

## Challenges for Introducing Nuclear Energy Program in Small Embarking Country

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**Abstract.** Nuclear Energy Program (NEP) for each country, especially for newcomer countries is a long-term process with lot of challenges for the political establishment of the country, as well as for the institutions and all involved stakeholders. According to the IAEA recommendations, the process can be divided in 3 continuous phases. The achievement of the infrastructure conditions for each of these phases is marked by a specific milestone at which point the progress and success of the development effort can be assessed and a decision made to move on to the next phase. These 3 milestones are:

- Milestone 1: Ready to make a knowledgeable commitment to a nuclear programme;
- Milestone 2: Ready to invite bids for the first nuclear power plant (NPP);
- Milestone 3: Ready to commission and operate the first NPP.

Some aspects which are analyzed for the case of Macedonia as an embarking country for NEP are the following ones:

- Covering the energy needs in the future energy mix including all options for new generation capacities
- Establishing the necessary infrastructure and capacities for nuclear power option
- Human resources needs for NEP
- Transfer the technologies in nuclear power from vendors to the country
- Financing the high investment nuclear power plant

All these highlights are treated in the paper, taking into account the results from the appropriated studies made in the academic institutions and energy companies in the country. The potential opportunities for development the NEP in Macedonia can be used as a base document with lot of collected database of national education, industry and energy infrastructure in Macedonia for further studies and research.

**Keywords:** Nuclear Energy Program (NEP), embarking country, IAEA recommendations, alternatives for NEP development, Stakeholders for NEP.

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### 1 Introduction

Nuclear Energy Program (NEP) for each country, especially for newcomer countries is a long-term process with lot of challenges for the political establishment of the country, as well as for the institutions and all involved stakeholders. Some aspects which are analyzed for the case of Macedonia as an embarking country for NEP are the following ones:

- Covering the energy needs in the future energy mix including all options for new generation capacities
- Establishing the necessary infrastructure and capacities for nuclear power option
- Human resources (HR) needs for NEP
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country. The potential opportunities for development the NEP in Macedonia can be used as a base document with lot of collected database of national education, industry and energy infrastructure in Macedonia for further studies and research.

The paper presents short summary of the proposed concept for introducing nuclear energy program (NEP) in Macedonia. Nuclear Energy Program for each country, especially for newcomer countries is a long-term process divided into 3 continuous phases. The achievement of the infrastructure conditions for each of these phases is marked by a specific milestone at which point the progress and success of the development effort can be assessed and a decision made to move on to the next phase. These 3 milestones, presented in Figure 1 are:

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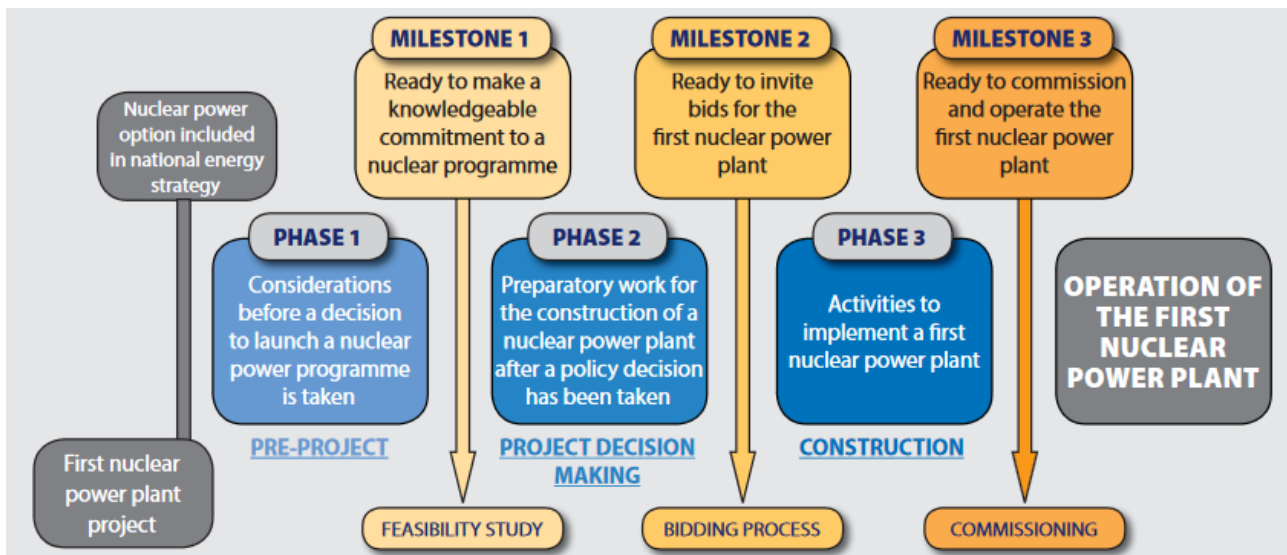


Figure 1. The phases in the development of a Nuclear Energy Program.

An organizational approach is proposed outlining the needs of the three main organizations:

- The nuclear energy programme implementing organization (NEPIO);
- The nuclear regulatory body (NRB);
- The nuclear power plant operating organization.

These organizations are analysed based on their respective responsibilities for the implementation of various infrastructure requirements through the successive phases of the programme. A wide range of technical competencies (both nuclear and non-nuclear), as well as leadership, general management and specific project management competencies will be needed to successfully implement the NEP. The number of required human resources for a nuclear power program in all three phases for a newcomer country in NEP is presented in Table 1.

Table 1. Staff for the three main organizations for the NEP

| Phase | NEPIO | NRB   | Operating organization of NPP |
|-------|-------|-------|-------------------------------|
| 1     | 10–20 | 0–10  | –                             |
| 2     | 20–50 | 40–60 | 10–30                         |
| 3     | 20–0  | > 60  | up to 700                     |

In terms of education/qualifications, during phases 1 and 2 of the development of nuclear infrastructure, most of the core staff should be of professional/high educational level required for national organizations NEPIO and NRB. However, when staffing of Nuclear Power Plant is in phase 3 of operation, highly professional staffs are the smaller part of the total workforce and the majority of the workforce is at the technical level of education. These employees should have less knowledge of nuclear energy, but should have adequate training in order to understand the quality and safety requirements for work in a nuclear environment because it is different from other engineering and industrial environments.

## 2 Affected Stakeholders for NEP in Macedonia

The long-term and sustainable nuclear energy program is related to several entities in the country that adequately participate. This section will identify stakeholders for NEP in Macedonia. Stakeholders for NEP in Macedonia, presented in Figure 2, can be divided into 4 categories:

- State and government entities;
- Entities in the energy sector that are most directly affected by the NEP;
- Industrial facilities and infrastructure;
- Academic entities that include the educational system in Macedonia.

As stakeholders by the state are government institutions represented by the following ministries: MF – Ministry of Finances, ME – Ministry of Economy, MEPP – Ministry of Environment and Physical planning, MJ – Ministry of Justice, MFA – Ministry of Foreign Affairs, MES – Ministry of Education and Science, MTC – Ministry of Transport and Communication.

Other government or state bodies that may be included in the NEP are:

- RSD – Radiation Safety Directorate
- ERC – Energy Regulatory Commission
- CMC – Crisis Management Centre

Government and state bodies can engage in building a national infrastructure of institutional capacities for the NEP as nuclear regulatory body (NRB) in the area of nuclear energy in Macedonia. Radiation Safety Directorate (RSD) has prepared legislation and international conventions in some parts that are associated with NEP. RSD has adopted a plan to protect the population in radiation emergency in Macedonia and Law on Ionizing Radiation Protection and Radiation Safety. Among other things, the competencies

| Stakeholders for NEP in Macedonia |             |   |  |                     |
|-----------------------------------|-------------|---|--|---------------------|
| State & Government institutions   |             | Power entities                              | Industrial entities                              | Academic entities   |
| Ministries                        | Reg. Bodies | Power production, transmission distribution | Design, construction and manufacturing materials | Education           |
| MF, ME, MEPP, MJ, MFA, MES, MTC   | RSD         | AD ELEM                                     | Civil engineering sector                         | Secondary schools   |
|                                   | ERC         | AD MEPSO                                    | Mechanical engineering sector                    | University programs |
|                                   | CMC         | Distribution companies                      | Power engineering sector etc.                    |                     |
|                                   |             |   | Civil Eng. Sector and materials...               |                     |

Figure 2. Classification of stakeholders for NEP in Macedonia.

of the RSD has about permits and licenses for carrying out activities with sources of ionizing radiation, leads the National Register of sources of ionizing radiation of occupationally exposed persons, as well as register of nuclear material.

2.1 Status of staff potential of the energy companies AD ELEM and MEPSO

For the study needs, detailed data are processed for both major energy companies ELEM and MEPSO. The situation with human resources potential in both companies is made based on data obtained from the person responsible for human resources in companies with sectional time for November 2016.

AD ELEM with its production capacities produce about 5000 to 6000 GWh electricity per year which is about 70% of the country needs. The last few years, Macedonia imports about 30% of electricity needs which is around 2500–3000 GWh per year. The company in November 2016 has total of 4032 employees of which have personnel with high education, technical staff and others. AD MEPSO is responsible for the transmission of electricity from producers and/or importers of electricity to distribution companies and direct customers. This company as a legal entity according to the Energy Regulation is publicly state national company that manages the 110 kV and 400 kV substations and transmission lines. From the total number of employees (563), with a university diploma is 179 staff, or about 32%. Technical staff responsible for maintaining the equipment and plant themselves in AD MEPSO is 136 employees or 24%.

From the analysis of two leading companies in the power engineering sector in Macedonia can be seen that they have over 4500 employees of which 750 are highly educated, and around 2800 are technical personnel.

2.2 Industrial potential for development of infrastructure

One of the main criteria for the decision to enter the country in the NPP is the readiness of the national infrastruc-

ture of industrial potential in a country. Since NEP includes long-term process with multiple stages and activities involving several entities of the highest state and government institutions to separate bodies NEPIO, NRB, energy and other companies, requires proper readiness of the national economy and industry. In the activities which may not include domestic industry, will certainly be involved and other foreign companies. However, the industry should have specific competencies and requirements for certain activities in the stages of NEP. The industrial infrastructure in Macedonia as stakeholder can engage in certain activities and stages of the NEP like as construction companies, companies in the machinery and metal processing business, companies of electrical engineering activity, production companies of certain materials and others.

In Phase 1 and 2 of analyzes and studies for the NEP can include in a laboratory, geotechnical and geological investigations, investigations of materials, hydrological surveys and others.

Designing, engineering and supervision of construction facilities in the area of infrastructure facilities such as roads and railways, hydro facilities of dams, canals and other special purpose equipment required for NEP.

In phase 3 of implementation of building infrastructure facilities of NPP on the building itself with its own mechanical equipment and machinery, own technical and operational staff and personnel to the final performance.

National companies which can participate in different phases of NEP are entities for the production of materials and equipment in the civil engineering and metal industries and metal structures. There are other smaller industrial entities of civil engineering, mechanical engineering, power engineering, information and communications technology sector, and the production of the materials that may be included in certain phases of activities of the NEP. There are a large number of enterprises in the field of design, engineering, construction and supervision that certainly participate in domestic industrial activity and are involved in international, regional or broader projects.

### 2.3 Educational system relevant for HR needs in NEP

The Macedonian education system will be analyzed in terms of the needs of NEP, i.e. those occupations and programs that are needed in the first two phases of the NEP. Analyzes take into account the secondary schools and the faculties in the three levels of higher education, or 1 degree of undergraduate studies, 2nd degree of master studies and 3rd degree of doctoral studies.

Lead role in the educational system in Macedonia to create professional staff (technical staff and craft activities) have secondary education with vocational schools in certain professions. The data of the curriculum of secondary schools appropriate for the NEP are taken from the Vocational Education and Training Centre of the Republic of Macedonia and the Office for Development of Education.

University academic degree obtained in higher education into three levels: undergraduate, postgraduate and doctoral studies. This section presents the studies competent for certain professions required to create staff for NEP in Macedonia. For the HR purposes to create a national NEP an analysis of the curricula (education programs) of undergraduate and postgraduate studies in the universities in Macedonia is made according to the following groups of profiles:

- Technical sciences
- Natural Sciences and Mathematics
- Medical Sciences
- Social Sciences

### 2.4 Development of human resources for NEP in Macedonia

The decision to enter into long-term and sustainable nuclear energy program of a country requires a detailed and multiyear analysis of several aspects such as: energy needs by NPP in the country, financing options and opportunities, human staff, national institutional infrastructure, development of the industry with the opportunity to engage in various stages of NEP and others. In order to define the goals for NEP in a country and the impact of competence of certain affected institutions and entities, detailed analysis are required:

- Type of contract (Turnkey, Build-operate-transfer (BOT) or build-own-operate-transfer (BOOT)).
- Type of financial funds depending on the type of contract
- Level of industrial development
- Necessary human resources for long-term and sustainable NEP

Countries should recognize the situation and find the gaps that need to be covered to get an adequate national infrastructure and facilities for NEP.

Based on the recommendations for the establishment of NEP, the experience of other countries that are far entered the NEP and already have operating nuclear power plants,

and of course taking into account the situation of the domestic economy and education, a comparison of the necessary staff for the implementation of NEP in phase 1 and phase 2 is made.

Certainly the creation of the necessary human resources and staff for NEP in a country depends on the policies and objectives of the Government for this program. Because Macedonia is a relatively small country with a weaker economic power, the initial steps in the NEP should start with their own staff from the energy sector, the academic community and with support of the state institutions (ministries and bodies already established as RSD).

At a later stage, depending on the decisions of the Government, in case of continuation of the NEP, additional appropriations and/or donations in kind of material equipment and scholarships for training courses and training of the necessary staff, as established bodies NEPIO and NRB, and the other affected stakeholders (energy companies and state institutions).

The first two items (preparation and evaluation of technologies) are in phase 1 of the NEP. Preparation period can be achieved with 20-30 professional staff personnel in NEPIO, need to prepare the necessary documentation for prefeasibility study. After deciding on the construction of NPP, continues with phase 2 procedure of procurement of technology and tender procedure for final selection and supplier of technology of the NPP.

The experiences of other countries that already have nuclear energy program and NPP in operation, show that the necessary personnel for the operator of the NPP are formed during the construction of the NPP, depending on the chosen technology of nuclear reactor.

For each country that develops a NEP, the workforce plan will be different, based on the following factors:

- Forcing the main objective of building a nuclear power program;
- The strategy of creating a NEP (fully “turnkey” or transition to maximum forcing the domestic industry) and subsequent relationship with the vendor;
- Availability of nuclear expertise from non-energy applications (industry, medical, agriculture, applied sciences);
- Access to available international nuclear expertise;
- Existing (if any) nuclear educational programmes;
- Availability and quality of non-nuclear workforce.

Workforce planning is an essential, ongoing human resources management process. Each organization involved in the NEP should develop and maintain its own workforce plan. At least for Workforce planning is defined as: systematic identification and analysis of what an organization (and a country) is going to need in terms of the size, type and quality of workforce to achieve its objectives. It determines what mix of experience and competencies are expected to be needed, and identifies the steps that should

be taken to get the right number of the right people in the right place at the right time.

If only a single unit NPP is planned, then it may not be appropriate for a Member State to develop all the competencies identified in [1], particularly those for the design, construction and commissioning of the plant. In this case, the Member State should focus on developing and maintaining the internal competencies to operate and maintain (and eventually decommission) the plant in a safe and secure manner and may contract out many of those competencies required during Phases 1 and 2 of the programme.

An additional consideration is the extent to which national capability is to be embedded in particular organizations or used as a shared resource. At one side, each organization (NEPIO, NRB, operating organization) may be developed to have all the capabilities and resources it needs to fulfil its responsibilities employed within that organization, but at the cost of higher overall resource requirements. At the other side, independent expert groups/organizations may be developed and strengthened for providing technical support to the various responsible organizations.

### 3 Concept and Alternatives for NEP Development in Macedonia

Based on the IAEA’s recommendations, the experience of many countries that have NEP and NPP operation, with taking into account national occasions, some investigations about NEP in Macedonia are done in past several years. The decision of entry of Macedonia in NEP should bring state institution (the Government, Parliament) with establishment of a nuclear energy program implementation organization (NEPIO). This government body should form under the authority of the Ministry of Economy which is responsible of the energy sector. The role of this body in the period of about 5-8 years is to prepare enough analysis and documentation in the form of Prefeasibility Studies for all 19 issues for NEP in the country.

NEPIO as a responsible organization, regardless of the decision on NEP in Macedonia, should continue to drive and

implement all activities necessary studies, research and analysis and prepare appropriate documentation for the decision of the Government to develop NEP in Macedonia.

Figure 3 presents proposed timetable for establishing the necessary infrastructure for NEP. After the implementation of the activities in phase 1, the government should make a decision about entering the NEP. In case of a positive response, in phase 2 continue to intensify activities such as:

Variants for construction of the NPP (own) or in joint regional project as well as options for financing and construction, tender procedures for the nuclear technology selection, informing the public about the options for the development of NEP in Macedonia and others issues.

At this stage it should be establish NRB - nuclear regulatory body depending on the chosen alternative for NPP. This body should have appropriate HR with knowledge and competences to issue licenses for operators of NPP, licenses for certain activities in nuclear energy in terms of dealing with nuclear fuel, NPP operators and others.

The analysis considers two variants of NPP construction in phase 2:

- Alternative 1 – to Build Own NPP in Macedonia
- Alternative 2 – Participation in the regional project of NPP in another country

The continuation of Phase 3 with NPP construction depends on chosen variant.

#### 3.1 Alternative 1 for construction of own NPP in location in Macedonia

Alternative 1 is an option on the development and construction of own NPP in the location in Macedonia. This option requires more active domestic governmental institutions and stakeholders as well as higher funding for implementation. This variant is an opportunity for the benefits of energy produced, but certainly requires higher duties and responsibilities. This option is certainly the best

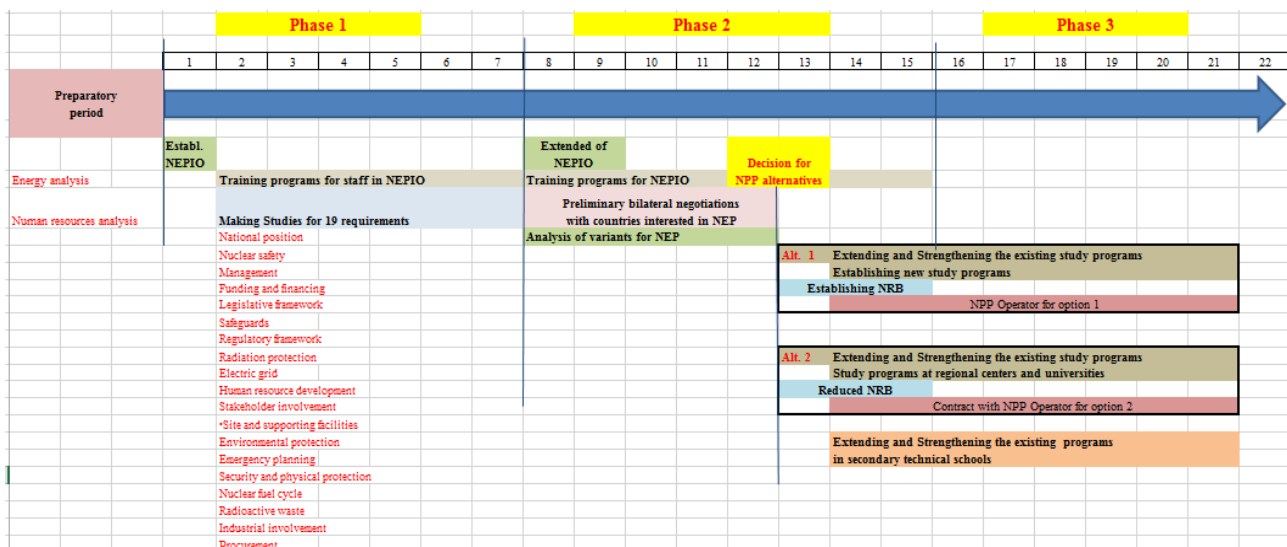


Figure 3. Proposed timetable for establishing the necessary infrastructure for NEP.

in the case of commercial use of SMR – Small Modular Reactors with a capacity from 100 to 300 MW per one unit of NPP, which in energy and installed capacity as well as financial terms are most favourable for Macedonia. Build units with high power (1000 MW) which are now commercially available on location in Macedonia, a variant with greater financial needs, which could participate and other external entities. Of course, no matter what power the NPP would be built at locations in Macedonia, the obligation of the country is the establishment of national bodies (NEPIO, NRB), industrial support of the project, and the operator whose responsibility it the safe operation of the plant.

This option requires high financial resources for building and strengthening national bodies (NEPIO and NRB), and long-term programs for sustainable development of human resources required for operation and maintenance of NPP. This option means strengthening the industrial sector to be involved in the operation, maintenance, supply services and other activities for NPP.

### 3.2 Alternative 2 for participation in a regional project of NPP abroad

Alternative 2 for Macedonia is to participate in a regional project of NPP, bringing together human resources and financial assets of more participants (companies or countries), involved in construction, operation and maintenance of NPP. This option means some limited available energy and management of NPP. All obligations and duties depend on the contract to reach participants in the joint project of the NPP construction.

In this case it should be contracted bilaterally with the

country where the NPP is located, as well as the owner and operator for the details of the investment, maintenance costs and required staff for NPP. Other issues for negotiations should be the benefits of energy production and of course the responsibilities in certain situations. In this option, the responsibility for NPP safe operation is the country where NPP is located as well as the operator.

This option takes far lower funding for building and strengthening national bodies (only NEPIO) and personnel that would be required under the contract for training in regional centres or country where the NPP is located. In this case, the industrial sector would be involved in the items of the contract or on a commercial basis for the required technical and other services for NPP. Table 2 compares the entities involved in infrastructure for NPP in phase 2 for both alternatives.

Alternative 1 is actually a comprehensive national involvement and responsibility for implementation of NEP in the territory of Macedonia. This option will require capacity building and the people involved in the NEP in Macedonia, starting from the highest governmental ministries, national bodies as the NEPIO and NRB, to the industrial sector and creating large educational programs for NEP. This of course entails higher long-term financial needs for phase 1 and phase 2 of the NEP.

Alternative 2 is a reduced form of national participation in the NPP on the territory of the country in the region with the joint participation of several entities. It means reducing the staff for NEPIO and the NRB can have a reduced form. Personnel can be realized with the staff by strengthening the existing curricula of universities and training centres using the programs at universities in the region.

Table 2. Comparing the HR needs and national infrastructure for NPP in phase 2 for both alternatives.

| Stakeholders in Phase 2      | Alternative 1<br>Own NPP in location in Macedonia  | Alternative 2<br>Participation in the regional project of NPP abroad                             |
|------------------------------|--|--|
| Ministries in the Government | Strengthening the capacity of ministries, Bilateral agreements   | Negotiations for participation in the regional project of NPP                                    |
| NEPIO                        | Strengthening with 20-50 staff   | Same as in Phase 1 with 20-30 staff  |
| NRB                          | Establishing the NRB with 50 staff   | Without NRB or reduced NRB   |
| Training programs for staff  | Regional Training Centres<br>Opening National Training Centres   | Regional training centres with relevant programs under contract and needs                        |
| Study Programs (SP)          | Completion of the appropriate study programs on the universities<br>New study program in nuclear engineering and nuclear physics | Regional educational centres<br>Completion of the appropriate study programs on the universities |
| Industrial Sector            | Strengthening existing and capacity building for NEP. Technology transfer  | Partial involvement with capacity building   |
| Owner / Operator of NPP      | Public state enterprise<br>Private Partnership based on BOO, BOOT  | Operator abroad, participation in investment and maintenance costs, and human resources.         |
| Funding for HR and staff     | High budget for establishing a national infrastructure as the NEPIO, NRB and personnel for NPP                                   | Lower budget only for NEPIO and for the staff of NRB agreed upon                                 |

#### 4 Proposal for the Development of Human Resources for Establishing NEPIO in Macedonia

By forming the NEPIO in Macedonia start the analysis of NEP in Macedonia in phase 1. NEPIO should be established under the authority of the Ministry of Economy which includes the energy sector. As staff and legal entities that can participate in NEPIO in Phase 1 are given in the following Table 3 and Figure 4.

Each of the proposed entities would participate in NEPIO and would be engaged accordingly their competencies and needs of NEPIO. NEPIO staff should be included in training programs organized by the IAEA or other relevant institutions. For staff and experts who are deficit in Macedonia (reactor physicists, nuclear energy engineers, experts on nuclear fuel and radioactive waste treatment) to be formed or to engage external experts from other countries.

In phase 2 if the decision to enter the NEP is positive, it is necessary to strengthening HR in NEPIO with preparing the appropriate documentation for further activities in order to help in governmental decision on NPP construction (alternative 1 or alternative 2).

Depending on the decision to be adopt it should be estab-

lished a national nuclear regulatory body (NRB) in complete form (for alt.1) or in reduced form or not to provide any form for NRB (for alt.2)

The process of training programs and courses for appropriate personnel in the departments of NEPIO should continue in Phase 2 and 3. For alternative 1, the NEPIO should be strengthened with more staff (50) which means a greater number of training programs. If passed alternative 2, the NEPIO can continue in the same form as the phase 1.

Alternative 1 means expanding the existing study programs (SP) at universities in Macedonia, as well as the establishment of new study programs in the field of nuclear reactor physics and nuclear engineering. These study programs are necessary for staff both in NEPIO, NRB as well as for sustainable staffing structure for the NPP operator.

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Table 3. Legal entities participating in NEPIO in phase 1

| Departments of NEPIO and responsibilities                             | Stakeholders and possible subjects as participants   | Organizational structure and (Number of staff)  |
|---|--|---|
| Department 1<br>Regulatory authorities                                | Ministries of Economy, Finance, Environment and Spatial Planning, Education, External and Internal Affairs, RSD and ERC              | Engineering staff and administration (2-3)  |
| Department 2<br>Information and public relations                      | Energy companies<br>Information and media  | Engineers of energy sector, professional journalists (1-2)                                |
| Department 3<br>Technical support                                     | University staff,<br>ELEM and MEPSO  | Engineers of electrical, energy, civil and mechanical profession and from IT sector (2-4) |
| Department 4<br>Commercial matters                                    | Ministries of<br>Economy, Finance, and External Affairs  | Economists, commercial and financial experts (1-2)  |
| Department 5<br>Legal and regulatory framework                        | Ministry of Justice,<br>Ministry of Environment, RSD   | Law experts and staff from ecology and environment (1-2)                                  |
| Department 6<br>Energy Markets and technologies for gen. electricity  | Departments of development from<br>ELEM and MEPSO, ERC   | Engineers of electrical, energy and mechanical profession (1-2)                           |
| Department 7<br>NPP Technologies and Nuclear fuel cycle               | Consulting firms with appropriate knowledge of the NPP technologies, experts from Universities and Academia, ELEM and MEPSO. RSD     | Nuclear engineers, Nuclear physicists (1-3)   |
| Department 8<br>Environmental Impact Evaluation of NPP Site Selection | Consulting firms with appropriate knowledge of the NPP technologies, experts from Universities and Academia, Ministry of environment | Engineers of civil, mechanical and ecology, nuclear physicists (1-3)                      |
| Department 9<br>Financial models for NPP                              | Consulting firms with knowledge of NPP technology and financial analysis, experts from Universities and Academia, ELEM and MEPSO     | Financial experts (1-3)   |
| Department 10<br>National industry Support for NEP                    | National infrastructure capacities in construction, mechanical, electrical and other technical sectors                               | Engineering staff (1-3)   |

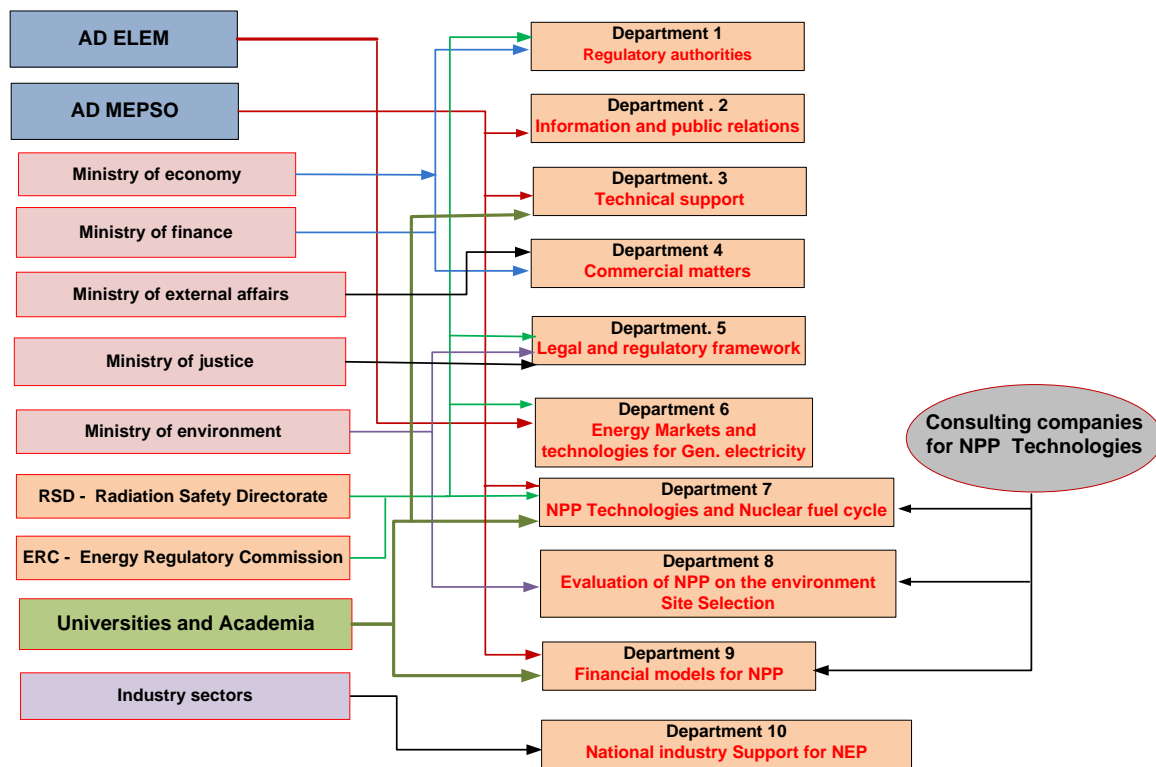


Figure 4. Scheme of the draft concept for NEPIO in Macedonia

### 5 Establishing the NRB for NEP

For the implementation of NRB for NEP in Macedonia, according to the requirements and needs, the situation is more complex. This NRB should be formed later than NEPIO in phase 2 after a positive decision to enter the NEP. As alternative proposal in phase 2 for the formation of NRB at an early stage can make expanding Directory for Radiation Safety (RSD), with appropriate departments with competencies needed for this body. RSD has already delivered a number of legal acts and conventions as well as legal norms in the area of radiation and radiation ionization plan of action in case of radiation hazard or accident, etc. Necessary human resources would be filled by existing staff and additional external experts with appropriate licenses. If the decision to construct the NPP in phase 2 is positive, depending on the alternative chosen this body should therefore be extended with human staff competent for the NRB.

Alternative 1:  
Own NPP in Macedonia

It is necessary to create NRB with full competences as an opportunity to cover the following issues:

- technology of nuclear reactors;
- technology of fuel cycle;
- engineering techniques and technical issues;
- radiation protection as applied to nuclear facilities and industrial use of radioactive sources;
- nuclear safety including risk analysis.

Necessary staff for NRB in the following areas (Table 4).

Table 4. Necessary staff for NRB

| Field to be covered                             | Staff                                |
|---|--------------------------------------|
| Nuclear Engineering                             | Forming new staff                    |
| Nuclear physics                                 | Additional training of local experts |
| Nuclear chemical                                | Additional training of local experts |
| Science of materials                            | Forming new staff                    |
| Mechanical, civil construction, earthquake eng. | Local experts                        |
| Electrical, energy and IT science               | Local experts                        |
| Environmental protection                        | Additional training of local experts |

Alternative 2:  
Participation in the regional project of NPP abroad

NRB can be reduced within the RSD or may not exist, because many of the obligations referred to variant 1, has national regulatory authority (NRA) which is located the NPP.

### 6 Study Programs for NEP

Study programs (SP) for NEP in Macedonia should be established in phase 2 after deciding which alternative of NPP realization would go Macedonia. If the decision is for alternative 1 of own NPP construction in Macedonia, then the following activities in study programs are necessary. Strengthening of existing and establishment of new study programs (SP) for NEP in phase 2 for alternative 1.



Establishing of a new joint interdisciplinary study program SP in nuclear physics and chemistry with materials in Faculty of Physics and Chemistry and Faculty for Technology and Metallurgy.

In alternative 1, it is necessary to establish the SP in nuclear engineering at technical faculties of engineering studies. Therefore, in the case for alternative 2, it is best to strengthen the existing curricula of technical faculties with additional courses as well as alternative 1, and the staffs in nuclear engineering are covered by study programs abroad. Accordingly contract in alternative 2 and staff needs, the nuclear engineering students from Macedonia would be sent an undergraduate degree studies, or graduates in Macedonia would go to higher degree, master or PhD studies.

## 7 Conclusion and Recommendations

The paper presents the investigation and gives the recommendations for the development of NEP in Macedonia in long period of over 20 years, which includes the preparation period (current period), phase 1 and phase 2 with continues in phase 3. It is proposed two realistic options for the construction and operation of NPP, alternative 1 for NPP construction on in Macedonia and alternative 2 to participate in regional NPP project in the region. The presented concepts of establishing NEPIO and NRB takes into account the structure of the bodies as well as the staff needed with appropriate competencies.

The implementation of the NEP in the country, especially for new beginner countries, entering the NEP is quite long and uncertain about the duration and outcome of the same activity. The complexity of the NEP implementation opens a number of risks that can be classified as:

- Risk in the options of developing the energy policy of the country;
- Political risk of rupture or standby state of the NEP to further favorable political circumstances;
- Financial risk for program implementation;
- Ensure appropriate quality and competent staff of all professions;
- Risk of outcome of public opinion and / or referendum decision on NPP construction.

Current situation of most countries in the region that do not have the resources for NEP and NPP, among which also include Macedonia:

- Insufficient human resources to support the infrastructure for the NEP;
- Insufficient educational structure to develop staff for NEP; and
- Lack of financial resources to support their development.

Possible solutions to overcome the gap in the short period:

- sharing resources on a regional basis with countries that already have institutions available for training programs
- Using the resources of the country supplier of nuclear technology is an effective way to establish national human resources.

Medium term development of personnel for NEP:

- sending junior engineers and technologists in international academic and nuclear training centers for the use of financial assistance from the IAEA and other international organizations;
- Sending the students of regional universities on studying programs of NEP;

Long term development of personnel for the NEP:

- Development of national centers for academic education and training.

Taking into account all the circumstances (political, macroeconomic, social, energy, etc.) in Macedonia and the region, as well as experiences in other countries, should make identification of specific risks that may occur in certain phases of development of NEP.

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