

# The Application of Technology Roadmapping Method Related to Sustainable Energy: Case Study in the World and Brazil

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**Abstract** The Technology Roadmapping Method (TRM) is a widely used method in the industry for the development of long term planning strategies, enabling to align market, product and technology over time. This article presents a survey about the uses of this tool regarding to studies on renewable energy in the World and Brazil. The TRM has proven useful efforts in organizing and guiding Research, Development and Innovation (R, D & I) in order to achieve the desired goals for each example. In Brazil, the highlight was the works of the SENAI/PR and CGEE.

**Keywords:** *Technology Roadmapping Method, roadmap, sustainable energy, world, Brazil*

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## 1. Introduction

In recent years, the growing worldwide concern with environmental issues, coupled with rising oil prices and uncertainties associated with its market, gave rise to the need to find sources of energy cheaper and less harmful to the environment. There is a stimulus for the use of new technologies, in particular, the so-called biofuels to replace fossil fuels.

The world economies have great dependence on oil, the main input of the global energy mix, accounting for about 36% [1]. However, such non-renewable fuel has caused serious damage to the environment, endangering the survival of life on Earth. As an example of damage to nature, there is global warming, this issue on the agenda of all nations, which is caused by the greenhouse effect [2].

But this threat is not restricted to environmental issues, also affecting the economic plan. Considering that oil is not renewable, each barrel is a barrel processed unless the world reserves. By being concentrated in a few countries, and find themselves increasingly scarce, are checked successive increases in its international price.

The continued use of sources of non-renewable energy such as oil and coal, runs counter to the sustainable development, according to the Brundtland Report, "is one that meets the needs of the present without compromising the ability of future generations to meet their own needs"[3].

In this context, renewable energies are gaining importance in the discussion based on a new paradigm of sustainable development. The use of renewable energy,

such as biomass, wind, solar and geothermal for instance, began to be permanently on the agenda of the governments of all countries and policies to promote research to develop new technologies for their production. To guide these policies it can use of technological forecasting tools in order to explore the dynamics of emerging technologies in the industrial sectors. Among examples of such tools it could cite the Technology Roadmap, which is a widely used technique in the industry for the development of long term planning strategies, making it possible to align market, product and technology over time.

## 2. Sustainable Energy

Renewable energy, derived from natural cycles of conversion of solar radiation, the primary source of almost all the energy available on Earth, are practically inexhaustible and do not alter the thermal balance of the planet. They are configured as a set of energy sources that can be called non-conventional, ie, those not based on the fossil fuels [4].

These fossil fuels are classified as non-renewable energy are those sources that will eventually cease, making it very costly or fatal to the environment with irreversible consequences. In contrast, renewable energy sources are offered by the environment with an abundance [5].

Thus, it can say that renewable sources of energy are clever ways of using the resources of the planet. Table 1 describes the main characteristics of renewable energy sources and the major described in detail below [6]:

**Table 1. Main characteristics of renewable energy source**

	Solar	Wind	Geothermal	biomass	Marine
Scale	extremely large	large	too large	too large	too large
Distribution	worldwide	coastal, mountains, plains	tectonic boundaries	worldwide	coastal, tropics
variation	depends on the time, day and season	highly variable	constant	depends on the time, day and season	depends on tide and season
Improvements	materials, cost, efficiency, and data source	materials, design, location, source data	exploration, extraction, use	technology, management of agriculture and forestry	technology, materials and cost

## 2.1. Biomass

It is the chemical energy produced by plants in the form of carbohydrates through photosynthesis. Plants, animals and their derivatives are classified as biomass. Wood products and agricultural residues, forest residues, animal dung, charcoal, alcohol, animal oils, vegetable oils, poor gas and biogas are forms of biomass used as fuel [4].

Renewal in biomass occurs through the carbon cycle. The decomposition or burning of organic matter or its derivatives causes the release of CO<sub>2</sub> into the atmosphere. In photosynthesis, plants convert CO<sub>2</sub> and water into carbohydrates, which make up your living mass, releasing oxygen. Thus, the use of biomass does not alter the average composition of the atmosphere over time provided that not occur in a predatory way.

## 2.2. Solar

It is the energy from the sun. It can be used directly for heating the environment, heating water and for the production of electricity, with the possibility to reduce by 70% the conventional power consumption.

Furthermore, the radiation can be used directly as a source of thermal energy for heating fluid, heating environment and to generate mechanical or electrical power. It can also be converted directly into electrical energy through effects on certain materials, especially for thermoelectric and photovoltaic [4]. It should be noted that other energy sources cited (biomass, wind, ocean energy, etc.) are indirect forms of solar energy.

## 2.3. Fuel Cells - Hydrogen

The fuel cell consists of an electrochemical device that directly converts the chemical energy of a fuel into electricity and heat. Typically, the hydrogen is used as fuel. In this case, hydrogen and oxygen are recombined at the surface of a catalyst and producing only water and heat as by-product [7].

There are numerous advantages of using fuel cells in aviation. One is to reduce emissions by almost one hundred percent. Another benefit is caused by decrease in the intensity of noise in the aircraft itself and around airports.

Moreover, the electricity generated can also be used to power electric pumps in hydraulic systems, and even replace the APU - Auxiliary Power Unit (usually installed in the tail device, capable of providing power to an aircraft on the ground or in flight) . The pure water derived from this process can be used in various ways, for example, in sanitary systems or even to use by passengers, resulting in a considerable reduction in weight of the aircraft since it is not necessary supply it with this input [7].

However, there are some limitations when employing these cells with hydrogen. How is chemically very active, it is not found in gaseous form in nature (H<sub>2</sub>). Thus, the

procedures for production and purification become also expensive. Besides, large amounts would be required for storage, requiring thus redesign of the aircraft.

## 2.4. Geothermal

It is obtained from the heat of the Earth which the magma, located below the Earth's crust, heats the deposits or streams of water at temperatures above 140°C. The water vapor, to find a crack in the crust, forming the emerging geysers, fumaroles and hot springs [5].

This energy source has almost no CO<sub>2</sub> emissions, a low operating costs and the area for the installation of the plant is small and can supply isolated communities. However, it is an expensive energy that needs to be put into use in the field and emits hydrogen sulphide, which has an unpleasant odor.

## 2.5. Wind

It is the kinetic energy of air masses (wind) caused by uneven heating in the Earth's surface. This type of energy has proven itself as a great alternative in the composition of the energy matrix of many countries because it is abundant, renewable, clean and available everywhere [4].

Its use for electricity generation on a commercial scale began in 1992 and, through knowledge of the aviation industry, equipment for wind generation have evolved rapidly in terms of ideas and preliminary concepts for high-technology products.

## 2.6. Marine (Wave/Tide)

Tidal power also has a potential energy to be harvested by humans, mainly in Brazil due to its vast coastline. The tides vary from place to place because they are influenced by the shape of the coastline and the seabed and the existence of bays and estuaries [7].

The largest power plant built in the world is located in France, La Rance, and operates more than 40 years with an installed capacity of 240 MW divided into 24 turbines. There is also a sizable one in Canada.

Despite such initiatives, these countries have not been investing in new ventures. Technology leads to stagnant tidal energy is not economically and environmentally feasible yet. The disadvantages are that energy is not available all the time, only during periods of the cycle. Salt also has a high power corrosive, requiring the use of special materials, raising the price of equipment. Although not generate greenhouse gases, their impact is on marine ecosystems, fauna and flora [7].

In general, the main barriers to greater use of renewables are economical, as the technologies employed are new, many are still under development, and therefore have very high implementation cost. This barrier can be overcome by government support being necessary technology investments in order to achieve economies of scale and become more competitive [8].

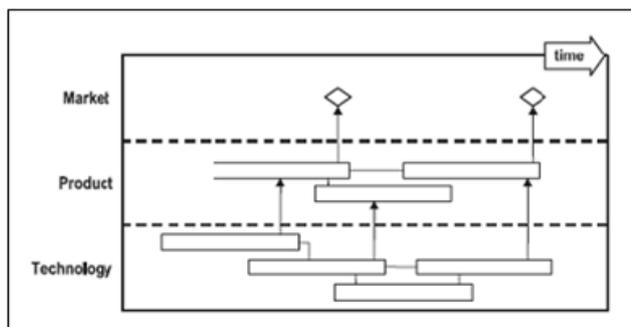
Thus, in order to organize and direct studies of this nature it is used technological forecasting tools. In this article the chosen one was the Technology Roadmapping Method (TRM).

### 3. Method TRM

The technology roadmaps are part of the tools that aim to explore the dynamics of emerging technologies in industry, in a long-term horizon and, especially, develop, implement and execute strategy maps to align the company's strategy to its technological capabilities [9,10].

The technology roadmap is a tool that provides support to an organization charged with developing a product or process, providing the method to turn your strategy to future actions and explicitly include a plan for the infrastructure, skills and technologies needed available at the right time.

Usually, the term roadmap refers to a layout of paths or routes exist or may exist in a particular geographic area to help travelers in planning the trip in order to reach a particular destination [11]. This definition helps to understand the Technology Roadmapping Method, which consists of plotting the roadmap for the evolution of technologies, products and existing markets (today) and will be built (the future), helping leaders (travelers) in an organization alignment of planning and development activities with business goals (target) [12]. The definition of TRM adopted is a flexible method whose main objective is to assist in strategic planning for market development, product and technology in an integrated manner over time as illustrated in Figure 1 [9,10,13,14], while the term technology roadmap is the document generated by the process.



**Figure 1.** Schematic technology roadmap showing how technology can be aligned to the development of products and services, business strategies and market opportunities

Studies of Kappel [14] and Garcia & Bray [15] suggest that the roadmap can be represented in two levels: industrial or corporate. Some organizations do technology roadmapping internally as one aspect of your technology planning (corporate technology roadmapping). However, the industrial level, the technology roadmapping involves multiple organizations, whether individually or in consortium (industrial technology roadmapping).

Organizations that use the technology roadmapping as a strategic planning process to benefit from the following possibilities [16]: (i) to produce greater alignment between research and development (R & D) initiatives in product development, (ii) clarify the views strategic, resulting in better informed decision making, (iii) Manage data, product plans and objectives at a high level, (iv) To

interact markets, products, technologies, customers and suppliers, (v) To enable the discovery of re-use technology and opportunities for synergy, (vi) Reveal gaps, challenges and uncertainties related to product, technology and training plans, (vii) Reveal weaknesses of long-term strategy before they become critical, (viii) Communicate and provide visibility toward strategic program around the organization, (ix) Enable growth of product portfolio in line with business demands and market, and (x) Provide guidance to project groups of people and enable them to quickly see changes in events or strategic directions.

## 4. Roadmaps on Sustainable Energy

### 4.1. World

Based on studies Phaal [17], referring to 1,300 roadmaps published online in English and covering the most varied fields of science, technology and industry, Loureiro [18] conducted a count of roadmaps in each of these large areas.

**Table 2.** Roadmaps public domain selected by Phaal [19]: number and percentage of large area

Area	Number of Roadmaps	%
Software, computing, information and communications technology	385	21.9
Energy	242	13.8
Sustainable energy systems	94	
Hydrogen & fuel cells	36	
Electricity	27	
Fossil fuels	25	
Nuclear	23	
Others	37	
Science	242	13.8
Policy, government and community	233	13.2
Industrial, business and other organisational	196	11.1
Transport	103	5.9
Electronics	94	5.3
Materials	62	3.5
Defense	61	3.5
Manufacturing	51	2.9
Construction	45	2.6
Nanotechnology	23	1.3
Chemistry	22	1.3
TOTAL	1759	100%

Phaal [19] updated its research roadmaps identifying more than 2,000 public domain. From this list it was made new counts, as shown in Table 2. This table reveals that the area has the largest number of roadmaps is Software, Computer and Information Technology and Communication with about 21.9%, in the second place come the areas of Energy and Science with 13.8%. Comparing with the results of Phaal [17], consolidated by Loureiro [18], it can note that the area of Information Technology and Communication remained in first place with the largest number of roadmaps, but there was an increased use of TRM in Energy and Science, areas considered strategic for nations and companies around the world.

From the pointed count was a survey of the characteristics of 94 roadmaps classified by Phaal [19] and sustainable energy systems, which were extracted the following information:

The most of the roadmaps were performed by one or more organizations of the United States being the country that applies the tools of TRM in studies of technological forecasting as shown in Figure 2 [19]. Second, there are the countries of the European Union (EU), noting that in some cases for the joint participation of the Organization for Economic Cooperation and Development (OECD).

Various types of organizations perform or commission studies roadmap, which features businesses, universities, research centers, institutes, foundations, industry associations, government departments, ministries. Among the organizations emphasize the participation of the United State Department of Energy (USDOE) and the International Energy Agency (IEA).

It appears that, despite the roadmaps exist from the 70's, have the documents reviewed publication date from 1999, therefore, the TRM can be considered a tool that has relatively recent use.

The vast majority of these roadmaps adopts the format of text, but some contain, in addition to text, representations in the form of bars, single and multiple layers, tables, flowcharts and / or graphics.

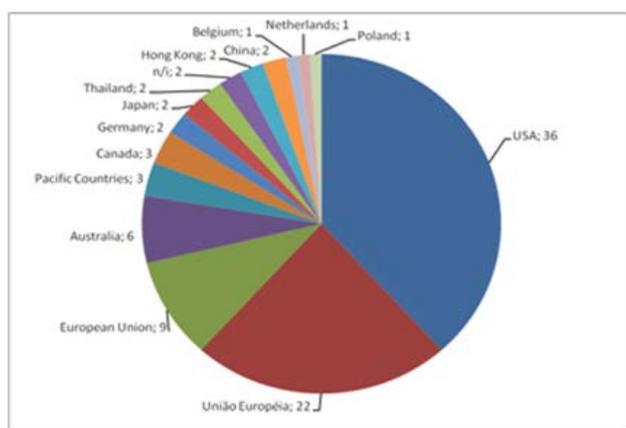


Figure 2. Number of roadmaps related to sustainable energy

About 32% of the roadmaps identified make predictions for the year 2020, using a long-term period range from 15 to 20 years. However, documents show 15 roadmaps by 2050, which highlights the importance given to global sustainable energy in the energy analysis of countries, institutions, companies and universities.

Table 3. Roadmaps for the types of sustainable energy systems

Type of Energy	Number of roadmaps
solar fotovoltaic	30
mix of renewable energies	27
biomass (biogas, biofuels)	19
wind	5
marine (wave, tidal)	4
fuel cells	1
geothermal energy	1

It is observed that the roadmaps addressing various types of sustainable energy, as shown in Table 3, with emphasis on solar energy, with emphasis on photovoltaics; mix of renewable energy (including solar, tidal, wave, hydro, geothermal, biomass, wind, fuel cells, hydrogen, etc.) and biomass with 30, 27 and 19 roadmaps respectively.

Some roadmaps found not only make predictions, but also define the technological barriers that need to be

overcome. There are, in some cases, proposals for actions to encourage and stimulate the sector study, identifying those responsible for such actions and establishing a time frame for making them. It should be noted also that certain roadmaps have also proposed government policies for the sector object of study in order to support the actions of industry, serving as a roadmap to guide the sustainable development mechanism.

Some documents take the name does not contain forecasts roadmaps structured desired goals over a predetermined time horizon, contrary Kappel [14], the researcher who emphasized that the roadmap should contain the explicit revelation of the time domain for each element presented.

The most of the roadmaps found can be classified as Science and Technology, according to Kappel [14], as they seek to identify trends, generate forecasts and set goals for the development of the sector studied.

Additionally, it was observed that in other major areas classified Phaal [19] there are roadmaps that could also be related to the field of sustainable energy systems, for addressing issues that have interface. Some examples are found in other classifications of roadmaps: Energy (Electricity, Hydrogen & Fuel Cells, Other Energy, Science (Life Sciences and Agriculture, Land) Policy, Government and Community, Industry, Business and Organizational others; materials, Construction, Nanotechnology, and Chemistry.

So if they are considered, the sample space of roadmaps to be analyzed would increase considerably, requiring a greater effort in research.

## 4.2. Brazil

In studies Phaal [19], shown in Table 3, there are no roadmaps developed in Brazil on the issue of sustainable energy systems in English. However, there are some Brazilian institutions such as Centro de Gestão de Estudos Estratégicos (CGEE) and Serviço Nacional de Aprendizagem Industrial do Paraná (SENAI / PR) among others, are conducting studies in various areas of national performance in order to subsidize the decision-makers by identifying the dynamics of innovation and competitiveness of the domestic industry. To achieve this goal, some make use of the TRM to provide an overview of the sectors of short, medium and long term, yet they often have not received such a designation. It should be noted that some of these roadmaps will be detailed below.

### 4.2.1. Serviço Nacional de Aprendizagem Industrial do Paraná SENAI/PR

An example of a successful initiative in Brazil is the series of roadmaps designed by SENAI / PR [20,21,22,23] called "Strategic routes for the future of the industry of the state." This project was created by the System of the Federation of Industries and Companies of Paraná (FIEP) in 2006 to draw maps of the routes to be traveled toward a sustainable industrial future for each of the sectors and areas most promising for the industry of Paraná on the horizon 10 years.

The specific project objectives are: (i) to sketch future visions for each of the selected sectors and areas, (ii) prepare a schedule of actions converged to focus efforts and investments, (iii) identify key technologies for the

industry of Paraná and (iv) to prepare maps of the paths and desirable for each of the sectors / strategic areas.

The Strategic Routes project in its first phase (period 2006 - 2007) addressed the sectors / areas: food processing industry, Consumer Products, Forestry and Agricultural Biotechnology, Animal Biotechnology and Microtechnology. It was later given to continuity in a second phase (period 2007 - 2008), designed the sectors / areas: Energy, Pulp and Paper, Metal Mechanic, Plastic, Health, Tourism, and Environment.

All roadmaps of the project were executed according to the same work methodology that consists of four steps:

- Stage 1- Preparatory studies: surveys were prepared of the current situation of each of the sectors / areas worked and studies on the technology trends that could impact the subjects / objects of roadmappings sectors.

- Step 2- Organization: the works were designed using the technique "Expert Panel" for each selected theme.

- Step 3- Conduct: We performed the following activities: brainstorming on the current status, visions of the future challenges, identify critical success factors, solutions and actions and agents involved.

- Step 4- Consolidation of Results: this step aims to systematize the end of all materials generated during the process. The roadmaps outlined during the meetings were completed and validated by the participants and consolidated information gave rise to technical reports.

For each view a roadmap was generated containing the proposed actions. Each roadmap is presented in the form of multiple layers, each layer refers to a critical factor identified, and the time horizon was divided into three periods (short, medium and long term). For each of these views have been identified to overcome challenges, critical success factors and actions to be implemented in the short, medium and long term, in order to achieve the desired future state in the industrial sector analyzed.

The following are the roadmaps regarding Forestry and Agricultural Biotechnology, Energy, Pulp and Paper and Environment to show respect to sources of renewable energy that is the subject of this work.

#### 4.2.2. Roadmapping Biotechnology Applied to Agriculture and Forestry Industries [20]

The study on Biotechnology Applied to agriculture and forestry industries Paraná and experience of participants of the Expert Panel supported the initial debate that culminated in the shared perception of the group on the current context in the state sector, key item to enter the stage of elaboration of visions the future.

It was developed and validated a set of four complementary views, shown below, comprising a desired scenario in which the industry of the state of agricultural and forestry sectors is entrepreneurial in Biotechnology and becomes reference in research, development, technology and innovation in the area.

Vision 1: Solution Provider in bioenergy

Vision 2: Reference in genetics and plant breeding

Vision 3: Innovation in plants with nutraceutical properties

Vision 4: Reference for plant biotechnology

Roadmapping Energy 2015 [21]

Similarly to the previous roadmap, the expert panel developed and validated a set of five complementary views, set out below, which make up the desired scenario

of a strong energy sector to support innovative and sustainable growth of the industry of the state.

Vision 1: Reference Planning in Systemic Energy Affairs

Vision 2: Reference Generation Distributed Renewable Energy

Vision 3: Model for Energy Efficiency Competitiveness

Vision 4: Solution Provider in Energy from Biomass

Vision 5: Energy and Logistics for Sustainable Transport

Environmental Roadmapping - until 2018 [22]

Following the same dynamics of previous roadmaps, the expert panel developed and validated a set of four complementary views presented below, which set the scene for a desired industry of the state that respects the environment and seek sustainable development.

Vision 1: Environmental management in the industrial chain internalized

Vision 2: Environmental management in the industrial chain internalized

Vision 3: Excellence in public policies for sustainable development of the industrial chain and society

Vision 4: Reference in education in sustainability

Vision 5: Model of interaction academy-industry-government on behalf of the Environment

#### 4.2.3. Roadmapping Pulp and Paper - Until 2018 [23]

From the same methodology as the previous examples, the expert panel developed and validated a set of four complementary views, displayed below, which make up a scenario where the desired industry of the state's pulp and paper industry becomes reference in research, innovation and technology, with the north, sustainable development.

Vision 1: Sustainable Industry Pulp and Paper

Vision 2: Excellence in R & D & I Fiber

Vision 3: Pole of Competitiveness in Packaging

Vision 4: Biorefinery for a Global Market

#### 4.2.4. Centro de Gestão e Estudos Estratégicos (CGEE) [24]

In the publication entitled "Green Chemistry in Brazil: 2010-2030" from CGEE a study was conducted in order to establish a dynamic of innovation and competitiveness for the Brazilian industry based on chemical processes that use renewable raw materials within the context of Green Chemistry.

It was analyzed the key technology platforms related to Green Chemistry, namely: (i) biorefineries - Route biochemistry, (ii) biorefineries - Thermochemical Route, (iii) Alcoholchemistry, (iv) Oleochemistry, (v) Sucrochemistry, (vi) Conversion CO<sub>2</sub>, (vii) Phytochemistry, (viii) Bioproducts and biofuels and bio-processes and (ix) renewable energy.

To conduct the studies were prospective information about the world scene and a national survey conducted by international databases Web of Science and Derwent Innovations Index on scientific production and patents related to this issue in the period 1998-2009 on various topics associated with. In addition to these surveys were used bibliographic information about the state of the art in order to identify the technological gaps to be overcome.

As a result of the work, maps were prepared technology (technology roadmaps) on the above key technology platforms in the world and in Brazil, the range of 2010-2030, divided into the periods 2010-2015, 2016-2025 and 2026-2030. For the subjects of biochemical and thermochemical biorefineries, different themes were

allocated over the time interval in the different stages that encompass research on bench, pilot stage, demonstration stage, scale-up, innovation / deployment, production / processing and marketing.

#### 4.2.5. Others-Technology Roadmapping for Ethanol [25]

The work done on the premise that if Brazil is to maintain leadership in the production of fuel ethanol will have to do planning in the actions of R & D throughout

the production chain sugarcane ethanol, which meets the goal of any process of technology roadmapping.

Thus, the roadmap proposed in the study aims to offer innovative proposals covering the whole cycle of the production chain - farming, manufacturing, products (sugar, alcohol, energy and others) and external environment through forward analysis. In the study the four components that were considered are the genetic improvement, handling, hydrolysis and thermochemical processes as shown in Figure 3 [25]. The approach of these components are explained below:

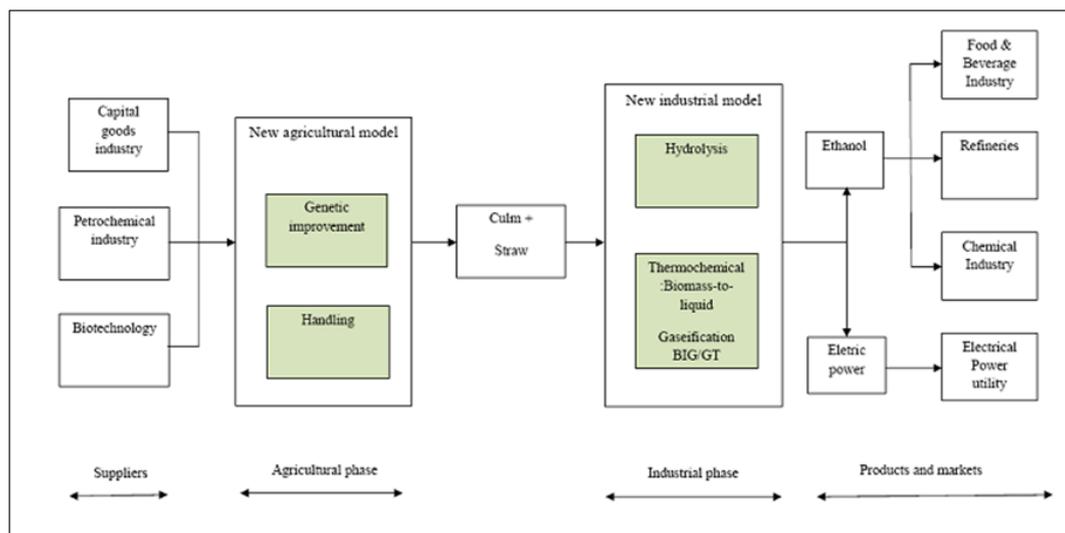


Figure 3. The four components of the technology roadmap

**Breeding:** incorporates new techniques of molecular biology and genetic engineering, knowledge areas that are rapidly developing for the generation of cultivars of sugar cane improved technologically specific purpose of ethanol production (sugar-energy) and electricity also incorporating requirements such as high agricultural productivity and resistance and tolerance to pests and diseases and adverse factors (drought, flooding, soil acidity, etc.).

**Management:** addresses the till, the recovery of straw, agricultural mechanization and management alternative. It should be noted that the first three issues are closely interlinked through the straw, which represents about a third of the biomass contained in the cane sugar that has historically been discarded, posture, no more accepted in the current scenario.

**Hydrolysis:** The process of transformation are of lignocellulosic materials for their conversion on Ethanol

**Termoconversion:** involves issues of gasification and BTL.

In addition, the paper also considers the external environment, analyzing the economic, social, cultural, international, demographic, environmental and political-legal influence the development of the productive chain.

Finally, it should be noted that all developed roadmaps presented as short, medium and long term period of five, ten and twenty years respectively, covering the time interval from 2010 to 2030.

#### 4.2.6. Technology Roadmap on Renewable Raw Materials [26]

Braskem held during the year 2009, a reflection process involving not only its internal departments but the university and research institutions. One result was the

development of a technology roadmap on renewable raw materials (rMPR) as proprietary methodology created by the authors. The roadmap does not represent Braskem's strategy but above all intended to be a document of departure for discussion, to be submitted to the various interest groups involved in the future of technology and innovation in Brazil.

The objective was to identify the products and technologies related to MPR that the horizons of 5, 10 and 15 years, could be developed. The identification of products and technologies from the document prepared by the university and was supplemented in internal discussions and interaction with the group itself. The information in this consolidated case was passed to the area of Corporate Innovation Braskem, which then built the first version of rMPR.

## 5. Discussion

Although Brazil has very favorable characteristics for the use of renewable energy, the nature of prospective studies that used the methodology of the technology roadmap focused on energy from biomass, particularly that related to pulp and paper industry and sugarcane. This is due to the fact that these segments represent successful examples of conventional biorefineries fully consolidated in the country.

The agroindustrial processing of cane sugar offers a diverse range of products such as bagasse, straw, molasses, vinasse and others. The bagasse and straw residues are lignocellulosic in nature that can be leveraged by both thermochemical route as the sucrochemistry route.

In thermochemical route, the lignocellulosic biomass is submitted at high temperatures and it can be obtained as the bio-oil products (by Pyrolysis) or synthesis gas (by gasification). In the sucrochemistry route, there is the fractionation of lignocellulosic biomass in all three fractions: cellulose, hemicellulose, lignin. From the pulp can be obtained ethanol second generation, from the hemicellulose can be obtained products such as furfural xylitol. And from the lignin can be obtained binders, adhesives and fuel due to its high calorific value [27].

However, in Brazil there are other studies of a prospective nature aimed at further study of other types of renewable energy. It may be mentioned the initiative in their studies CGEE entitled "Photovoltaic solar energy in Brazil: subsidies for decision-making" [28] and "Critical and sensitive technologies in priority sectors. Hydrogen energy in Brazil. Subsidies for competitiveness policies: 2010-2025" [29].

The literature showed that the tool made the Technology Roadmap has been used for studies involving renewable energy systems in developed countries, especially the U.S. and the EU. The TRM has proved useful in organization efforts and in guiding the research of Research, Development & Innovation in order to achieve the desired goals for each example discussed. In Brazil, the highlight was the work undertaken by SENAI / PR and CGEE.

It should be noted also that the base change of raw material for industry, arising from the replacement of oil and coal to renewable sources such as biomass, is configured as a rare opportunity for countries and companies to consolidate and / or gain leadership positions called the bioindustry. In this sense, efforts to P, D & I are indispensable and must be aligned with the strategies by which to achieve the desired objectives.

In general, the article also showed that the main obstacle to the advancement of renewable energy sources is its high cost comparison. Today, coal and natural gas are the main sources and will remain cheaper than those alternatives for some time.

Thus, it is necessary to participation of the state, companies, universities and regulatory bodies to encourage research and the use of renewable energy sources for the above obstacle can be overcome, and thus the sources of renewable energy may have a weight significant in the global energy matrix.

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