Using Scenario Analysis to Manage the Strategic Technology Planning for Environmental Sustainability Issues in Taiwan

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***Abstract*--The industry competitiveness will drive profitability when government and companies invest right resources in the right place to close the technology gap. Not only for private company but also for government they are facing the challenges on making the limited resources on the right way. For industry development the R&D investment should be the origin for its competitiveness. Government people want to know how to create a systematically process to understand future challenges. And base on the challenges government could identify the important issues, scenarios, and technology gaps that industry will faces. Considering the environmental sustainability issues that industry and government will face in the future. The purpose of this study is to explore the scenario of environment sustainable issues and provide for technology development planning. The approach is composed of several methodical steps. They are scan, foresight, scenario analysis and technology development strategy. The scenario analysis use workshop for depth discussion. The research propose technology development themes for the government. The process help the government to decide the direction of technology research development.**

I. INTRODUCTION

Environmental sustainability is a challenge faced by the future society. Although environment and climate change issues are acknowledged in the social planning process, a more studious attention on environmental sustainability and challenges brought about by the climate change will be necessary.

When faced with the environmental changes, peoples' observation can never catch up with the speed of change. For public policy makers, an early apprehension of the future changes will be helpful to planning of the contingency programs. We need to be able to observe the future environmental changes with an envisioning perspective and plan ahead to allow the society to respond to the changes.

To understand of future changes and the impact they may bring about, scenario analysis is a commonly used method. Scenario analysis is mostly applied in the challenges of climate change. Since it is very complicated and requires the investment of considerable resources, such as the expert methods, a cost-effective and easy-to-operate structure is necessary for assisting in future planning. Similarly, the use of scenario analysis on environmental change issues also requires a proper structure.

When we engage in the discussion of future changes, there are some ways to help us think about how to respond to changes in the environment. In discussing how to respond to future changes, there are several basic questions often asked. What will happen in the future? What specific goals will be reached? What is likely to happen? [2]

This study uses scenario analysis to plan for the important scenarios for future development. The study results accumulated from prospective observations form the backbone of scenario issues construction and analysis. The main purpose of this study is to address the possible development picture of Taiwan in terms of the issue of sustainable environmental development. In addition, this study explores the important technical directions in the scenarios as a way to plan for the technical capabilities which Taiwan need to build in response to the environmental changes in the future.

The paper is organized as follows. The second paragraph is literature review the importance of environmental sustainability issues, and their impact on Taiwan; application of scenario analysis and summary of the methods. The third describes the methods and steps for conducting scenario analysis. The fourth suggests three important scenario contents in the research. The possible picture of the future development of scenarios is also presented. The fifth provides the technology development process that could be the information for R&D investment for government. The final is conclusions based on the results of scenario analysis.

II. LITERATURE REVIEW

A. Environmental sustainability issues

From 1992 to 2012, the earth's population had increased from 5.5 billion to 7 billion. As the population grows, the consumption of resources increases, which has become a challenge to the earth's environment. The United Nations presented the "The Future We Want" report at the 2012 UNCSD (Rio + 20)[16]. The meeting called for the global leaders to come to terms with the urgency of sustainable development. As a result of global climate change, extreme weathers will be more frequent in [8]. Global population growth has boosted the demand for energy. Energy development and use are the important issues for the government. In the "The Future We Want" report, the importance of the development of renewable energy, improvement of energy efficiency, continuity of sustainable development and response to climate change was emphasized. In addition, the green economy is considered an important tool for the elimination of poverty and realization practice of sustainable development. When promoting a green economy, the stake holders must be involved.

Food security is also an important issue related to climate change and environmental sustainability. Faced with extreme climate change, governments need to construct resilient agricultural development and include "sustainable

agriculture" in their policy considerations and prevent economic development and agricultural practices that cause damages to the environment, maintain an eco-friendly environment beneficial for food production and continue to enhance food security and biodiversity with policy and environment related approaches. In addition, attention must be given to the soundness and safety of water supply systems.

According to the UN report, Taiwan is highly susceptible to climate [16]. During the past century, the average temperature of the island has increased 1.3℃, twice the global average. If the global temperature continues to climb, melting polar icebergs, the sea level rise. Sea-level rise will lead to flooding of low-lying coastal areas in the southwestern part and the Lanyang plain of Taiwan. As Taiwan is located at the junction of the tropical and temperate zones, the impact of climate change on the plants in particularly serious as they will face the test of climate screening. The temperature changes will shorten the crop growth period and reduce the production. The rise of night temperature will have great impact on food crops yield and quality [5].

Uncertain factors affecting sustainable development in the future include social and environmental factors. Factors such as population, economic development, regional demand for resources, increased demand of industrial and agricultural sectors have put Taiwan's limited resources under pressure. Therefore, these factors will also have an important impact on the environment and sustainable development in Taiwan. External factors affect the sustainable development of the environment and may have an impact and limitations. To understand and respond to the future challenges of environmental sustainability, scenario analysis is conducted in the related study for simulation and discussion of future scenarios.

B. Scenario analysis

Scenario planning considers a variety of possible future situations and uses important variables beyond the control to foresee and conceive the future prospects with an aim to preplan for the unpredictable events in a prudent way [19]. An effective scenario should be planned with a systematic cognitive framework [4]. Scenario analysis can help managers grasp the possible future change in a visible way [1].

Scenarios are “tools for ordering one’s perceptions about alternative future environments in which one’s decisions might be played out” [13]. Scenario analysis and future planning began their development after the Second World War when the Western world was at the stage of reconstruction [7]. Scholars believe that future development research can be divided into three periods as the scenario analysis was applied. At the first period, scenario analysis mainly focused on the quantitative methods for exploration. The quantitative methods included trend analysis, cross-impact analysis and growth model, etc. These methods are the basis for the application and development of scenario analysis. During this period, prospective studies were believed to generate feasibility or surprising results [10]. Scenarios were used as the prediction on the uncertainty in the future with the purpose assisting with the planning of public policies [7].

The second stage unfolded when future research and scenario analysis began to enter the business world to allow companies to grasp the unpredictable external environmental factors in the future. For example, during the oil crisis in 1973, GE (General Electric) [19] made way to envision the future with scenario analysis. The positive impact brought about by GE in scenario development and strategic connections led to the approach switch from the traditional development prediction to prospective study which is more exploratory. In the view of prospective study, the future development is not a linear progression of the current status. Many unexpected external factors would affect the development of the scenario, causing the trend to generate destructive and discontinuous change. Creativity and imagination are more important at this stage. Therefore, the key point of scenario analysis is to stimulate the collective imagination and creativity in the future [18].

The scenario development at the third stage, primarily deals with the sustainable development of the future. At this point, the objective of scenario development is to achieve sustainability through social restructuring [10]. Sondeijker [15] holds that it is more difficult to perform the scenario planning at this stage. She also believes that proactive actions are needed for understanding the long and uncertain future facing us. Thus, the exploration on the future requires discussion from a macroscopic perspective centered on the large-scale developments.

Scenario analysis examines the process of possible events in the future by considering a variety of possible results. By pooling and analyzing the results and their impacts generated from the trends or driving forces, scenario analysis helps decision makers to make more informed choices. Scenario analysis is a strategy research tool with three or four commonly used scenario models in practice while the most likely and the worst situations are all discussed. The key steps of scenario analysis are as follows [15] .

1. Identify significant impact variables for scenario construction.
2. Propose possible scenarios by exploring combinations of impact variables.
3. Construct a set of technology alternatives and classify them into groups.
4. Generate a set of technology assessment indicators.
5. Evaluate the technology alternatives by technology assessment indicators.

III. RESEARCH METHOD

This study used scenario analysis to plan for the important scenarios of future development and construct and analyzes the scenario issues based mainly on the results of prospective

observational studies. During the process of scenario construction, scenarios workshops were held with the participation of the experts from the industry and academia whose backgrounds included technical application and market analysis.

The scenario workshops of this year focused on the two major trend issues of manufacturing improvement and environmental sustainability for scenario construction and concept development in order to consider the key deciding factors of scenarios. Scenarios were written after being constructed with the use of story lines to aggregate the scenario developments proposed by the participants for compilation and description. In addition, the major technical items in the scenario development were discussed with the important technological development directions in each scenario being raised as the sources of technical applications and demands.

After the completion of scenario, to apprehend the history of scenario development for long-term observation of the picture of scenario development. Therefore, this study proposes the history of scenario development, combining the timeline with scenario development to allow dynamic advancement in the future for long-term observation and correction of the development picture of scenarios. In the process of the scenario development, the driving factors such as policies and technologies were included for observation of the subsequent impact of policy and technical needs, application opportunities on scenario development. This will serve as the direction to be addressed in the discussions on the important technical items and a link to the subsequent technical development directions. An experts meeting was held after the completion with the experts from the industry and academia discussing the content of the scenarios and technical items.

IV. RESULTS

A. Major driving forces

Based on the aforementioned scenario analysis method, the major driving factors and variables of scenario development and important uncertain factors are discussed in this study, which includes apprehension of the current sustainable development issues and discussion on the main objectives and the challenges faced.

To identify decision-making criteria, expert discussions were conducted concerning decision factors from the social, technological, economic, environment and political (STEEP) perspectives. Expert panel identified the important factors that influence the scenario development. Through evaluations from different combinations of these variables, final choices of scenarios were proposed. Furthermore, experts have to discuss the important technologies that enable the scenario development. The driving forces and variables that impact environmental sustainability is listed in Table 1. The driving forces are summarized from United Nations [16], World Economic Forum [20], Council of Agriculture [5], Dow Chemical [6] and Global Reporting Initiative [9].

The discussion mainly identified the important driving factors which were used as the axis of the scenario story line for writing the future scenarios. After discussion by the experts, the important scenarios of sustainable development in Taiwan as well as the process of the development of the scenarios in the next decade were completed.

B. Taiwan's 2025 Environmental Sustainability Scenario

For the 2025 environment and sustainable development scenarios, after the workshop discussions, three future scenarios were proposed, namely urban food autonomy, low-carbon footprint energy and the endless resources. Each scenario is described as follows.

Scenario 1: Urban food autonomy

1) Driving Forces

Greenhouse gas emissions have caused global warming, which lead to frequent weather anomalies such as drought, blasting rains, floods and typhoons. Global climate change affects the growth of food crops which rely on the weather.

According to the forecast by the United Nations, the world's current urban population is 3.2 billion and will be increased to 5 billion in 2030[16] . By 2030, three-fifths of the world population will live in cities as urbanization continues throughout the world to grow. In the past, 90% of the global population lived in rural areas while there are about 50% of the population living in cities. It is expected to that 80% of the population will be concentrated in cities in 2040. During the urbanization across the world, a large amount of irrigation water will be switched to industrial and livelihood use, which will transform many pieces of fertile agricultural land into non-agricultural uses, resulting constant

TABLE 1 MAIN DRIVING FORCE AND VARIABLES THAT IMPACT ENVIRONMENTAL SUSTAINABILITY

Categories	Driving forces	Variables
Social and Economic system	Demographic change	Population, lifestyle,…
	Economic development	GDP, industry structure,…
	Technology innovation	Pollution control, recycling technology, renewable energy, ….
	Regional development	Land use, irrigation area,…
Environment system	Climate change	Temperature, humidity, rain, typhone,…
Politics system	Law and regulation	Resource allocation, environment protection regulation, ….
	Policy intervene	Energy price, energy policy, renewable energy investment, ……

loss of agricultural land. In order to increase the yield per unit area, pesticides and fertilizers have been used extensively, causing soil acidification and destruction of the natural environment.

The 2015 report of United Nations' World Water Assessment Program (WWAP) indicates that 40% of the global population will suffer from water shortages in 2030 [17]. The report mentions that increased demand for food due to growing global population, economic growth and urbanization are factors causing increased water demand and water management has become an important issue.

Rapid industrial development and population growth have led to gradually increasing global energy demand and energy consumption will continue to grow in the next decade. It estimated that from 2010 to 2030, the annual growth of the world's primary energy consumption is will average 1.6%.

2) Scenario

With the booming urbanization and heightened awareness of low carbon footprint, low food ingredients with low carbon footprint has become a consumption choice for the people. The green farms set up in a city for planting has shortened the time and distance of food deliveries, and enabled all-year production of the crops without harvest failure caused by the climate impact; the consumers will have food security and autonomy, enjoying fresh, clean and safe foods. To cope with the development of urbanization characterized by limited land and dense population, the cities produce crops sufficient for their needs.

The green farm building has an eco-friendly growth environment for crop growth and is equipped with an experiment and planting monitoring center for collecting plant data and crop growth status. With independent and stable source of electricity, it provides sunlight, air and water the needed for crop production, imitating the natural system. The green farm also provides safe shelter to the plants against pests and harsh weather.

The green farm building supplies sunlight, air and water needed for the production of crops based on analysis of the big data accumulated for individual crops. The light source mainly comes from natural sunlight while the short is complemented with artificial light (such as OLED lighting) based on the needs of individual crop productions for combination of both sun and artificial lighting. Proper lighting is provided and adjusted during different growth phases based on the characteristics and spectral needs of the plants in order to enhance their growth. The air temperature, humidity, and content required for the crop in each growth stage are regulated to ensure a pest and bacteria-free growth environment with air filtering function. Clean water is supplied from the recycled rainwater and waste water from urban residences, offices and factories, which is processed in the water purification system while the closed circulatory system of the green farm also provides water source to the plants. The power system of urban farm building uses of green energy as the power source. In addition, it has high-efficient energy conversion equipment for converting the kitchen refuse or organic waste into energy and energy capture equipment allowing the reuse of power not used up elsewhere.

Proper crop production bases in the urban and suburban areas are planned through the regional agricultural crop management system and GIS is used to grasp the production condition and adjust the crop planting of each base to meet the basic needs of the local community and record the entire growth process in the farm.

In addition, the harvest information is disclosed in line with the production yield so that consumers can easily and instantly grasp the crop yields and origin and choose the items to buy or even book the crops based on the production forecast. The fruits and vegetables are delivered to homes through the transportation or delivery system. The agricultural products are guaranteed to be safe, fresh, chemical and additive-free. Fruits and vegetables are produced from the buildings in the city and are instantly delivered to the homes within a short distance after harvesting on the day.

According to the development scenarios, the main technical needs include:

- Greenhouse technology (plant factory)
- Crop parameters big data
- Bionic micro-climate system (sunlight, air, water)
- Air filtration system
- Water recycling system
- Regional food crops management system
- Full traceability control technology
- Instant ordering logistics system

Scenario 2: Low carbon footprint energies

1) Driving forces

According to the estimates by United Nations, the current world's urban population of 3.2 billion will increase to 5 billion in 2030. By 2030, three-fifths of the world’s population will be living in cities. The global urbanization growth will continue to accelerate.

The rapid development of industry and rapid population growth has caused gradual global energy demand increase. Energy consumption in the next decade will continue to grow. It is estimated that from 2010 to 2030, the world's primary energy consumption will grow at a rate of 1.6% annually. EU carbon emissions by 2030 will reduce by 40% over 2014. US oil and gas supplies are growing, slowing down the United States and Europe's external energy demand while the stable economic growth in Asia shits the energy demand to Asia. China will become the world's largest importer of net energy in 2035.

The research by Research and Markets [11] (2015) indicates that smart grid development in South America will continue to grow and cumulative investment from 2015 to 2025 is expected to reach $38.1 billion. Investment projects

include advanced metering infrastructure (AMI), distribution automation (DA), wide area measurement (WAM), home energy management (HEM), information technology (IT), as well as the battery storage capacity.

2) Scenario

Thanks to the transparency of information, the awareness on the issues of environmental safety and sustainability among the consumers have heightened significantly. The government and industry have invested in the development of renewable and clean energies for obtaining the energy needed on the hand and reducing the loss of energy during the transfer on the other hand. Renewable and clean energies such as solar energy and wind energy have seen continued decline in costs and have thus been widely used in everyday life. The development of new energies such as biomass energy, geothermal, etc., have also obtained a stable progress in the related technologies and continued to have breakthroughs in efficiency.

The continued development of network communications has allowed the network infrastructure to be widely established in cities and the communities and the concepts of mass outsourcing and data transmission sharing have also been applied to the power transmission sharing planning to form a sharing-type power network.

A power network is a complicated system consisting of generation, transmission, distribution and end-users---an integrated intelligent power system which operates with a smart grid through information, communications and automation technologies, providing automation and security and allowing close cooperation between the users and the supplier. Advanced sensors, measurement technologies and two-way communication control are used to enhance the operating efficiency of the power system, power supply quality and power grid reliability and integrate and analyze the power use information to achieve the best allocation of power resources.

Communication networks and the power networks have been gradually combined to allow the electricity produced to be distributed in a way similar to the network communication to where it is needed through the best routes. Each home, office and school have the micro power collection and generation system ability to collect for creating renewable energies which are not only for the consumers' own use, but are also shared with others instantly through network connections. People are informed of the power consumption of their own home appliances at a particular time. The peak power distribution in the area or community is optimized based on the accumulated power transfer and use data on the Internet for the household power use pattern to be adjusted based on the temperature and estimated power consumption to reduce overuse and maintain stable power supply. Through continuous information feedbacks, power supply and demand can be properly planned configuration. The power network uses data analysis to plan for the concentration or distribution of power to achieve the best application and decentralization of power. Renewable energies are produced at homes, factories and offices and green power is shared among one another through the energy network.

According to the development scenarios, the main technical needs include:

- Renewable clean energies
- New energy technologies
- Smart grid
- Electricity network
- Big data
- Cloud computing
- Sensor
- Regional energy distribution

Scenario 3: Endless resources

1) Driving forces

Food, water and energy have become important core issues around the globe in 2030 and have pushed the governments to exert continuous attentions and efforts in policies and technologies. Due to global population growth and the middle class consumption patterns, future demands for food, water and energy increase by 35%, 40% and 50% respectively. Climate change makes the unusual weather patterns more drastic as food, water and energy become even scarcer.

High international environmental standards, compliance with environmental regulations by the countries, effective use of resources and reduction of wastes are all efforts aimed to secure a winning position in the supply chain. Resources use and conservation have become an important part in the process of product design and manufacturing. The outcomes of products are carefully conceived at the design stage, so the materials can be recycled and reused again and again. There will be two circulatory systems in the future: ecological circulatory and industrial circulatory systems. Ecological circulatory products are made of biodegradable raw materials, and are finally back to the ecological cycle to provide nutrients; industrial circulatory product materials continue to return to the industrial cycle for reuse or upgrade to be made into new products. Non-toxic materials and clean energy, water saving processes replace environmentally hazardous, energy-consuming and water-consuming raw materials and manufacturing processes and recovery channels are properly planned to make the product supply chain, products and recycling environmentally friendly.

2) Scenario

With changes in the environment and limited energy resources, a new wave of industrial revolution has forced the government and business community to make thorough analysis for understanding the challenges of future manufacturing and industrial development. Solutions provided by the scientists, industry and environmentalists

positively address the industrial models truly needed by mankind. Businesses and consumers are starting to pay attention to "Do we know what kind of products the customers need, and what kind of products does the environment expect?" The cycle chain of products consumption, consumption and the impact on the environment has become the key point in the product materials, design and manufacturing emphasis the point, which is not to passively reduce environmental destruction, but a responsibility to protect the environment in a positive way.

A new industrial system must humbly learn from the nature in which there is no such thing as waste ── everything is basically a nutrient and can be returned to the soil.

Manufacturing processes are benefited from the development of new materials and application of simulation technologies. businesses can apprehend material texture and plan for the recycling during the product design stage and all the materials used for production are safe and healthy while hazardous materials such as lead, aluminum, etc. will be excluded to avoid environmental and health hazards

The reuse and redesign of recycled products, has also become an important part in the development of innovative products. Materials are applied in production in an optimal way to reduce unnecessary material waste and resource consumption. The government also provides incentives to industry to reduce unnecessary waste and future recycling paths including biological cycle and industrial cycle are clearly defined before materials are used for manufactured. One of the important tasks of product design is to be able to reduce the use of materials and processing operations after recovery. Laminate manufacturing technology can be widely used with simulation and design programs being applied. The materials selected can be used for fast printing for customized features. Advances in science and technology have brought incentives to the industry for reducing unnecessary waste of resources. With the government's emphasis on environmental protection and the corporate awareness of environmental responsibility and brand image, the construction of a recycling or reuse system which enables the recycled products to return to the industrial or biological cycle has received heavy attention. As a result, a new operation model of permanent relationship built between businesses and customers through the use products has been established to ensure the advantages of recovery of resources for reproduction or upgrade.

In addition, given the importance of the water resources to the daily needs, a great variety of fixed or portable appliance or equipment are widely used for water resources processing to assist the recycling and use of water resources. Moreover, desalination technology, recycled water and the use, recycling and discharge of water are all included in the regional ecosystem. Resource management related technologies and infrastructure combined with urban development and planning, it is widely used in everyday life.

According to the development scenarios, the main technical needs include:

- Recyclable materials
- Environmentally friendly materials
- Recycling and reproduction technology
- Upgrade and reproduction technology
- Laminated Manufacturing Technology
- Water recycling technology

C. Future scenario development process

For the future development scenario, this study presents a future scenario development process with each 5 years being a block to form the basis for trend development observation and understanding (Figure 1).

The process of the development of future scenarios includes three parts: driving forces, scenarios and promoting factors. Generally speaking, the environment and sustainable development are affected by population growth, climate change, technology and network development, as well as the efforts by the governments to implement the green policy. The three scenarios presented in this study are discussed from the perspectives of energy, food and resources. The development of scenarios can only be realized with the support of related technologies which are discussed in terms of policy promoting factors and technical promoting factors in this study. For the technical contributing factor, according to the experts of various technical fields, the development of clean energy, traceability management and control and water recycling are important technologies for the next five years. The information communication technology and mega data are the infrastructure. The collection and analysis of data can help grasp the future energy and resources needs. In addition, the policy is a contributing factor. For sustainable development of the environment, policy will play an important role. Especially after 2020, more specific policies are needed for promotion of environmental sustainability.

V. CONCLUSIONS

The study suggests possible development scenarios for the issue of environmental sustainability based on the scenario development and analysis approaches. For a scenario, not only important driving factors and scenario content are included, but also contributing factors. Through a scenario, researchers and stakeholders can communicate with each other while the discussion on the contributing factor can help policy planners understand the future policy focus. In addition, the discussion on the technology contributing factor can serve as a reference for the government in the R & D of technologies. The future needs can be grasped through the description of scenarios in order for the R & D resources to be invested in the development of the technologies needed in the future.

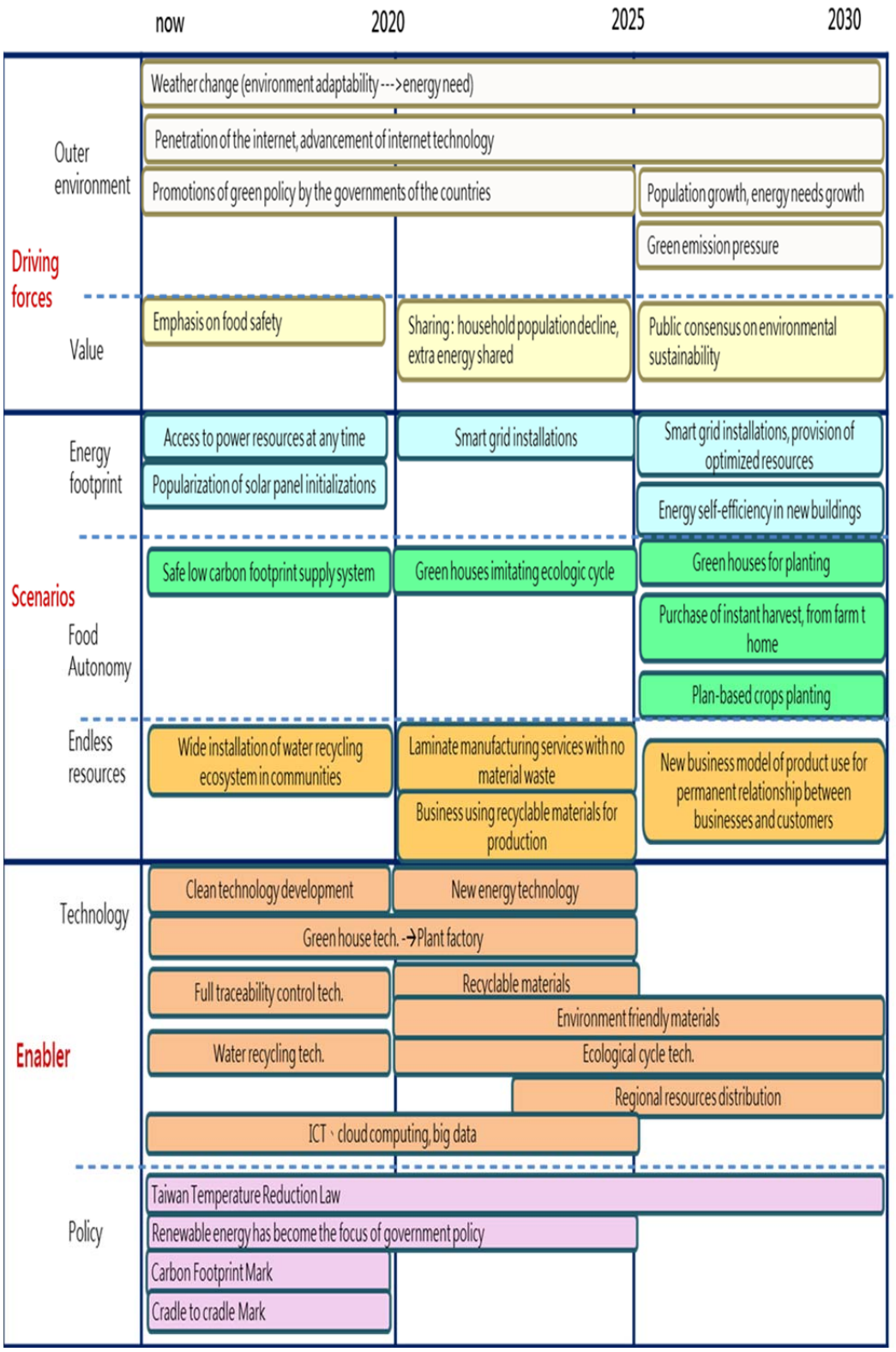

Figure 1 Environmental sustainability scenario process

VI. STUDY LIMITATIONS

There are two limitations in this study. First, the scenario development is limited. When developing a scenario, the scenario discussed and conceived by the experts is affected by the driving factors. Second, the scenario shows only description of execution as the author relied only on the discussion and judgment of the experts, lacking the quantitative method to supplement the scenario content. This can be the area to be improved in the future studies.

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