Nuclear R&D Policy Implementation Trend Analysis during 2012 to 2021: Comparing 4th and 5th Nuclear Policy Promotion Plan

Youngjune Kim [a*], Youngjoon Lee [b], Youngwoo Lee [b], Eunje Lee [b]
[a] *International Cooperation Team, Korea Atomic Energy Research Institute*
[b] *Nuclear Policy Research Department, Korea Atomic Energy Research Institute*
* *Corresponding author: youngjune@kaeri.re.kr*

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1. Introduction

Nuclear technology development, inherently prolonged, expensive, and fraught with risks, relies heavily on sustained policy frameworks [1]. Due to these characteristics of nuclear technology, the development of nuclear energy requires a consistent investment of public resources over a long period of time, which naturally results in other characteristic of nuclear technology, i.e. socio-political construction.

This analysis aims to empirically analyze the implementation trend of nuclear research and development (R&D) policy comparing before and after policy change, focusing on research projects composition and knowledge network during 2012 to 2021. While existing literature predominantly addresses higher-level policy path dependence [2], scant attention has been given to micro-level policy tendencies. This research bridges the gap by scrutinizing R&D policies as sub-policies within the nuclear R&D domain.

2. Research Scope and Method

2.1 Research Scope

The conceptual scope of this study is the implementation of nuclear research projects as a result of nuclear policy formation. The policy implementation in the policy science is what happens after the formation of a policy (e.g. a law, plan, and policy direction) that is about decisions on what to do, how to use resources, and who is responsible for what [2]. While a policy made at a higher level decision makers provides a guideline, an implementation policy develops it into the action plan by administrators who has discretionary powers [3]. As figure 1 shows, once the policy formed after decision made high-level elected politician, the policy at the implementation stage is inevitably affected and reviewed to change.

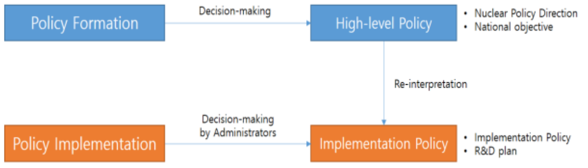


Fig. 1. The Process of Policy Formation and Implementation

The temporal scope covers a 10-year period from 2012 to 2021. This period includes the period of the 4th Nuclear Power Promotion Plan (2012-2016) and the 5th Plan (2017-2021). Particularly, there was the focusing event that the presidential election in 2017 resulted in dramatic policy change in nuclear policy to the nuclear phase-out policy (탈원전, *tal-won-jeon*). This case could empirically show how the high-level policy (i.e. nuclear policy direction led by higher decision-maker) change impacts to the implementation policy (i.e. nuclear research policy program and projects).

2.2 Research Method

This research employs descriptive statistics and network analysis to dissect trends and structural features of nuclear energy technology development projects.

The data collection is basically focused on each research project funded by the Ministry of Science and ICT within the framework of Nuclear Research and Development Program (NRDP, 원자력연구개발사업, *wonjareok-yeongugaebal-saeup*). 5,628 research projects implemented from 2012 to 2021 were collected through the National Technology Information Service (NTIS), with an average of about 563 research projects per year. Among them, a total of 1,656 research projects categorized in the Nuclear Technology Development Program (NTDP, 원자력기술개발사업, *wonjareok-gisul-gaebal-saeup*) were supported in 14 sub programs over 10 years, with an average of about 165 research projects per year.

The data extracted from each project were composed of project name, budget, principal investigator, institutional affiliation, research summary, and keywords, etc. In particular, the keywords suggested by who is in charge of the project were used for the keyword co-occurrence network analysis. A total of 655,290 data were extracted and secured from 5,628 research projects through the refinement process and applied to the data analysis. The network analysis was conducted by performing network property analysis, centrality analysis, and cohesion analysis, respectively [4].

3. Analysis Result

3.1. Project Composition Trend

As shown in the figure 2 below, a total of 5,628 research projects were supported by the Nuclear Research and Development Program from 2012 to 2021, with an average of about 563 projects per year.

Looking at the trend in the composition of the projects in each period, a total of 3,226 projects were supported during the Fourth Nuclear Power Promotion Plan and the First Radiation Promotion Plan (2012-2016), while a total of 2,402 projects were supported during the Fifth Nuclear Power Promotion Plan and the Second Radiation Promotion Plan (2017-2021), a decrease of 824 projects in terms of quantity.

Fig. 2. Numbers of nuclear R&D Projects in NRDP by year (2012-2021)

The nuclear technology development program was supported as a single program, but was diversified in 2017 with the establishment of 13 new subprograms.

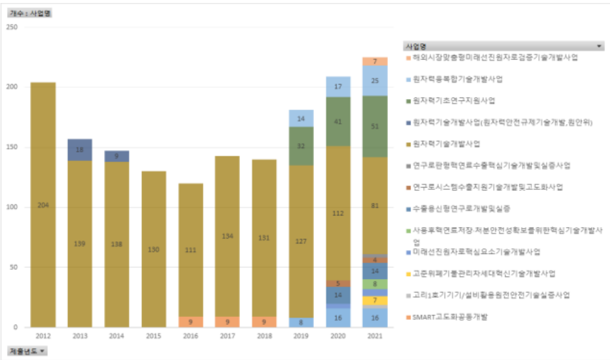


Fig. 3 NRDP R&D Subprograms Composition by year

In terms of R&D stage, from 2012 to 2016, more research projects were funded for applied research than basic research, but from 2017, applied research was reduced and basic research was expanded. In particular, the number of applied research projects decreased from 51 in 2016 to 34 in 2017, while the number of basic research projects doubled from 42 to 84.

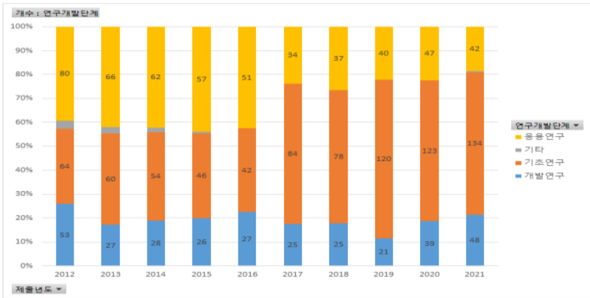


Fig. 4. Yearly Composition of Projects by R&D stage (NTDP)

In terms of research entities, participating research institutes accounted for about 70% of the projects in all periods, followed by universities at 24.5%, SMEs at 2.96%, and large companies at 2.23%. The proportion of R&D conducted by universities was the lowest in 2016, but it gradually increased from 2017, and in 2021, they organized and conducted a total of 73 research projects.

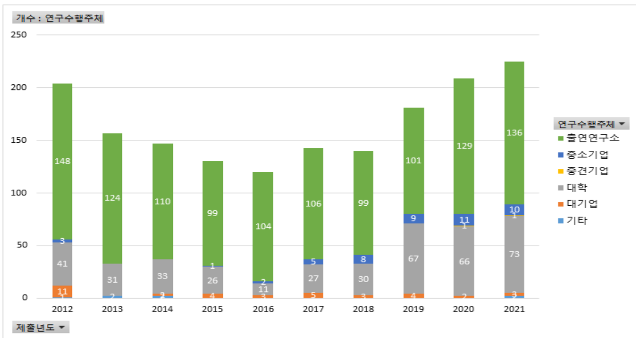


Fig. 5. Yearly composition of Projects leading Entities (NTDP)

3.2. Knowledge Network Trend

The results of keyword network analysis confirms the clear differences between the Fourth and the Fifth as show in the figure 6. The number of links decreased from 202 to 105, the density decreased from 0.079 to 0.023, and the average connectivity changed from 5.6 to 2.1. The difference in concentration is stark, dropping from 22.3% to 6.2% during the Fourth Plan. This is because government research support for NTDP during the Fourth Plan period was focused on relatively specific research topics to achieve specific goals, while sporadic and new research topics were supported during the Fifth Plan period, resulting in differences in knowledge network composition between the fourth and fifth periods.

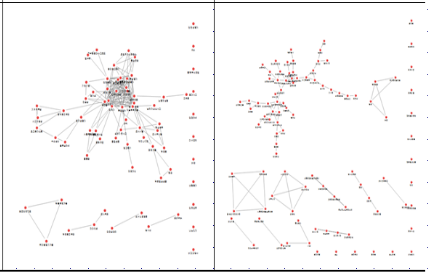
구분	제4차 원자력진흥종합계획, 제1차 방사선진흥계획 (2012~2016)	제5차 원자력진흥종합계획, 제2차 방사선진흥계획 (2017~2021)
연결정도 (# of links)	202	105
밀도 (Density)	0.079	0.023
평균 연결정도 (Average Degree)	5.6	2.1
집중도(%) (Degree Centralization Index)	22.3	6.2
파당 개수 (# of Cliques) (최소 연결노드: 3)	26	18
네트워크 지도 (circular map)		

Fig. 6. Comparing the Network Property between 2012-2016 and 2017-2021.

A comparison of the centrality analysis of the keyword network shows the most influential and centralized research topics. While the knowledge networks developed during the Fourth Plan (2012-2016) mainly centered on research topics such as the development of specific nuclear systems (e.g. Sodium Fast Reactor), the Fifth Plan (2017-2021) has seen the emergence of new research topics, such as *nuclear safety, spent fuel, decommissioning, digital twins, and artificial intelligence*, resulting in a new knowledge network that differs from the Fourth Plan.

4. Conclusions

This analysis examines how executive policies for nuclear R&D change in response to changes in the socio-political environment in terms of project composition and knowledge networks.

The results of the analysis are summarized below. Firstly, we found that although the number of projects supported through the MTDP program through the support of MSIT has decreased, a number of new sub-programs at the basic research stage have been formed due to the reduction of existing projects at the applied research stage. At the same time, the participation of universities has increased significantly.

Secondly, the knowledge network has expanded significantly since 2017, but its number of links and density have decreased significantly. Meanwhile, the number of cliques, the sub-networks that make up the overall network, has decreased, but it is difficult to see a significant difference on the network map constructed through visualization.

Thirdly, the centralization analysis, which represents core research topics, also confirmed the change in the knowledge network. If the research projects from 2012 to 2016 were mainly composed of projects in the applied research stage related to the development of specific systems, from 2017, the network expanded with the emergence of new research topics related to digital twin and ICT along with safety-related research topics. In other words, in terms of research topics, we found a change from a trend of concentrated support in a specific field to a form of expansion to new topics.

The analysis is notable in that it empirically confirms the socio-political characteristics of nuclear energy by focusing on research and development projects as examples of research implementation policies.

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It is also important to note that public investment in nuclear energy can be fundamentally influenced by the socio-political environment. This is because research policy on future nuclear systems, such as small modular reactors and advanced nuclear systems, for which there is currently a wide variety of research being conducted in parallel, is also influenced by the environment. This naturally suggests that the development of nuclear technology requires a different strategy tailored to the characteristics of each technology, and it is hoped that this will be complemented by further research.

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