures to manage emergency situations.		
The rate in which the operation of the technology can be done without specific knowledge.		
The rate in which the installation of the technology requires a local object.		
The rate in which the technology can do without frequent supplies of raw materials for operation.		
The rate of demands of technology on a specific and expensive location.		
The rate of demands of the technology on technical tasks during the commissioning.		
The rate in which the operation of the technology requires the skill of the operator.		
The rate in which the technology needs energy for its own consumption to operate.		
The rate in which technology requires a large information provision to operate.		
The rate in which the technology has a specific I&C for operations.		
The rate of uninterrupted performance of the technology due to maintenance and repairs.		
The rate of the quality of operating regulations for normal, abnormal and critical conditions.		
The rate of level of protection of the technology against local natural disasters.		
The rate in which technology protects the lives and health of operators.		
Míra, v jaké technologie neznečišťuje životní prostředí.		
The rate in which the technology does not require on-site waste management.		
The rate in which technology is protected against insiders and terrorists.		
Accessibility and competitiveness		
The rate of acceptability of the installation time of the technology.		
The rate of the technology's capability to ensure power generation for the operation of the monitored entity for 10 years or more.		
The rate of acceptability of the price of the technology.		
The rate in which the technology is such that it does not reduce the expected annual return below the acceptable value according to [20].		
The rate in which the transport of technology and the supply of spare parts are feasible.		
The rate in which the financial demands on the technology and its long-term operation are acceptable.		
The rate of difficulty of granting an operating permit.		
The rate in which specific objects are not needed for waste disposal at a given location.		
The extent to which the technology does not require site-specific equipment to reduce contamination of environmental components.		
The rate of acceptability of the scope of the emergency planning zone.		
LEVEL OF INTEGRALSAFETY		

Table 1. A tool for evaluating the integral safety of variants in order to obtain the optimal variant

Domain	**Risk rate**	**Classification criterion**
Social	*By accident or failure of technical facility, it is affected:*	
	0	less than 50 humans
	1	50 - 500 humans
	2	500 - 5000 humans
	3	5 000 – 50 000 humans
	4	50 000 – 500 000 humans
	5	more than 500 000 humans
Technical and Economic	*Accident or failure of technical facility causes damages:*	
	0	less than 0.05 p
	1	equal to p
	2	between p and 0.05 ABT
	3	between 0.05 ABT and 0.075 ABT
	4	between 0.75 ABT and 0.1 ABT.
	5	higher than 0.1 ABT.
Environment	*Accident or failure of technical facility causes:*	
	0	very low damages of environment
	1	damages of environment with which the nature cope during the acceptable time
	2	moderate damages of unrenewable resources of nature and natural reservations.
	3	medium damages of unrenewable resources of nature and natural reservations
	4	unreturnable damages of unrenewable resources of nature and natural reservations
	5	devastation of landscape, unrenewable resources of nature and natural reservations

Table 2. Scale for determination of rate of risk that planned technical facility means for its surroundings (rate of coexistence disruption); by analogy to scales in [50]; p – annual insurance, ABT-the annual budget of territory governance (safety rate = 1 - risk rate)

The evaluation of Table 1should be performed by specialists from different domains (technology, region safety, public administration, investor, emergency service) [50]. The resulting value is the median for each criterion, and in cases of great variance of the values in one criterion it is necessary, so that the worker of public administration responsible for territory safety may ensure further investigation, on which each assessor shall communicate the grounds for his / her review in the present case, and on the basis of panel discussions or brainstorming session, the final safety rate value is determined. Judgement of acceptability of integral safety is performed according to Table 3 [50].

The level of safety	Values in % n/N
Extremely high - 5	More than 95 %
Very high - 4	70 - 95 %
High - 3	45 - 70 %
Medium - 2	25 - 45 %
Low - 1	5 - 25 %
Negligible - 0	Low than 5 %

Table 3. Value scale for determining the safety rate; n = the number of criteria with YES; N = five times the number of criteria in Table 1.

At selection of variant, it is possible in simple case to use the level integral safety according to result in Table 1; the higher number, the better variant for a given territory. The variant with maximal integral safety rate is the best one.

From safety reasons it is better to use a two-step procedure:
- based on Table 1 and Table 3 to exclude all variants where safety is less than high,
- from the rest variants to select this which is better from economic or time viewpoint.

More precisely sophisticated procedure [50] is the following:

- for each variant which have according to result in Table 1 minimally high integral safety according to Table 3 to calculate benefitsof variantfor the given territory,
- for each from these variantsto determine the differences Dsbetween annual benefits ofa technical facility for the given territory and maximum annual losses of technical facilities caused by trade-off with risks. In this case optimal variant is the variant with the maximum D.

5. Future research plans

Further research is planned to focus mainly on the application of the proposed methodology aimed at reliable electricity supplies in the given territory so that the source that is most suitable in all respects is chosen during the selection process, i.e. availability of resources, technologies, costs and personnel requirements. It will be important to use feedback from practice when applying the described methodology, which aims to ensure the protection of the lives and health of the population, the protection of property and the protection of the environment.

6. Conclusion

Since no objective decision-making on real matters is usually black and white, the benefits and impacts caused by the risks taken must always be weighed. The paper shows a method that is in line with professional knowledge and procedures in the EU and developed countries. The methodology considers all important aspects that are important from the point of view of long-term sustainability of the solution. It is based on the assessment of incommensurable factors by a team of experts who have an auxiliary scale for categorizing risks. Therefore, evaluations also need to be carried out by a team of experts who are not under political, financial or other pressure. In case of disagreement among experts, a way to proceed is proposed. Three ways of selection of optimal variant are shown; the most precise selection is based on comparison of annual benefits of a technical facility for the given territory and maximum annual losses of technical facilities caused by trade-off with risks.

The implementation of the described method of ensuring energy production, which is the basis of the extraction of raw materials, industry, transport, operation of critical infrastructure and services, aims to ensure the protection of the lives and health of the population, the protection of property and the protection of the environment. Such a comprehensive approach based on current knowledge in the context of the security management process has the potential to contribute to overall integrated security and the elimination of potential risks in the given territory.

7. References

[1] *Adoption of the Paris Agreement* FCCC/CP/2015/L.9/Rev.1 (UNFCCC, 2015).

[2] Anadon, L., D.,Chan, G., Bin-Nun, A. Y. & Narayanamurti, V. (2016). *The pressing energy innovation challenge of the US National Laboratories*. - Nat. Energy 2016, 1, 16117. - [on-line] Available on - URL: https://doi.org/10.1038/nenergy.2016.117

[3] AusAID. (2012). *Building on Local Strengths: Evaluation of Australian Law and Justice Assistance*. - Canberra: Australian Agency for International Development. - [on-line] Available on - URL: https://www.dfat.gov.au/development/performance-assessment/aid-evaluation/program-evaluations/building-on-local-strengths-evaluation-of-australian-law-and-justice-assistance

[4] Carelli, M. D. & Ingersoll, D. T. (2015). *Handbook of Small Modular Nuclear Reactors*. - ISBN 978-012823-91-62. Amsterdam: Woodhead Publ.

[5] Cox, M. (2008). *Security and Justice: Measuring the development returns*. - London: Agulhas. – [on-line] Available on - URL: https://agulhas.co.uk/app/uploads/2020/10/DFID_2008_Security_and_justice_measuring-_he_development_returns-.pdf

[6] Daas, D., Hurkmans, T., Overbeek, S., Bouwman, H. (2013). *Developing a Decision Support System for Business Model Design*. - Electronic Markets, 23(3), 251–265. – [on-line] Available on - URL: https://doi.org/10.1007/s12525-012-0115-1.

[7] DOE. Advanced Small Modular Reactors. – [on-line] Available on - URL: https://www.energy.gov/advanced **;** https://www.energy.gov/science/advanced-and-sustainable-energy

[8] Dostál, V., Štěpánek, J. & Syblík, J. (2020). *Business plán reaktoru EW*. - Zpráva pro ÚJV. Praha: ČVUT 2020.

[9] EPTA. - [on-line] Available on - URL: https://eptanetwork.org/index.php

[10] Genus, A. & Coles, A. (2005). *On Constructive Technology Assessment and Limitations on Public Participation in Technology Assessment*. - *Technology Analysis and Strategic Management*, 17(2005), 4, pp. 433-443

[11] IAEA. - [on-line] Available on - URL: https://www.iaea.org/

[12] IAEA. (2011). *Status of Small and Medium Sized Reactor Designs: a Supplement to the IAEA Advanced Reactors Information System (ARIS)*. - Vienna: IAEA.

[13] IAEA. (2013) *Approaches for Assessing the Economic Competitiveness of Small And Medium Sized Reactors*. - Vienna: IAEA.

[14] IAEA. (2013) *Status of Innovative Fast Reactor Designs and Concepts*. - Vienna: IAEA.

[15] IAEA. (2013). *Advances in Small Modular Reactor Technology Developments: A Supplement to the IAEA Advanced Reactors Information System (ARIS)*. - Vienna: IAEA.

[16] IAEA. (2015). *The Fukushima Daiichi Accident*. - ISBN 978-92-0-107015-9. Vienna: IAEA, 218 p.

[17] IAEA. (2020). *Considerations for Environmental Impacts Assessment for Small Modular Reactors*. - IAEA-TECDOC-2915. Vienna: IAEA, 48 p.

[18] Ingersoll, D. T. (2016). *Small Modular Reactors: Nuclear Power Fad or Future?* - NY: Woodhead Publishing, ISBN 978-0081002520.

[19] Ismail, O. & Hendrickson, D. (2009). *What is the case for a security and justice focus in development programming? An assessment of the existing literature and evidence*. - Birmingham: Global Facilitation Network for Security Sector Reform, University of Birmingham.

[20] Keeney, R. L & Raiffa, H. (1993). *Decision with Multiple Objectives*. - Cambridge: Cambridge University Press, 569 p.

[21] Kittner, N., Lill, F. & Kammen, D. (2017). *Energy storage deployment and innovation for the clean energy transition*. - Nat Energy 2, 17125 [2017]. https://doi.org/10.1038/nenergy.2017.125

[22] Kralikova, R., Sokolova, H., Wessely, E. & Polak, J. (2013) *Approaches to assessment of hot environment*. - DAAAM International Scientific Book 2013. chapter 14. Vienna. DAAAM International. pp. 317-328. ISBN 978-3-901509-94-0

[23] Lim, M. (2010). *Environment-Strategy-Structure-Operations (ESSO) Business Model*. - In: Knowledge Management Module at Bangor University.- Wales. - [on-line] Available on - URL: http://www.communitiesofinnovation.com/L/Dr_Michael_Lim_%20Business_Model_Knowledge_Creation_and_Innovation_Lecture%209.ppt

[24] Liu, Z. & Fan, J. (2014). *Technology Readiness Assessment of Small Modular Reactor (SMR) Designs*. - Progres in Nuclear Energy. 70 (2014), pp. 20-28.

[25] Locatelli, G., Mancini, M. (2011). *The Role of the Reactor Size for an Investment in the Nuclear Sector: An Evaluation of Not-Financial Parameters*. - Progress in Nuclear Energy. ISSN 0149-1970. 53 (2011), 2, pp. 212-222. Doi:10.1016/j.pnucene.2010.10.002

[26] Lojan, R. (2015): *Ľudská dôstojnosť a hodnota ľudského života*. - In: Nové horizonty, Bratislava, ISSN 1337-6535, Vol. 9, Issue. 1, pp. 10-14

[27] Lukas, L. & Hromada, M. (2011). *Risk analysis in context of kritical infrastructure protection*. - Annals of DAAAM for 2011 & Proceedings of the 22nd International DAAAM Symposium, Volume 22, No. 1, ISSN 1726-9679, Katalinic, B. [ed.], Vienna, pp. 1469 - 1470

[28] Machleidt, P. (1994). *Nové demokratické formy hodnocení techniky za účasti veřejnosti*. - In: Teorie vědy 3 (1994), 1-2.

[29] Machleidt, P. (2005). *Hodnocení techniky (Technology Assessment) aneb jak zvládat technická rizika*. - In: Člověk a rozhodování - rizika a nejistoty. Praha: ČVUT.

[30] Margolis, R. M. & Kammen, D. M. (1999). *Underinvestment: the energy technology and R&D policy challenge*. - Science 285, no. 5428, pp. 690–692 (1999). http://www.jstor.org/stable/2898477.

[31] Mileva, A., Nelson, J. H., Johnston, J. & Kammen, D. M. (2013). *SunShot solar power reduces costs and uncertainty in future low-carbon electricity systems*. - Environ. Sci. Technol. 2013, 47, pp. 9053–9060. https://doi.org/10.1021/es401898f

[32] Mysak, L., Prochazkova, D., Dostal, V. & Prochazka, J. (2022). *Proposal of Reduction of Emissions of Marine Shipment*. - In: Understanding and Manageing Risk and Reliability for a Sustainable Future. ISBN 978-981-18-5183-4. Singapore: Research Publishing. DOI:10.3850/978-981-18-5183-4_R15-02-063-cd

[33] Narayan, D., Chambers, R., Shah, M.K. & Petesch, P. (2000). *Voices of the Poor: Crying Out for Change*. - Washington D.C.: The World Bank.

[34] Necesal, L., Lukas, L. & Jasek, R. (2011) *Measures for critical infrastructure protection in the Czech republic*. - Annals of DAAAM for 2011 & Proceedings of the 22nd International DAAAM Symposium, Volume 22, No. 1, ISSN 1726-9679, Katalinic, B. [ed.], Vienna, pp. 0843-0844

[35] NUVIA. (2016). *Market And Technical Assessment of Micro Nuclear Reactors*. - Washington: Nuvia Limited, 56p.

[36] Obama, B. (2017). The irreversible momentum of clean energy. – Science 2017, Vol. 355, Issue 6321, pp. 126–129. DOI: 10.1126/science.aam6284

[37] OECD. (2015). *Nuclear New Build Insights into Financing and Project Management*. - Paris: OECD.

[38] OECD. (2016). *Small Modular Reactors: Nuclear Energy Market Potential for Near-term Dep-loyment*. - Paris: OECD.

[39] OECD. (2021). Small Modular Reactors: Challenges and Opportunities. - Paris: OECD, 81 p.

[40] OECD: *OECD Statistics.- [on-line] Available on - URL:* https://stats.oecd.org

[41] Office of Technology Assessment. – [on-line] Available on - URL: http://ota.fas.org/otareports/

[42] Pannier, C. P. & Skoda, R. (2014). *Comparison of Small Modular Reactor and Large Nuclear Reactor Fuel Costs.* - Energy and Power engineering. 6 (2014), 4, pp. 82-94. DOI: 10.4236/epe.2014.65009

[43] Pedraza, J. M. (2017). *Small Modular Reactors for Electricity Generation.* - New York, NY, Berlin Heidelberg: Springer. ISBN 978-3-319-52215-9.

[44] Prochazkova, D. & Prochazka, J. (2020). *Analysis, Management and Trade-off with Risks of Technical Facilities.* - Praha: ČVUT, ISBN 978-80-01-06714-7. 172p. Doi:10.14311%2FBK.9788001067147

[45] Prochazkova, D. (2011). *Strategické řízení bezpečnosti území a organizace*. - Praha: ČVUT, ISBN 978-80-01-04844-3. 483 p.

[46] Prochazkova, D., Prochazka, J. & Dostal, V. (2021). *Risks of Power Plants with Small Modular Reactors*. - In: Proceedings the 31st ESREL Conference. Singapore: Research Publishing Services, ISBN 978-981-18-2016-8, pp. 124-131, Doi:10.3850/978-981-18-2016-8_125-cd

[47] Prochazkova, D., Prochazka, J., Rusko, M., Kollar, V., Majernik, M. & Ilko, J. (2020). *Safety Management of Complex Facilities*. - Proceedings of the 31st DAAAM International Symposium, pp.0366-0375, B. Katalinic (Ed.), ISBN 978-3-902734-29-7, ISSN 1726-9679, Vienna, Austria DOI: 10.2507/31st.daaam.proceedings.051

[48] Prochazkova, D., Prochazka, J., Rusko, M., Mikulová, M. & Iľko, J. (2017). *Model for critical infrastructure safety management*. - In Annals of DAAAM for 2017, Volume 28, No.1. The 28th DAAAM International Symposium. Zadar, Croatia, 08-11th November 2017. pp. 0602 – 0610. Vienna : DAAAM International, ISSN 2304-1382. ISBN 978-3-902734-14-3. DOI: 10.2507/28th.daaam.proceedings.085.

[49] Prochazkova, D., Prochazka, J., Říha, J., Beran, V., Procházka, Z. (2018). *Řízení rizik spojených s ukončením provozu technického díla a s předáním území do dalšího užívání*. - ISBN 978-80-01-06527-3. Praha: ČVUT, 114p. Doi:10.14311%2FBK.9788001065273

[50] Prochazkova, D., Prochazka, J., Říha, J., Beran, V., Procházka, Z. (2018). *Řízení rizik procesů spojených se specifikací a umístěním technického díla do území*. - Praha: ČVUT, ISBN 978-80-01-06467-2. 134p. DOI:10.14311%2FBK.97880010 64672

[51] Prochazkova,, D. & Rusko, M. (2017). *Relation between human system safety management and environmental management*. - In Journal of Environmental Protection, Safety, Education and Management. Vol. 5, No. 9, ISSN 1339-5270

[52] Prochazkova,, D., Wessely, E., Rusko, M. & Králikova, R. (2011). *Human System Safety Management and Environmental Management Relation*. - In DAAAM International Scientific Book 2011. pp. 103-118. ISSN 1726-9687; DOI: 10.2507/daaam.scibook.2011.09

[53] Projects – EPTA Network. – [on-line] Available on - URL: https://eptanetwork.org/database/projects

[54] Rip, A., Misa, T. & Schot, J. (eds). (1995). *Managing Technology in Society: the Approach of Constructive Technology Assessment*. - London: Pinter 1995.

[55] Roseveare, C. (2013). The rule of law and international development. Department for International Development (DFID), London, UK (2013) 87 pp.

[56] Roseveare, C. (2013). The rule of law and international development. – Literature review – not policy. – [on-line] Available on - URL: https://assets.publishing.service.gov.uk/media/57a08a0be5274a27b20003c7/Literature_Review_RoL_DFID-GSDCH-PEAKS_FINAL.pdf

[57] Rosner, R. & Goldberg, S. (2011). *Small Modular Reactors – Key to Future Nuclear Power Generation in the U.S.* - Chicago: University 2011, 81 p.

[58] Rusko, M., Kralikova, R. & Mikulova, M. (2016). The Management Tools and Methods Application of the Organization to Environmental Protection. - Proceedings of the 27th DAAAM International Symposium, pp.0283-0288, B. Katalinic (Ed.), ISBN 978-3-902734-08-2, ISSN 1726-9679, Vienna, Austria, DOI: 10.2507/27th.daaam.proceedings.042

[59] Schellnhuber, H. J., Rahmstorf, R. & Winkelmann, R. (2016). Why the right climate target was agreed in Paris. - Nature Climate Change, 2016, vol. 6, issue 7, pp. 649-653, https://doi.org/10.1038/nclimate3013

[60] Schot, J. (2001). *Towards New Forms of Participatory Technology Development. - Technology Analysis and Strategic Management* 13(2001), 1, pp. 39–52.

[61] Schot, M. & Rip, A. (1997). *The Past and Future of Constructive Technology Assessment*. - Technological Forecasting & Social Change 54 (1997), pp. 251–268.

[62] Stenberg, C. (2020). Energy Transitions and the Future of Nuclear Energy: A Case for Small Modular Reactors. - Washington Journal of Environmental Law & Policy. Vol.11, Iss.1(2020)

[63] Stewart, F. (2004). Development and security. - Conflict, Security & Development, 4:3, 261-288, DOI: 10.1080/1467880042000319863

[64] Stocker T.F. et al. (2013). Climate Change (2013): The Physical Science Basis. - Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge Univ. Press, New York, 1585 p. (pp. 33-115).

[65] Tarr, J. A. (ed.). (1977). *Retrospective Technology Assessment – 1976.* - San Francisco: The San Francisco Press.

[66] The importance of safety, security and justice. - [on-line] Available on - URL: https://gsdrc.org/topic-guides/safety-security-and-justice/concepts/the-importance-of-safety-security-and-justice/

[67] Trancik, J. E. et al. (2015). Technology Improvement and Emissions Reductions as Mutually Reinforcing Efforts: Observations from the Global Development of Solar and Wind Energy. - MIT, 78 p.

[68] UJV. (2017). *Design of the Active Zone and Feasibility Study of a Small Modular Reactor Cooled by Molten Salt.*- Řež: Centrum výzkumu 2017, 48 p.

[69] UJV. (2022). *Plan of Use of Constructed Energy Well Reactor in Practice*. - Řež: Centrum výzkumu 2022, 205p.

[70] UNDG. (2013). *A Million Voices: The World We Want*. - New York: United Nations Development Group.

[71] UNDP: What is human development?. – [on-line] Available on - URL: https://hdr.undp.org/about/human-development

[72] Van Eijndhoven. (1997). Technology Assessment: Product or Process? *Technological Forecasting and Social Change* 54 (1997), pp. 269–286.

[73] Vujić, J., Bergmann, R. M., Škoda, R. & Miletić , M. (2012). Small Modular Reactors: Simpler, Safer, Cheaper?*Energy*. - Proceedings of the ICE - Energy 45(1), pp. 288–29, 5ISSN 0360-5442. DOI: 10.1016/j.energy.2012.01. 078.

[74] World Nuclear Association: Small Nuclear Power Reactors. (Updated July 2023). - [on-line] Available on - URL: https://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/small-nuclear-power-reactors.aspx

[75] Zhang, Z. & Sun, Y. (2007). *Economic Potential of Modular Reactor Nuclear Power Plantas based on the Chinnese HTR-PM Project*. - Nuclear Engineering and Design. 237 (2007), pp. 2265-2274.

[76] Zheng, C. & Kammen, D. M. (2014). An innovation-focused roadmap for a sustainable global photovoltaic industry. - Energy Policy 2014, 67, pp. 159–169. https://doi.org/10.1016/j.enpol.2013.12.006

[77] Rip, A. (1999). *STS in Europe. - Science, Technology and Society 4(1999), 1, pp. 73-80.*