A technology roadmap for energy productivity in Iranian steel industry

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***Abstract*— Nowadays, the most important features of business are complexity and continuous change. So industries and companies couldn't pursue their policies & plans safety without considering external factors and imagination of future. So, in this situation industries & companies need should decide to forecast future. This forecasting should be comprehensive and multi-dimensions. Using techniques such as "roadmap" at corporate level, which forecasts future according to past and present conditions of company, could form strategic thinking concept and then managers will be able to develop different strategies or alternatives with respect to their stakeholders' opinions. Thus, road mapping is considered as a popular approach for long range planning. In the other words, roadmap integrates & communicates between vision, values and objectives with strategic actions necessary for achieving these targets. Improving energy productivity is one of the most concerns for developing countries. It is necessary to define and develop plans and actions for reducing energy consumption in these countries. In this paper, we develop such issues for Iranian steel industry from "energy productivity" view. For this reason, we customize technology-product roadmap model. Then we estimate energy savings in coke making, direct reduction, and blast furnace processes after execution of designed roadmap in Iranian steel industry for short, medium & long times. The results show energy savings between 8% to 15% for different interval times. Also, we notice the roles and responsibilities of each player related to performing this roadmap.**

Keywords*— *Targets, actions, energy efficiency, technology roadmap,steel industry

I. INTRODUCTION

Nowadays, industries and companies couldn't pursue their policies & plans safety without considering external factors and imagination of future. So, in this situation industries & companies should decide to forecast future. One of the most popular approaches for long range planning is "roadmap" which shows paths necessary for achieving future targets. Road mapping integrates & communicates between vision, values and objectives with strategic actions necessary for achieving these targets [1]. Companies use "roadmap" for different strategic targets, because there are various techniques & forms for this issue [1]. The main feature of roadmap process is graphical and time-based structure used for defining, showing and communicating between many plans in different organizational levels [2]. There are some cause and effect relationships between these plans. It means in some cases, execution of one plan needs completion of other plan(s). So "roadmap" is an integrative approach which helps effective planning process thorough an organization [2].

"Roadmap" term was presented during late 1970. Motorola & Corning were pioneers companies in applying roadmap [3]. They had different targets, so they used roadmap in different approaches. Corning approach was critical events charting. In the first time, Corning made its vision and goals. Then this company identified important activities & events which are predecessors for achieving vision. Finally, all of activities and events related to goals were organized and projected graphically. This approach helped Corning to achieve its goals [4].

But Motorola approach was based on technology. Motorola used this approach for analyzing current and future technologies. This company found emerging new technologies in vehicle industry could make opportunities or threats for Motorola in comparison with its competitors. So Motorola pursued strategies for utilizing potential opportunities and reducing potential threats. In the other words, Motorola used roadmap as a tool for forecasting emerging new technologies & analyzing their impacts on organization [4].

One of the most important and applied roadmap is "Technology Road Map (TRM)". This method has been

adopted (and adapted) by many different organizations in different sectors, at the firm, sector and national levels, to support a range of different strategic goals [5]. TRM tries to link between technology development and customer requirements, and then it shows directions priorities in developing technologies [2]. In fact, the main benefit of TRM is preparing information necessary for better decisions about technological investments [2].

Many managers distinguish strategic role of technology for value creation & competitive advantage in their organizations. Nowadays, this role is more important if we notice the larger production costs and complexity, the rapid rate of technological change and the globalization of competition. Because of increasing impacts of technology, managing technology will be one of the key responsibilities for companies. Technology management requires some processes to assure technological resources & assets will be assigned efficiently to reach short term and long term targets [4]. Also it needs processes that could assess impact of market & technology evolution on an organization. On the other hand, identification of investment alternatives is very important as like as organizational opportunities & threats.

So there is one critical question which any organization cope it: "How we can gain maximum benefit via investment on technology, if we notice two processes – market pull & technology push-?"[4]. Because of restrictions on financial resources for each organization, answer to the above question requires complete analysis of investment alternatives. This issue influences competitive situation of the organization.

Technology roadmap is a flexible method used in various industries for strategic & long range planning. It shows structured and graphical communications between markets, products (services) and developing technologies over the time. Fig. 1 illustrates perhaps the most useful and powerful format that roadmaps can take, comprising a multi-layered time-based chart, showing how various functional strategies align [5]. TRM is a time-based chart and contains several layers which have inter-relationships [4]. Although the format of TRM is simple, the development process of TRM is approximately complicated and challengeable [4]. There are many problems for creation & developing technology roadmap, especially when we consider human effects.

II. Problem Definition

Improving energy productivity is one of the most concerns for developed and developing countries. For governments and for manufacturing companies, global warming, rising energy prices, and customers' increasing ecological awareness have pushed energy efficient manufacturing to the top of the agenda. Governments and companies are both striving to identify the most effective measures to increase energy efficiency in manufacturing processes [6]. Also EC and IEA confirmed energy efficiency is the single most important contribution, at least until 2020 [7]. Now, energy consumption for complex units around the world is approximately 22.1 GJ/ton [8]. Therefore, it is very important and useful for each country to reduce energy consumption for industry sector. Of course, it is necessary to define and develop plans and actions for reducing energy consumption in these countries.

One of the main reasons for lag of Iranian industries is no sufficient attention to current and future requirements of markets. Thus Iranian industries should reorganize, renovate and re-plan in order to meet these requirements. Using technology roadmap can fulfill this issue.

In this paper, we propose a useful tool (Technology Road Map=TRM) for strategic technology management in Iranian steel industry. So, in first, we introduce "T-plan approach" and describe "roadmap architecture". Then a technology roadmap for energy productivity and saving in Iranian steel industry is introduced. In the third section, we describe the results derived from TRM.

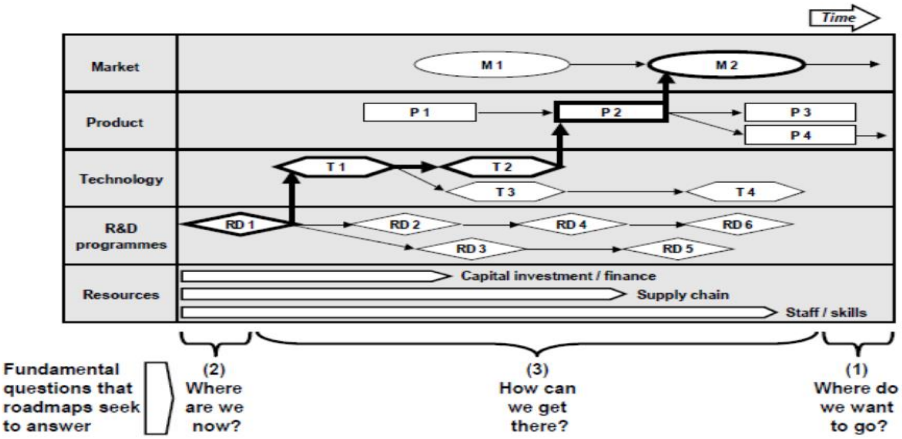

Fig. 1-Multi-layer roadmap form for integration and alignment of strategic plans

III. Road mapping energy productivity in Iranian steel industry

In the first stage, it is necessary to define roadmap architecture. The purpose of it is to provide a framework for visualizing and showing roadmap. There are various approaches for road mapping and they depend on purposes and format of roadmap [9]. In this paper, we use T-plan approach for recognition of architecture for Iranian steel industry, because it is very popular and user friendly.

A. *T-plan approach*

Since 1970, the origin of roadmap, more than 300 roadmaps were made and each one had different approach. The most important approach is T-plan that helps organizations to reach their future targets [4].

Roadmap architecture contains definition of two axes: Firstly, horizontal axis (or time dimensions) and secondly, vertical axis (or layers). In general, T-plan has three standards layers (Figure 2) [4]. "Drivers" contain stimulants or trends which are important and critical. Sometimes they are named as "Strategic goals". "Resources" are focused on any financial or non-financial resources. "Responses" are tangible systems, products or services for transforming resources to targets [4].

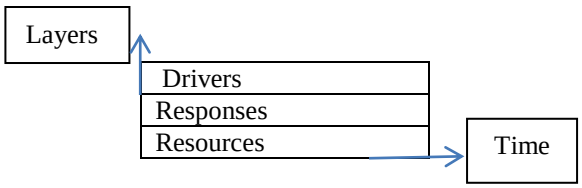

Fig. 2- Roadmap architecture in T-plan approach

When we use technology roadmap at industry/corporate level, we should adapt it with industry/corporate situations & features. In Iran, steel industry is an energy-intensive industry [10]. So if we want to develop a technology roadmap for Iranian steel industry from "energy productivity" view, we should customize technology-product roadmap model. In the next section, proposed roadmap architecture for Iranian steel industry roadmap is described.

B. *Proposed roadmap architecture*

As it is said, two tasks should be taken if we want to design architecture of each roadmap based on T-plan approach. The first one is time horizon and the second one is layers introduction.

1) Time horizon

Vision is an important input for developing roadmap. Because of defining vision for energy productivity in Iranian steel industry for 2025, we should set our time horizon identical for both "roadmap" & "vision". Besides on, we have to divide this time horizon to three intervals, just is short term (2013-2015), medium term (2016-2020), and long term (2021-2025). So all of layers in the next section should be fixed within these interval times.

2) Layers

There are three layers of technology roadmap for energy productivity in Iranian steel industry as following:

-Layer 1: Market/Goals……This layer is about goals set by experts based on steel industry vision provided for end of time horizon (2025).

-Layer 2: Plans/Action ……In this layer we define and recognize plans/actions which are necessary to reach goals in layer 1. These plans/actions are categorized to products, technologies, processes and resources (financial, human resources, energy resources and etc.). Also they belong to short, medium or long time intervals.

-Layer 3: Players……For execution plans/ actions in layer 2, we have to define various players and their roles or responsibilities for each plan/action. This task is done in layer 3.

C. *Flowchart of road mapping for Iranian steel industry*

Figure 3 shows the steps required for preparing roadmap. In this section we describe each step in detail.

1) Scope

Roadmap scope is whole of industry level and encompasses upstream and downstream steel units in Iran.

2) Vision statement for energy consumption

Vision is the art of seeing things invisible [11]. Management and executive agreement on the basic vision for which the firm strives to achieve in the long run is critically important. Vision statement answers the question: "What do we want to become?"

One of the most important approaches for vision making is technology foresight [12]. By using this approach, experts (as focus group) developed two scenarios for future of Iranian steel industry: "Standard-rule based" & "process-technology based". Then they combined them and proposed vision statement of energy consumption according to this aggregated scenario for 2025. It could realize what does steel industry in Iran wants to become. This vision statement is [10]:

> *"Iranian steel industry in 2025 protects its economic driving forces, produces goods with high value added. It has processes & activities which are energy saving; also it substitutes energy-intensive technologies with green & new technologies, and gains optimum energy productivity indices."*

3) Strategic themes

Each interval time has embedded concepts that form and organize proposed plans/actions. These concepts are named as "strategic themes". Strategic themes contain two major concepts (elements): a- Optimization of energy consumption, and b- Increasing production capacity. When we combine them, we get S.T. *Table I* shows these strategic themes [10].

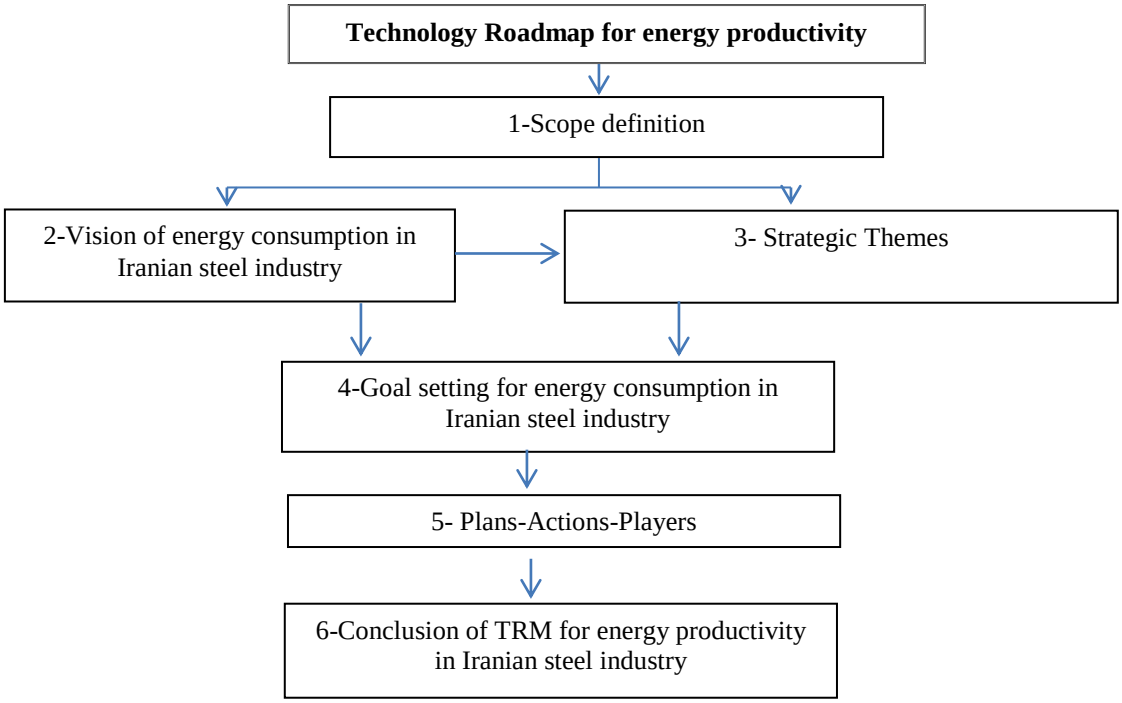

Fig. 3- Flowchart of road mapping for Iranian steel industry

Table I- Strategic Themes (S.T.)

Time horizon / Elements of S.T.	Short (2013-2015)	Medium (2016-2020)	Long (2021-2025)
A)Optimization of energy consumption	A1	A2	A3
B)Increasing production capacity	B1-1 , B1-2	B2-1, B2-2, B2-3	B3

Descriptions of these themes are as following:

A1) Reach to satisfaction level of energy productivity indices for current units

A2) Transform steel industry to the best industry in Iran based on energy productivity indices

A3) Reach to world class of energy productivity indices

B1-1) Improve productivity level in current units

B1-2) Expand R&D activities in steel industry

B2-1) Reach to optimum & economic capacities in current units

B2-2) Construct new units for steel industry with respect to regional situations (feasibility study)

B2-3) Produce goods with high value added

B3) Transform Iranian steel industry to one competitive & economic industry in world class

"World class" in above statement means average performance of large steel production units around the world. They are [10]:

- Posco
- Nippon Steel
- Tata Steel
- Arcel or Mittal
- JFE Corporation

4) Goal setting

We used combined method for goal setting in Iranian steel industry roadmap. In the other words, explanatory method (top-down) & exploratory method (bottom-up) are used simultaneously. We translated vision into goals according to time dimensions and strategic themes. Finally, there are 12 goals for short term, 10 goals for medium term, and 5 goals for long term. A few of these goals are only for current factories, and a few for new ones. Also there are few common goals.

5) Plans/Actions/Players definition

These plans and actions should be executed if we want to achieve the specified goals. So in this stage, a form for plans/actions definition was designed. It was requested a few experts to complete it. *Table II* shows the format of this form. As we see, each table has been assigned to one individual goal. Then respondents identify plan(s) or action(s) necessary for achieving specified goal. Also he/she completes kind of plan or action; time estimation for performing it; players & roles of them for doing this action or plan.

Table II- Form of plans/actions

Goal code: Goal title:								
Plan/action title	Kind of	Plan or	action		Time estimation	players	Roles of players	
	Process	Product	Technology	resource				

With analyzing completed forms, we summarized plans/actions required for achieving the specified goals as follows: 30 short term plans/actions, 24 medium term plans/actions, and 7 long term plans/actions. Also we identified about 17 key and effective players have responsibilities for performing this roadmap. These players contain both governmental and private firms and act different roles – such as planning, monitoring, financing, production, R & D, education, technology transfer, consulting - during execution of roadmap.

IV. CONCLUSION

Developing a technology roadmap for energy productivity in Iranian steel industry has many results and outcomes. In this section, we estimate and calculate quantitative energy savings in steel industry. One of the most relevant & important indices for energy consumption is energy efficiency index [10]. If we want to calculate the gap between energy efficiency in Iranian steel industry and the world steel industry, we can use (1):

$$I_i\,(new) = I_i\,(old) + f_s * [\, I_w - I_i\,(old)\,] \qquad (1)$$

Where:

I_i (old) = average energy efficiency index in Iranian steel industry

I_i (new) = average energy efficiency index in Iranian steel industry (after roadmap implementation)

I_w = average energy efficiency index in world steel industry

f_s = the rate of reduced gap between world energy efficiency index & Iran energy efficiency index

According to goals identified in roadmap (sec. 2-3-4), fs is equal to 0.5 for short, 0.8 for medium, and 0.9 for long interval. If we calculate Ii (new) for important processes in steel industry and compare it with Ii (old), then we could estimate potential energy saving in these processes. Equation (1) was used for coke making, direct reduction and blast furnace processes in Iranian steel industry. Table III shows results of using TRM for estimation of energy efficiency index in these processes. In this table, we see current average energy efficiency index (Ii) for coke making, direct reduction and blast furnace processes by gigajoule per Ton. If this index multiplied current production rate of each process, then we get total current Ii in Iran by Terajoule (i.e. column 3 in table 3).We assume current production (i.e. year 2012) will be continued during time horizon of TRM. So in next columns, potential energy savings are calculated by Terajoule.

- Overall energy saving for short term is about %8.4
- Overall energy saving for medium term is about %13.4
- Overall energy saving for long term is about %15

According to roadmap approach, validation of these results requires experts' judgments [2, 4]. Experts confirmed these outcomes during different meetings and mentioned usefulness of technology roadmap for Iranian steel industry.

Table III- Estimation of Energy Efficiency Index in Iranian Steel Industry based on TRM

process	Current* I_i (GJ/T)	Total current I_i In Iran* (TJ)	Potential energy saving (with respect to current production)** (TJ)		
			Short term	Medium term	Long term
Coke making	6.9	22080	7040	11264	12672
Blast furnace	16.25	40625	4812.5	7700	8662.5
Direct reduction	12.5	127500	4080	6528	7344
Total		190205	15932.5	25492	28678.5

**Data derived from [10]*

***Year of current production is 2012*

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REFERENCES

[1] Hosseini Nassab, M.R., & Javadi, H., & Arbabshirani, B.,"Analytical Review of Technology Roadmap Applications", Proceedings of 4th National Conference on Management of Technology, 2010, Tehran, Iran.

[2] Phaal,R., & Clare.J.P. & Probert, R., "Technology Road mapping: A Planning framework for Evolution and Revolution', Technological Forecasting & Social Change, Vol.71, 2004, PP. 5-26.

[3] Willyard, C.H., & Mccless, C.W.,"Motorola's Technology Roadmap Process', Research Management, Vol.30, 1987, PP.13-19.

[4] Pour Mohammad, A., & Peymanlhah, S., & Sedghi, N., & Ghaffarzadegan, M., & Nilforoushan, H.,"Technology Roadmapping", 2010, 1th edition, RIPI, Tehran, Iran.

[5] Phaal, R., & Clare.J.P. & Probert, R., "Developing a technology roadmapping system", Technology management: A unifying discipline for melting the boundaries, 31 July-4Aug. 2005, pages 99-111.

[6] Bunsea,K., Vodickaa,M., Schönslebena, P., Brülhartb,M, Ernstb,F.O., " Integrating Energy Efficiency Performance in Production Management –Gap Analysis between Industrial Needs and Scientific Literature", Journal of cleaner production, Volume 19, Issues 6–7, April–May 2011, Pages 667–679.

[7] Institute for Industrial Productivity, " To and beyond 2020: Industrial Energy Efficiency Policies and Low Carbon Roadmaps for Europe", Eceee seminar: The Challenge of the IEA World Energy Outlook, November 21, 2012, Brussels.

[8] DOE, Steel Industry Marginal Opportunity Study.
Available at:
http://www1.eere.energy.gov/industry/steel/pdfs/steelmarginalopportunity.pdf. 2005.

[9] Phaal, R., & Farrukh, C.J.P., & Robert, D.R.,"Characterization of Technology Roadmaps: Purpose & Format", Proceedings of the Portland International Conference on Management of Engineering & Technology, 2001, PP. 367-374.

[10] Technical Reports of "Optimization of Energy Consumption in Iranian Steel Industry" project, 2012, SABA, Tehran, Iran.

[11] David, Fred R.,"Strategic Management", 11th Editions, Prentice Hall, 2007.

[12] Nazemi, A., Ghadiri, R.,"marine Foresight: Iran 2025", 2009, National Research Institute for Science Policy, Tehran, Iran.

BIOGRAPHY

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