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Provide a product life Cycle Optimization Model Using Agent Based Simulation

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Abstract
With increasing competition in global markets, organizations are paying more attention to the life cycle of their products. To achieve this goal, careful decision-making about the variables affecting the product life cycle is necessary, and the more factors are considered, the better the result. Therefore, in this research, an attempt has been made to provide a life cycle optimization model for the electricity industry. In this model the factors of consumer, producer, government, investor and technology direction Simulations have been considered with the help of which we try to study the process of electricity generation and optimize this process according to changes in consumption and technology, as well as reducing the level of carbon dioxide emissions and its effects on the environment. To analyze the results and optimize the model, Anylogic software was used. After implementing the model to optimize the results, a number of scenarios were examined according to the opinions of experts and the final conclusion was reached. According to the studies, the results of the optimization model presented with the actual results available between 1390 to 1398 corresponded to a small distance, which indicates the high validity of the model, also to optimize the model to reduce air pollution and Reducing carbon emissions by changing the technology factor, we saw a reduction in fossil fuel consumption and thus a significant reduction in air pollution.

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Introduction

With increasing competition in dynamic global markets, along with changes and product development over time, customer satisfaction has found an important and vital place in the organization. Given this importance, senior executives of organizations are well aware of how to succeed in this dynamic and vast market must pay special attention to the life cycle management of products, technology and customer satisfaction. On the other hand, not all customers in the market are equally effective in the success of our organization. Therefore, satisfying the main and effective customers of the organization will be more important.

Therefore, it is necessary to implement a system in the organization to retain and attract customers according to the stages of the product life cycle and taking into account the new and dynamic business conditions of today. The product life cycle is the period when the first product enters the market until the product becomes obsolete and gives its market share to other competitors. Since the main goal of companies is to make a profit in the market, so managing the product life cycle and its sustainable design will be important and vital. .(Lindeijer and Guinée 2002)

According to the contents of this study, a model has been tried to optimize the life cycle of products in power plants, for this purpose, the factor-based simulation paradigm has been used to optimize the proposed model. Therefore, first, the life cycle of electricity generation should be examined, and then, using factor-based simulation, we should try to present a model, identify a behavioral pattern, and optimize the life cycle of the electricity industry.

In this model, consumer, producer, government, investor and technology factors are considered. With the help of these factors, we try to study the process of electricity production and optimize this process according to changes in consumption and technology, as well as reducing the level of carbon dioxide emissions and its effects on the environment. In this study, the Sustainable Product Development Process (SPD), in which about 80% of a product's total environmental impact is determined, has been used to translate R strategies into new product needs. The aim of this study was to investigate the implications of adopting the R strategy for decision making in sustainable product development.(Diaz, Schöggl et al .

2020).

Emily et al. Reviewed a research study entitled "An Optimization Simulation Model for Sustainable Product Design and Efficient End-of-Life Management Based on Individual Manufacturer Responsibility."

This study combined two decision-making issues, namely the choice of design alternative and the determination of the EOL option for product families based on individual producer responsibility throughout the life cycle, taking into account possible uncertainties. (Ameli, Mansour et al. 2019)

Cao et al. Presented a factor-based simulation model of the company's financial distress for different stages of the product life cycle. This research proposed a new factor-based simulation model to simulate the causes and processes of financial distress in the company. The overall framework of the model consisted of four factors: organizational environment, product, bank and large environment.

Research background

Solis and teammate Proposed a multi-objective product life cycle optimization model for an integrated algal biorefinery toward a sustainable circular bioeconomy with resource recirculation in mind. In this paper, a new multi-objective optimization model is developed focusing on an algal biorefinery that simultaneously optimizes cost and environmental impact ،adopted the principle of resource recovery and recirculation, and combined the life cycle assessment method to properly calculate the environmental impact of the system.(solis, San Juan et al. 2021).

Zupak, using factor-based simulation and modeling, evaluated the life cycle stability to evaluate the location of the biorefinery. In this paper, he states that the use of factor-based modeling (ABM) and life cycle sustainability assessment (LCSA) as part of an integrated approach allows for optimal assessment of potential effects. (Zupko,2021)

Rand and teammate Conducted a study (modeling the basis for the release of a new product market: a review of strengths and criticisms). The purpose of this study is to encourage researchers to turn to innovation management by considering factor modeling and simulation as a way to gain deeper insights into market behavior and more informed decision making. The results of the research review study indicate that different areas of new product market dissemination and innovation management are available in a wider range that can be analyzed using factor simulation.(Rand and Stummer 2021).

Diaz and teammate Reviewed a study entitled, Sustainable Product Development in the Circular Economy: Implications for Products, Actors, Decision Support, and Product Lifecycle Information Management. For this purpose, we first examine the amount of megawatts of electricity consumed (domestic, industrial, etc.) in different conditions, and based on that, try to provide a suitable model for generating electricity and reducing the amount of fuel consumed by power plants, as well as reducing air pollution caused by fossil fuels used in power plants.

As we know, with the advancement of technology, the pattern of electricity consumption in various industries has changed drastically, and as a result, due to the increase in consumption, we are facing power outages due to the shortage of megawatts of electricity generated versus megawatts of electricity consumed.

On the other hand, due to the reduction of water resources in the country and also the increase in air pollution caused by carbon emissions from fossil fuels in power plants, we face limitations to increase electricity generation capacity in power plants. In order to solve this problem and supply the required megawatts of electricity consumption in different sectors, we need to provide an optimization model in which both the lack of resources and the discussion of environmental impacts are considered. Since part of the electricity production in the country is in the hands of the private sector, so we can consider the role of the investor in this colorful industry and with the help of technology and investment, we can examine different scenarios.

According to studies and surveys of life cycle and factor-based simulation, which are both tools for system management, both of these methods try to study the interaction and impact of factors on each other.

Although the LC and ABM methods are two different tools, they have similarities in terms of roots and performance.

The life cycle examines the interaction between factors in the product supply chain, while factor-based simulation has a broader view of the system, and examines the interaction and relationship between all factors in the system.

In the following, we examine the proposed model for realistic simulation and optimization of the electricity industry supply chain using factor-based simulation, and also with the help of the Monte Carlo method, we examine the validity and accuracy of the proposed model.

Walter et al. Have focused on product-cost optimization in the early stages of a product life cycle. This paper states that, while theoretical concepts for product costing methods have evolved over the decades, little emphasis has been placed on their integration into modern information systems. (Walter, Leyh et al . 2017)

Manda et al. Study Value Creation through Life Cycle Assessment: A Way to Practice Using Life Cycle Assessment in Chemical Companies to Create Sustainable Value. In this study, it was stated that value creation opportunities include cost reduction, risk reduction, product differentiation and new products to meet unsatisfied needs. However, the relationship has different aspects of sustainability from one company to another depending on the context.(Manda, Bosch et al. 2016).

Chao et al. Presented a study entitled "Life Cycle Assessment, Life Cycle Energy Evaluation, and Life Cycle Carbon Emission Evaluation in Buildings." This review study introduces three types of life cycle studies that are often used to assess the environmental impact of building construction with a major focus on whether or not they can be used to make decisions. These three streams are: Life Cycle Evaluation (LCA), Life Cycle Energy Evaluation(LCEA) and life cycle carbon emission evaluation (LCCO2A). They were compared with their evaluation objectives, methodology, and findings. (Chau ،Leung et al.2015).

Methodology

According to the tools used to analyze the results and optimize in this study, information about variables should be collected at two levels: discrete and continuous and finally, with the help of AnyLogic software, we can simulate the product life cycle model and then we optimize the problem variables by expressing different scenarios according to the conceptual model of the research, which reduces fuel consumption, reduces carbon dioxide emissions from fossil fuels and produces the required amount of megawatts of electricity.

In this study, we first identified the factors (Agents) affecting the life cycle of the electricity industry according to the influencing factors (ability in February 2016) and defined different parameters for each. Next, we have to extract the information related to each of the agents and simulate it with the help of Anylogic software and identify the status of the product (MW of electricity) at each stage of the life cycle. In order to increase sales, market share, profitability, quality, etc., we can provide appropriate strategies according to the location of the product in the life cycle.

Table 1: Agent used in simulation

Description	Agent
Includes MW of electricity consumption, home sector	Household Consumption
Includes MW of electricity consumption, industrial sector	Industrial Consumption
Includes MW of electricity consumption, agricultural sector	Agriculture Consumption
Includes total MW of electricity consumption, sections (public + public consumption + street lighting)	General Consumption
It has an effective and decisive role on all factors except the technology factor.	Government
Electricity generator	Market
It is a factor that can have a positive or negative effect on the consumption of different parts.	Technology
This factor meets the shortage of megawatts by investing in a variety of power plants according to existing factors.	Investors

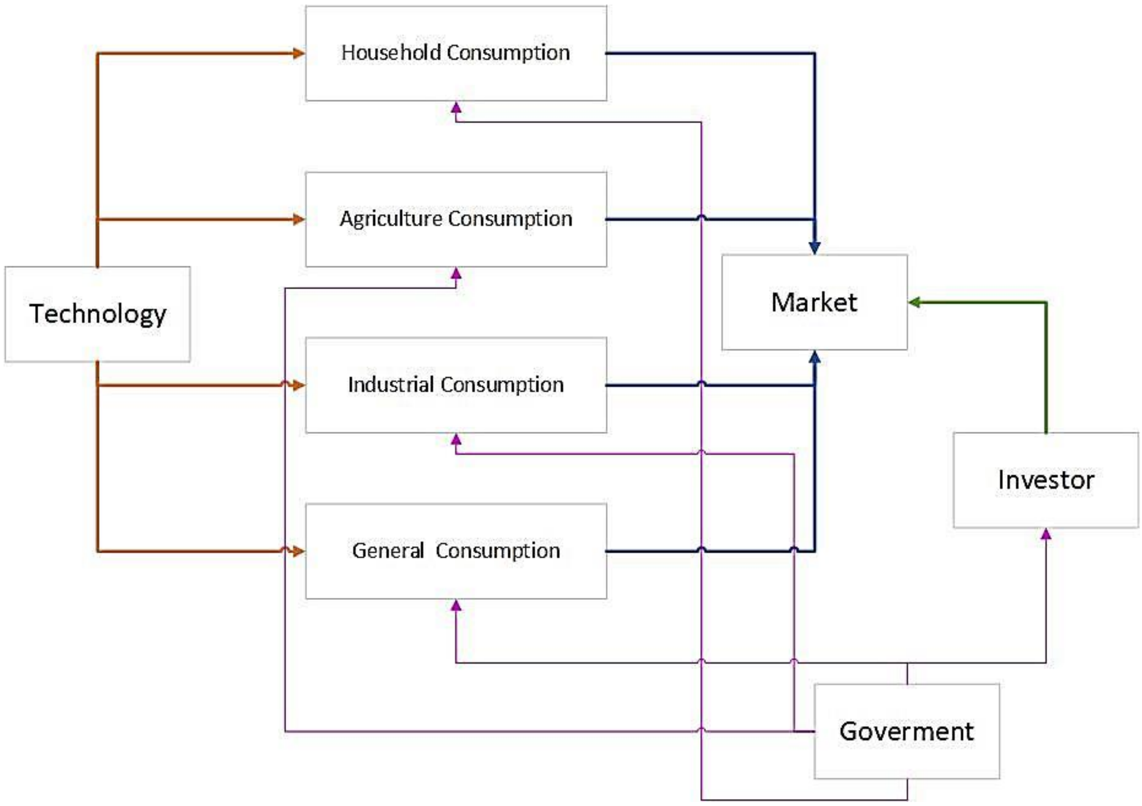

Figure 1: Optimization Model

According to the proposed model (Table 1), we have four factors under the heading of consumer, which are: household consumer, agricultural consumer, industrial consumer and general consumer (ability in February, 2016).

These agents request their energy from the market agent, and the market segment, according to the number of available power plants, generates electricity and provides it to consumers in different sectors.By examining the various causes of financial distress at different stages of the company life cycle, the simulation model was implemented in four specific cases that are related to the stages of onset, growth, maturity and decline life cycle, respectively.

A comparative analysis was then performed between the simulation results and the actual situation in the four proposed specific cases , which showed that the proposed simulation model is a promising tool for a comprehensive analysis of the causes and processes of financial distress. (Niven and kao, 2019)

Pooh et al. Presented an article entitled "Optimizing the product life cycle for the production of rubber gloves". The introduction of the article states that the production of elastic gloves may have adverse effects on the environment, including global warming, carbon footprint, acidification, photochemical ozone formation, eutrophication, and human toxicity. Therefore, product life cycle assessment is used as an environmental management tool to assess its environmental impact. Life cycle optimization is implemented to minimize energy consumption and greenhouse gas emissions by proposing five alternative process improvement scenarios (Poh, Chew et al., 2019).

Tau et al. Presented a study entitled, Product Life Cycle Design to Create Sustainable Value: Sustainable Product Development Methods in High Value Engineering. This study provides a framework for sustainable product development in high value engineering using life cycle based approaches along with sustainable value modeling and analysis methods. A sustainable value model is presented based on understanding value from economic, social and environmental perspectives.(li , Tao et al., 2015).

The nominal capacity of power plants can be seen separately in 96 months of model implementation.

The results show that the amount of MW of electricity generated by the hydroelectric power plant in this implementation is equal to 13.539 MW, gas generated by the power plant (gas) equal to 24.342 MW, electricity generated by the steam power plant (steam) equivalent 15.822 MW, combined cycle power plant (equivalent) 27.130 MW and power plantRenewable is equivalent to 1.116 MW.

According to the information extracted from the 53-year report of the Ministry of Energy (February, 2016), the nominal capacity of the mentioned power plants is as follows:

hydroelectric power plant (hydro) equivalent to 12.191 MW.

Gas power plant(gas).equivalent to 26.180 MW.

Heater power plant(steam) equivalent to 15,829 MW.

Combined cycle power plant equivalent to 27,130 MW.

Renewable power plant equivalent to 1.119 MW.

Finding

In order to optimize the proposed factor-based simulation model, using the opinions of experts, three scenarios with different conditions have been studied that each of them aims to reduce the effects of air pollution, optimize the consumption of liquid fuels and fossil fuels.

In order to study different scenarios, we consider a time period of 10 years, ie the results of the scenarios until 1410 will be examined in the following.

In the other part of the model, the government factor is located and the government influences all the factors in the model because according to the instructions issued by the government, the nominal capacity of power plants is calculated or a power plant in the public sector enters the production cycle or leaves it.

In addition, the government can influence consumers in various sectors with the issued instructions and laws.

On the other hand, due to the fact that according to the information extracted from the electricity industry, there is always a gap between the amount of megawatts produced and megawatts consumed in different sectors ،as we know, this distance indicates the lack of megawatts of production compared to megawatts of electricity required for consumption.

In this situation, the investor enters and tries to compensate for the shortage of megawatts of electricity generated by investing in power plants in the production cycle.

However, in order to enter the cycle and choose how to supply the existing amount of MW by investing in the commissioning of power plants: heating, gas, combined cycle, hydropower and renewable electricity, the investor must also consider the policies and instructions issued by the government.Therefore, the government factor will affect all seven factors in the model.

The last factor in this model is the technology factor.The factor of technology can have a positive or negative effect on the amount of megawatts of electricity consumed by consumers in different sectors. Because sometimes with the advent of technology, consumption has increased.

For example, with the introduction of gas cooler technology, the consumption has increased a lot, or vice versa, with the introduction of other technology, the consumption has decreased.

For example, with the introduction of low-energy lamp technology into the market, consumption has decreased dramatically.

According to this model, in this research, first, information related to the four dimensions of the life cycle model should be collected , then based on the information obtained and with the help of factor-based simulation model, we study the behavior of variables and finally optimize the objectives of the problem.

To validate the model, Monte Carlo simulation with a random number core was used.

With the help of this simulation, we calibrated (standardized) the two levels of attractiveness created by the government to select the power plant, the percentage of investor probability of investing to supply the required megawatts of electricity.

For this purpose, we ran the model 1000 times with different random values and finally we obtained the values that with the entry of information in 1390 as initial values after 8 years (96 months) Gas, heaters, cycles

Combined, hydropower and renewable energy converged to the values available in 1398 from the 53-year report of the Ministry of Energy.

Therefore, we can conclude that the model that performed the simulation correctly and close to reality for 8 years will also predict the results for the next 10 to 20 years correctly and close to reality.

According to the diagram shown in (Figure 2,) the nominal capacity of the country's power plants in a period of 8 years of simulation is about 83 thousand megawatts.

Meanwhile, the results of the 53-year report of the Ministry of Energy have stated that the total nominal capacity up to 1398 is 449.82 MW.

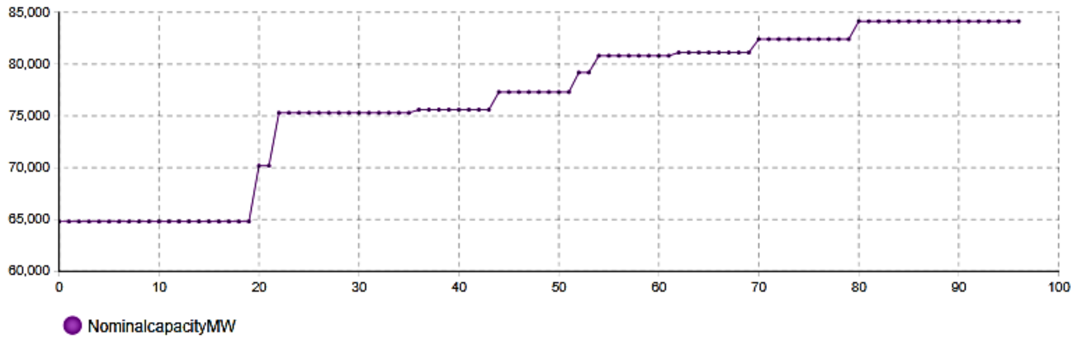

Figure 2: Nominal capacity of the model for 96 months

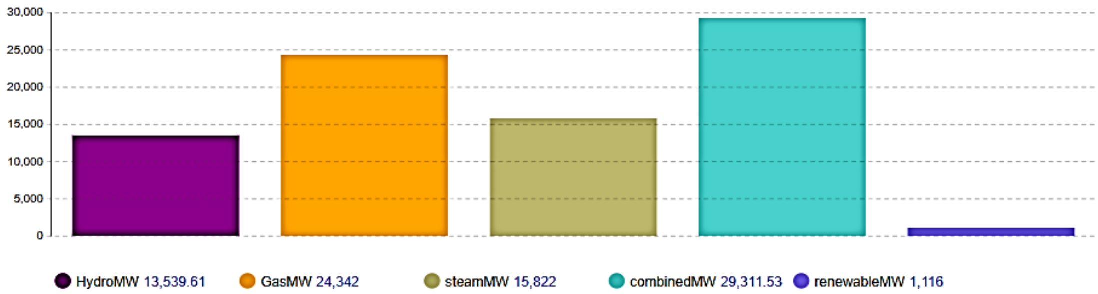

Figure 3:

However, according to the results of this simulation, if most of the gas power plants and the combined cycle are still out of the production cycle, we will face a severe shortage of megawatts of electricity generated against the megawatts of electricity required by consumer agents.

Therefore, by applying this scenario, we will definitely face many interruptions and many problems in the field of electricity generation in the future, considering the lack of water resources.

As a result, if the government is to focus on expanding renewable power plants, some sort of planning must be done for other power plants that the amount of fuel consumption is reduced, but in contrast, we do not see a huge shortage of megawatts of electricity for consumer agents.

Scenario 1

Due to drought and lack of water resources, the government will have to remove most of the hydro and steam power plants from the power generation cycle.

In this scenario, in the operating sector of the government, according to the policy considered in the field of complete elimination of two hydropower and heating power plants, the degree of attractiveness for these two power plants was considered zero.

We considered different attractions for the other three power plants. However, considering the carbon emission issue, we tried to make the renewable power plant more attractive than the other two power plants.

In addition, in the capacity reduction section, the sliders of the two heating and hydroelectric power plants were placed at number one, which means that these two power plants are completely out of the power generation cycle.

According to the second scenario and the departure of two heating and hydropower plants from the production cycle and taking into account the effects of slides applied, the amount of megawatts of electricity produced by the gas power plant, combined cycle and renewable cycle has increased, respectively.

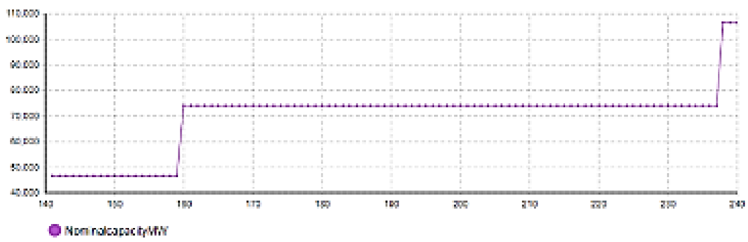

Figure 4: Nominal capacity of scenario 1

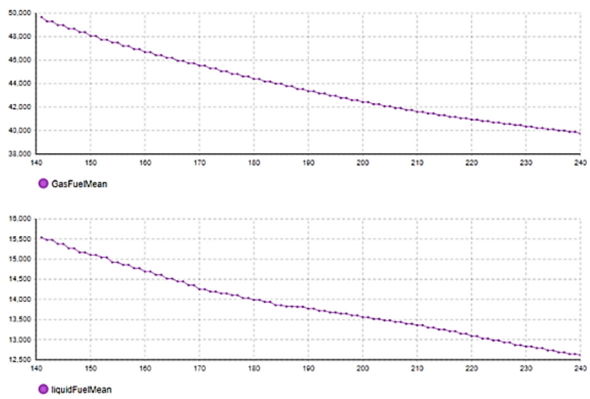

Figure 5 : Fuel consumption scenario 1

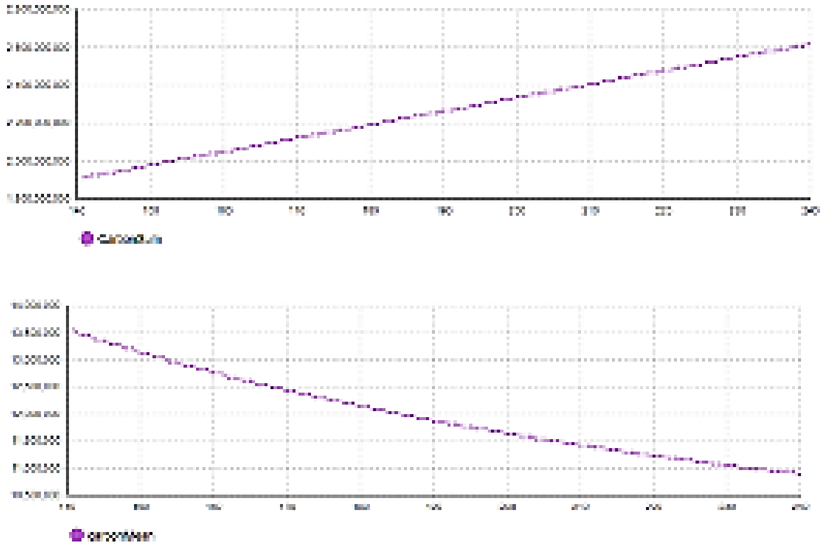

Figure 6 : Emitted carbon gas Scenario 1

According to the above scenario, we saw positive effects such as reduced fuel consumption (liquid and gas) and carbon emissions.

Due to increasing air pollution and environmental impacts and lack of fossil fuel reserves, the government should focus on renewable power plants.

If in order to reduce the amount of pollution in the government, we reduce the attractiveness of gas power plants and combined cycle and add to the attractiveness of renewable power plants, heaters and hydropower ،also if we remove 80% of the gas power plant and 70% of the combined cycle power plant from the electricity generation cycle, the following results will be obtained:

After 20 years (240 meters), the model implementation of the nominal capacity of the plant has increased by 100,000 MW which this incremental leap occurred once in 1403 and again in 1309.

And In the period between 1403 and 1409, the nominal capacity was constant.(Twice the investment has been made to meet the shortage of megawatts of electricity produced compared to megawatts consumed.)

Given the attractiveness that the government has created for investors, the capacity of the hydropower plant has increased significantly, and in contrast, the capacity of both gas and combined cycle power plants has been drastically reduced to prevent air pollution and carbon emissions.

As a result of this reduction, the consumption of fossil fuels including liquid fuels (diesel and furnace oil) and gaseous fuels has also decreased significantly in this regard.

As fuel consumption has decreased, so has the average carbon emission rate.

Compared to the 10 years of operation of the model, the amount of carbon emissions has been reduced to about 3,000 cubic meters, which will definitely have a positive effect on air quality in the long run.

Compared to the previous scenario, the nominal capacity of power plants has increased, which occurred in an increasing trend once in 1401 and the second time in 1404, after which until 1410 the trend of MW of electricity production has remained constant.

(Two investments have been made to meet the shortage of megawatts of electricity produced.)

According to the second scenario and the departure of two heating and hydropower plants from the production cycle and taking into account the effects of slides applied, the amount of megawatts of electricity produced by the gas power plant, combined cycle and renewable cycle has increased, respectively.

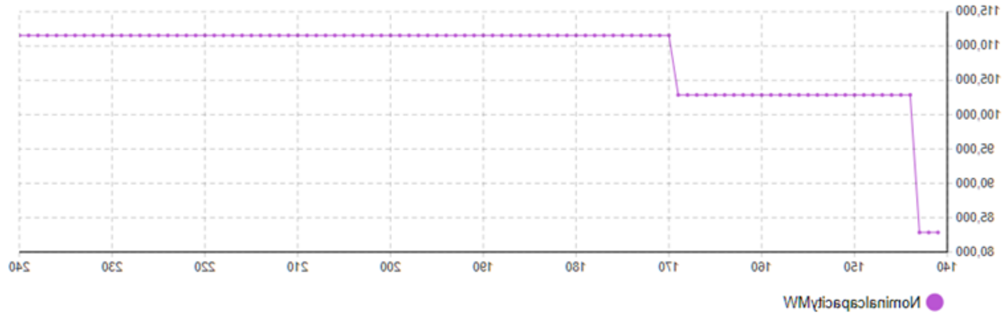

Figure 7 :Nominal capacity of scenario 2

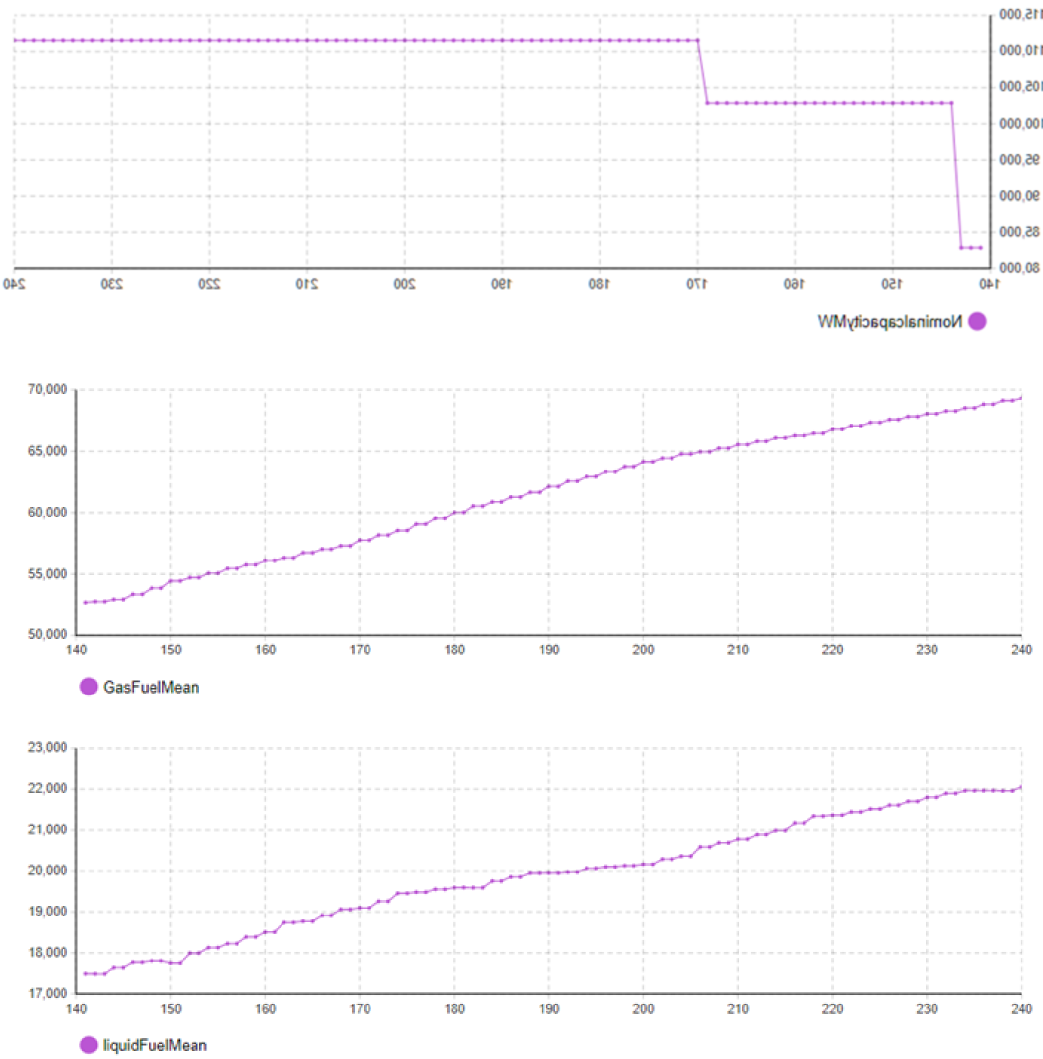

Figure 8 : Fuel consumption scenario 2

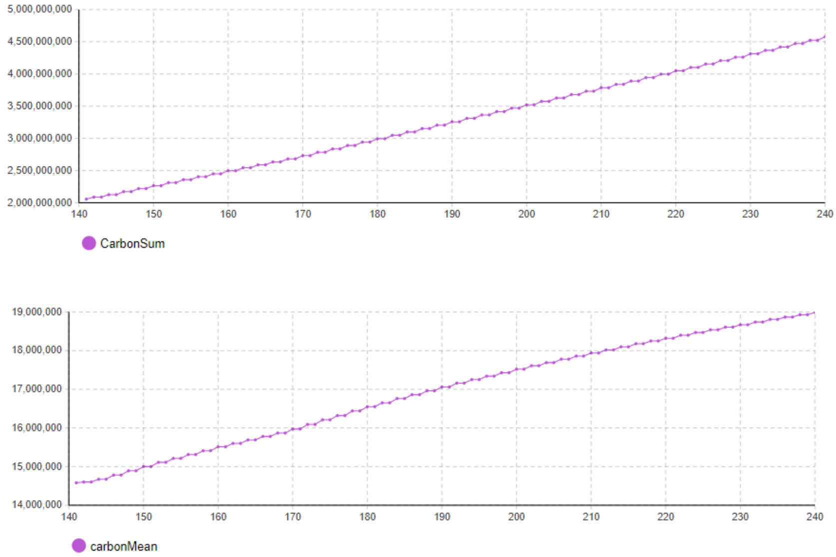

Figure 9 : Carbon emission scenario 2

Scenario 3

Suppose technology enters the market that reduces household consumption by up to 40%. In this scenario, we assumed that technology such as low-power lamps would result in a 40 percent reduction in the amount of megawatts of electricity consumed by the home consumer.

In this scenario, various attractions have been applied by the government to the investor, which also takes into account environmental considerations. In addition, given the scarcity of water resources, we assumed that about 40% of hydroelectric and steam power plants play a role in the production cycle.

We had an increase in capacity in two stages, the first time this increase occurred in 1403 and the second time this increase was observed in 1407 ، and then the process of producing megawatts of nominal fixed capacity is considered.

(Two investments have been made to increase the capacity of MW of electricity produced.)

It is also important to note that compared to the previous two scenarios, the amount of nominal megawatts of electricity was much lower until 1410.

Due to the increase in gas fuel consumption, the amount of carbon dioxide emissions in this period for the third scenario has increased significantly, which is one of the weaknesses of this scenario and will lead to increased air pollution.

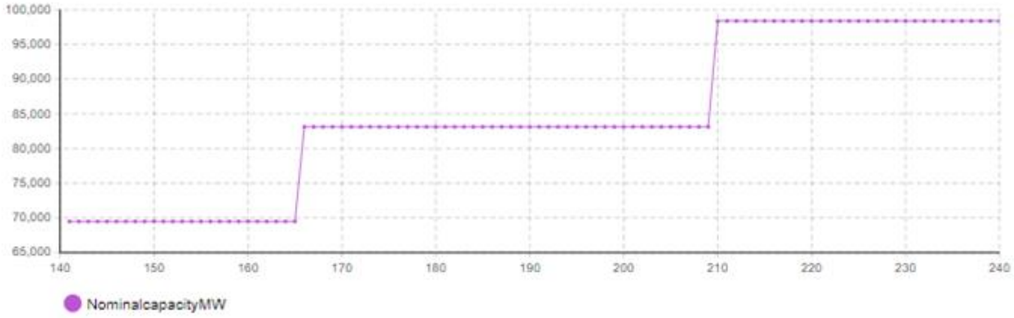

Figure 10

Figure 11

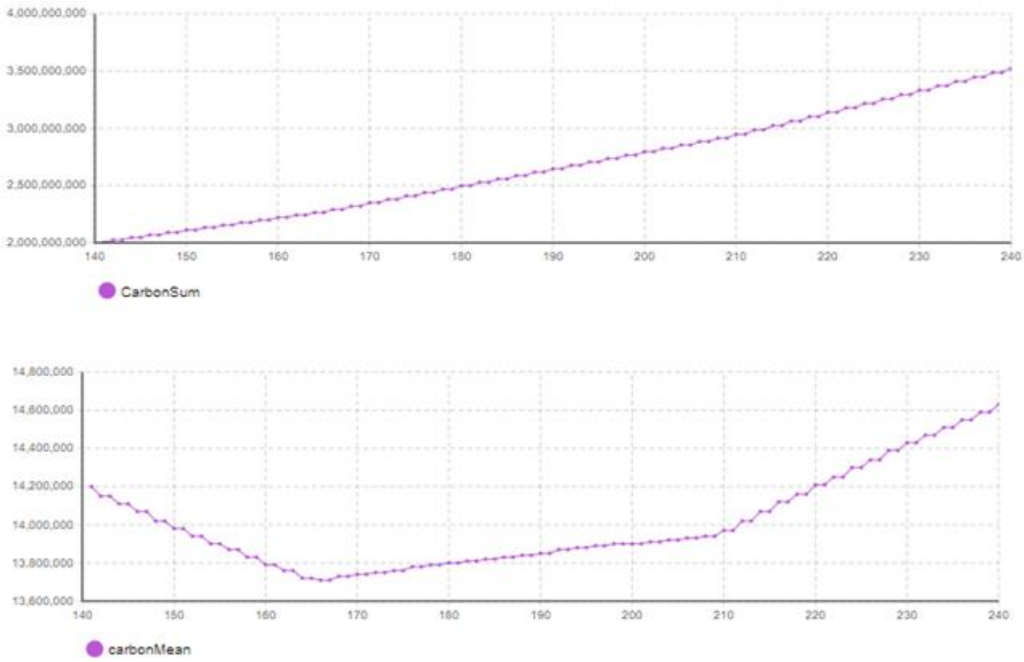

Figure 12 : Carbon emission rate Scenario 3

Discussion and conclusion:

According to the proposed model of the life cycle of the electricity industry in the country and its simulation with the help of Anylogic software and operating paradigm, three scenarios for optimizing the model according to the results for the next 10 years were presented and examined.

With the studies performed and the slides compiled in the software, we can change the model to examine different conditions and model it.

To be able to reduce air pollution and consumption of fossil fuels, as well as reduce the shortage of megawatts of electricity generated in the consumption sectors.

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