A Development of Key Performance Indicators for the Public R&D of Energy Technology using Balanced Scorecard Approach

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Abstract—**The purpose of this paper is to develop a BSC framework for measuring the performance of public R&D projects of energy technology, along with a series of performance indicators for use with the proposed evaluation framework. As a result, we developed a new BSC framework for public energy R&D project which is composed of perspectives including 'energy industry,' 'performance,' 'R&D processes' and 'infrastructure.' Furthermore we suggest critical success factors for each perspective and relevant performance indicators by which the performance of a public energy R&D project can be measured properly.**

Index Terms—**balanced Scored, energy, performance indicator, R&D performance**

I. Introduction

ENERGY security is closely linked to the political and economic stability of a country and is vital for all nations. To achieve this imperative, governments around the world are investing heavily in R&D in the energy field. Energy research is indispensable also for a country's capability to effectively respond to changes in the external environment and for their overall technological competitiveness. In advanced countries, the center of gravity in national R&D policy has already shifted toward the energy and environmental technologies [1]. In Korea, government-funded energy technology research programs began in the late 1980s, and this field is today one of the key R&D areas receiving considerable public funding. As can be seen in Fig. 1, the percentage share of energy R&D in the overall R&D funding from government and public sources amounted to about 9% in 2012. The Korean government's investment in energy R&D is expected to grow continuously, going forward. A funding plan for energy research is, besides, set forth in the 'National R&D Total Roadmap,' a master plan established by the National Science and Technology Council, in 2006.

The government's effort to strengthen national competitiveness in various technology fields including energy technology not only leads to a continuous expansion in R&D investment but also results in a structurally more complex R&D system. Yet, there is no proper management system to comprehensively integrate and coordinate the increasing number of R&D projects funded by the government. It is, therefore, no accident that R&D programs by the public sector draw criticism for their inefficiency, with bureaucratic inertia often cited as the main culprit. Government R&D programs, as a matter of fact, leave much to be desired in terms of efficiency, compared to private-sector R&D [2]. The first step toward resolving the issue of efficiency plaguing government R&D programs is creating a performance evaluation system to track progress in each program and developing consistent performance indicators.

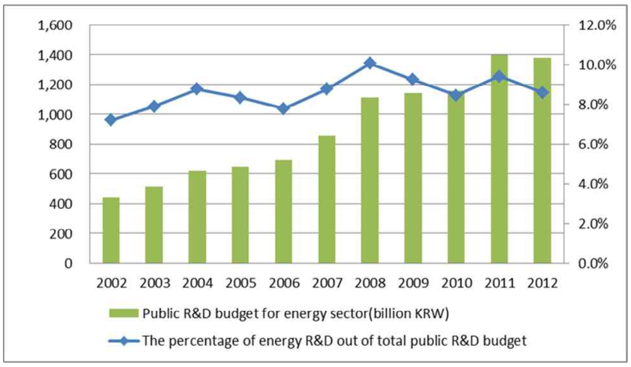

Fig.1. Trend of R&D investment in energy

The government's effort to strengthen national competitiveness in various technology fields including energy technology not only leads to a continuous expansion in R&D investment but also results in a structurally more complex R&D system. Yet, there is no proper management system to comprehensively integrate and coordinate the increasing number of R&D projects funded by the government. It is, therefore, no accident that R&D programs by the public sector draw criticism for their inefficiency, with bureaucratic inertia often cited as the main culprit. Government R&D programs, as a matter of fact, leave much to be desired in terms of efficiency, compared to private-sector R&D [2]. The first step toward resolving the issue of efficiency plaguing government R&D programs is creating a performance evaluation system to track progress in each program and

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developing consistent performance indicators.

Energy technology is distinct from many other fields in that its state of progress is closely linked to medium to long-term national energy strategy. Another aspect that clearly distinguishes it from other fields is the importance of technology spillover. Public-sector R&D in the energy field is planned according to an order of priority and in a manner to lead to simultaneous development of core component technologies and basic technologies, so that related technology areas can benefit from spillover effects. Equally important is public-sector R&D activities' contribution to the industrial sector. In other words, the industrial and commercial applicability of R&D results must be a major criterion for evaluating the performance of energy research. This paper is an attempt to develop a series of performance indicators for the evaluation of public R&D projects for energy considering the characteristics of public R&D and energy technology. Meanwhile, to measure the extent to which capabilities in a given R&D project are aligned with its priorities and goals, this study uses the balanced scorecard (BSC) framework.

The BSC is a performance evaluation tool developed by Kaplan & Norton [3], widely employed by not only researchers but also practitioners around the world. Unlike other performance management tools, often exclusively focused on financial aspects of performance, the BSC gives an equal importance to non-financial aspects of performance. The BSC measures organizational performance from four perspectives: financial, customer, internal business processes and learning & growth. The BSC derives a series of success factors for a business organization and links them with its strategy for their efficient management, so that the organization may successfully implement its strategy and attain its vision.

Nowadays, governments and public-sector organizations are increasingly following the lead of companies in adopting the BSC, as a systemic approach to performance management and process innovation [4]. In Korea, the National Maritime Police Agency implemented a BSC-based performance management system in 2004, for the first time in the public sector. The Ministry of Education and Human Resources and many other public organizations jumped in as well, starting from 2005. These government agencies and public institutions are using their BSC-based performance management system to increase customers' satisfaction with public services they provide and create a performance-oriented organizational culture [5].

However, the BSC, as a performance measuring tool originally designed for enterprises, does not fully meet the evaluation needs of the public sector. Being non-profit organizations, public-sector organizations must measure their performance and the appropriateness of their activities to organizational goals from a non-financial perspective. For them, financial performance is not an end in itself, but only a means to an end. Also, for public institutions, customers receiving public services and paying for these services are not the only stakeholders. There is a need for these institutions to assess the appropriateness of their interaction with the government and other sponsors funding their operations. Meanwhile, the kinds of capabilities that interest them are those that can enable them to create social value. Citing precisely these reasons, Olive et al. [6] pointed out that the four perspectives proposed by Kaplan & Norton must be re-adapted to the needs of public-sector organizations, to enable them to use the BSC for performance measurement, or that new perspectives should be added that address their specific performance characteristics.

In recent years, companies in private sector are trying to actively adopt the BSC approach to measure the performance of R&D activities as well as R&D organizations [7] – [10]. This phenomenon comes from their imminent understanding that R&D is a vital solution to cope with increasing uncertainty in the business environment and harsh competition and thus the performance of R&D should be measured systematically from a strategic perspective. Efforts so far made to re-adapt the BSC for the purposes of R&D organizations or activities include the attempt by Garcı´a-Valderrama et al. [10]. They developed a BSC approach specifically designed for R&D, based on the existing BSC literature. To create a new framework closely adapted for R&D, they add, for instance, '*innovation'* to the existing four perspectives under the original BSC model.

There have been, on the other hand, few attempts to re-adapt the BSC for the public R&D activities. In particular, there is a paucity of researches to suggest a framework to develop a series of performance indicators of public energy R&D projects. The BSC approach proposed by Jordan & Mortensen [11], based on the logic chart developed for a technology development program by the US Department of Energy, is one of the few examples. However, this approach, although it retains the basic concept of the BSC, sacrifices the various advantages of the original model in the process of its re-adaptation. Because public R&D is different from the R&D performed by private sector in various viewpoints and energy technology has its own characteristics compared with other technologies, it is necessary to consider the characteristics of public R&D and energy technology in developing relevant performance indicators.

The purpose of this paper is to develop a BSC framework for measuring the performance of public R&D projects of energy technology, along with a series of performance indicators for use with the proposed evaluation framework. The rest of this paper is organized as follows: In section 2, we present a modified BSC framework, re-adapted to reflect the characteristics of public R&D and energy technology development projects, and performance indicators to be used under this framework. In Section 3, we discuss the validity of the performance indicators presented in the previous section. In the last section, we present the conclusion.

II. BSC Model for Public R&D of Energy Technology

A. Characteristics of public R&D of energy as a subject of BSC

Kaplan & Norton [12] states that the four fundamental perspectives of the BSC must be aligned with each other through the strategy map. In other words, the financial perspective, customer perspective, internal process perspective and the learning and growth perspective must

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have causal relationships with each other and must be relevant and appropriate to the vision and strategy of the organization evaluated. This also means that the indicators under the four BSC perspectives are not general ones, but those that are directly derived from an organization's strategy, so that their efficient management makes it possible for the organization to carry out its strategy successfully. In this sense, the BSC may be regarded as a strategic tool for the success of an organization and its long-term performance management system, rather than a simple performance measurement tool [13].

Originally the BSC was developed as a performance evaluation tool intended for use in private-sector business organizations, engaged in manufacturing or service sectors. But the subject in this paper, public funded energy R&D project, is different in some aspects. The BSC used in this study is, therefore, to measure the performance of R&D field, in public dimension, at the level of projects, not of organizations as shown in Fig. 2. Hence, the design of the BSC begins with the definition of the vision and mission of energy technology development projects. Once the vision and mission are defined, perspectives can be derived from them, and critical success factors (CSF) are selected next, for each of the perspectives so derived. This is, then, followed by drawing up a strategy map according to causal relationships existing between the perspectives. Finally, key performance indicators (KPI), quantitative indicators measuring the success factors, are developed.

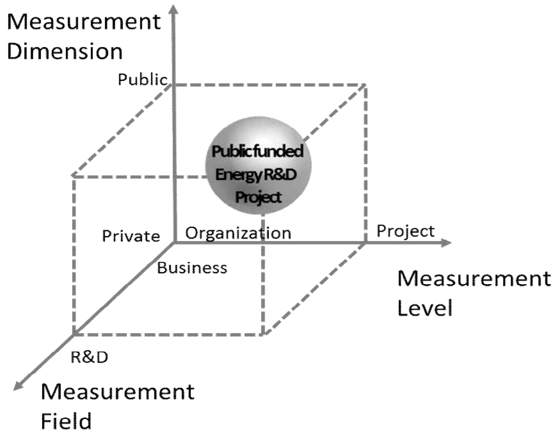

Fig. 2. Characteristics of public energy R&D in BSC

B. Defining the perspectives

The missions and visions of government-funded energy technology development projects, considered in this study, coincide mostly with the goals set out under the National Energy and Resource Technology Development Master Plan (2006-2015). In this study, we, therefore, formulated a common mission for the projects considered as follows: "Building a technology innovation system for the creation of a sustainable energy system." As for the perspectives, the main axes of a BSC model, we selected the following four: 'R&D performance,' 'energy industry,' 'R&D processes' and 'infrastructure' as illustrated by Fig. 3.

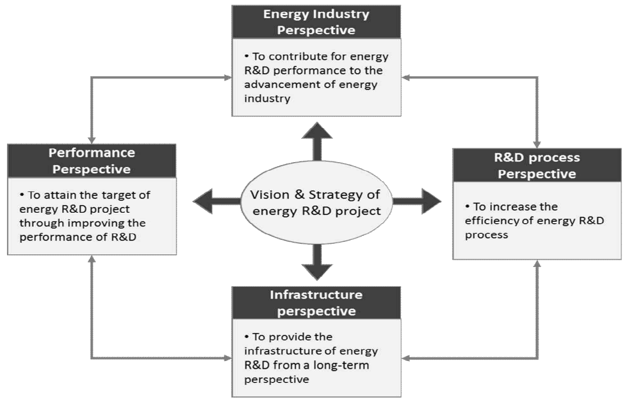

Fig. 3 Perspectives of public energy R&D in BSC

R&D Performance Perspective

Energy technology development projects are most often projects that are highly goal-oriented and are carried out to attain specific objectives. Therefore, the most basic performance indicators are the concrete output of a project, on the one hand, and on the other, its overall outcome. To re-adapt the original BSC for the purposes of energy technology development projects, the financial perspective was replaced in this study, by a performance perspective, and two CSF, 'R&D output' and 'Effectiveness of R&D,' were selected for this perspective. It must be noted that for public projects, performance is a means, and not a goal, unlike for business organizations whose ultimate goal is financial performance.

Energy Industry Perspective

Individual energy technology development projects, although they are directed toward a specific goal, can have a wide-reaching industrial impact and produce an influence on the industry as a whole, especially if they are large and complex projects. The perspective occupying the uppermost position in a strategy map constitutes the first segment in the chain of causal relationships linking the four perspectives, and must serve as the point of convergence in the overall evaluation of performance. Hence, the top-most perspective must be one that is the most fundamental for the evaluation of a given project. The end goal of an energy technology development project is not financial performance, but the performance of the energy industry it helps improve. Industrial growth is, besides, the goal of all government-funded R&D projects. Therefore, for the modified BSC, used in this study, 'energy industry' was selected as the uppermost perspective, and two CSF were chosen for this perspective: 'advancement of the energy industry" and 'technology commercialization,' which corresponds to the financial success achieved from the industrial application of technologies developed from a project.

'Advancement of the energy industry' is a factor which measures to the extent to which an energy technology project is appropriate to the strategic goal of the overall energy industry. If an energy technology project underway is not aligned to the goal of the energy industry or fails to meet its technology needs, it is unlikely that this project, even if brought to a successful conclusion, will produce results that

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have great industrial value. 'Commercialization,' meanwhile, corresponds to the financial performance achieved through the industrial application of the output from a technology research project. Commercialization, here, measures both the commercialization performance of the public sector and the derivative commercialization performance by the private sector.

R&D Process Perspective

Efficient R&D processes are paramount for an energy technology project to be able to satisfy the technology needs of the energy industry and achieve a high level of technological performance. The internal process perspective in the original BSC was, in this study, replaced by the 'R&D process perspective' to narrow the focus on the efficiency of processes that are specific to R&D activities.

For energy technology projects, efficient use of available resources is as important a success factor as profits generated from the commercialization of their results. Two CSF were, therefore, selected for this perspective: 'resource input' and 'efficiency of R&D,' with detailed indicators defined for each of the evaluation items.

R&D Infrastructure Perspective

R&D processes cannot be meaningfully improved without the improvement of R&D infrastructure. The infrastructure needed for improving R&D performance includes trained manpower and efficient systems for the utilization of information and resources. In this study, infrastructure, insofar as it supports the performance objectives under the above three perspective, was selected as the fourth perspective. 'Infrastructure,' here, must be understood as a concept combining innovation and learning, and are assigned two CSF: 'energy R&D manpower development' and 'energy innovation support & diffusion system.'

C. Strategy map

A strategy map, in the context of a BSC, is a diagram showing the causal structure linking the different perspectives, and thereby, illustrating the steps through which organizational values are created. A strategy map was drawn up also in this study, as shown by Fig. 4, by placing the four perspectives described above in their respective position within the causal structure. The energy industry perspective, the uppermost perspective, is followed by the performance, R&D process and infrastructure perspectives, in this order. The causal relationships between CSF under each perspective are also shown in Fig. 4. For example, the target output, whilst it is an effect with regard to the creation of an efficient R&D system, is a cause with regard to technology commercialization and R&D performance. In sum, the CSFs are linked to each other through a causal relationship, and converge with each other at the level of the energy industry perspective.

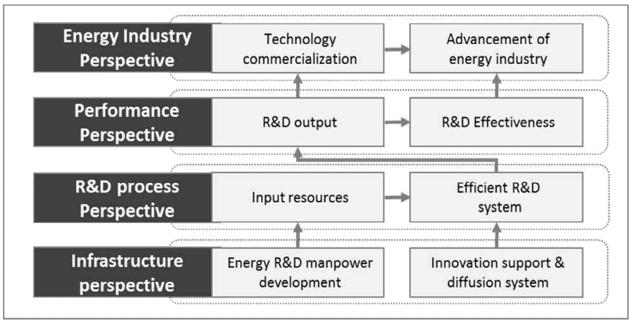

Fig. 4. Strategy map of public energy R&D

D. Key performance indicators (KPI)

The key performance indicators (KPI) are indicators allowing the conversion of the quantitative and qualitative criteria for evaluating the CSF into objective and measurable values [13]. In this study, we developed the following KPI as

TABLE I
BSC FRAMEWORK FOR PUBLIC ENERGY R&D

Perspective	CSF	Definition	KPI
Energy Industry	Advancement of energy industry	Effects of R&D results on the advancement of energy industry	Likelihood of new market creation, Rate of reduction in energy consumption, Rate of reduction in pollution (like CO2), Rate of fossil energy substitution, Rate of localization, The number of employment creation, The number of success of generic technologies for public use
	Technology commercialization	Financial performance resulting from the commercialization of R&D results	The number of technology transfer, Amount of revenue increase or cost reduction from technology commercialization, Amount of technology exports or import substitution, Amount of technology loyalty
Performance	R&D output	Direct results of R&D	The number of patents, The number of papers, Qualitative level of patents or papers
	Effectiveness of R&D	Degree of technological achievement compared with planned R&D objective	The percentage of R&D objective achievement
R&D Processes	Efficiency of R&D	Degree of efforts of management to achieve R&D objective efficiently	Efficiency index (DEA, TFP, ROI etc.)
	Input resource	Amount of various input resources to perform R&D	Development costs, Man-hour, Project period, Ratio of resource usage compared to original plan
Infrastructure	Energy innovation support & diffusion system	Degree of efforts to support energy R&D and to spillover R&D results	R&D information & resource utilization system, Researcher & research exchange program, The number of public relations of R&D results
	Energy R&D manpower development	Degree of efforts to cultivate able energy R&D personnel through performing R&D projects	The number of Ph. D's and Masters involved in projects, The number of employees in energy industry among project members, Manpower development programs for energy R&D

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illustrated by Table 1. for each of the CSF under the four perspectives, drawing on the performance indicators for the public service and R&D fields provided in the 'Internal Evaluation Manual for National R&D Projects 2009,' a publication by the Ministry of Strategy and Finance, and other relevant literature.

To ensure the validity of the process of indicator selection, we took into consideration the seven required attributes for evaluation indicators proposed by Falknet & Benhajla [14] - operationality, clarity, completeness, non-redundancy, representativeness, forecasting and differentiability - and the five selection criteria for evaluation indicators by Jerry [15] that they be specific, measurable, attainable, realistic and timely.

III. Testing the Validity of KPI

In order to use the BSC for the evaluation of government-sponsored energy technology development projects with medium to long-term technology visions, goals and strategies, the original model needed to be appropriately re-adapted to fit the specific purposes of this type of projects, while ensuring that the modified model remains faithful to the original concerning the basic constitutive principles. Lee & Han [19], in a study discussing whether the BSC, originally intended to measure organizational performance, can be used for programs such as national R&D projects, proposed the following four principles as the fundamental principles governing this performance evaluation model: balance, comprehensiveness, structure and focus on strategy as shown by Table 2. In modifying the original BSC framework to suit the purposes of public-sector energy technology projects, we ensured that our modified framework abide by these four principles.

TABLE II
Fundamental Principles of BSC

Principle	Description
Balance	The various perspectives composing a BSC must be selected in such a manner that a balance exists between them
Comprehensiveness	All major factors influencing the performance of a target organization or program must be discovered and included among the measured items
Structure	There should be a causal link between the perspectives as well as between indicators
Focus on Strategy	The perspectives and indicators must measure the concrete results a target organization or program achieves by carrying out its mission or strategy

IV. Conclusion

The government budget for energy technology research is increasing steadily every year, and this makes an efficient system for managing the performance of related R&D projects a more crucial requirement than ever. This study has been an attempt to develop indicators for measuring the performance of energy technology development projects and a BSC-based performance evaluation system, having four perspectives including 'energy industry,' 'performance,' 'R&D processes' and 'infrastructure.' As the performance indicators and evaluation system proposed in this study are closely adapted for the specific needs of government-funded research projects and may be used for internal evaluation by project teams, their uses are likely to contribute to the maximization of performance in public-sector research programs, as well as to the reduction of funding requirements.

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