A new multi-objective dynamic model to close the gaps in sustainable development of industrial sector

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Abstract. The GHGs emissions by different activities show that the main part that is 25% belongs to electricity and heat production and the industrial activities counting as 21% of total emission. About 37% of the electricity consumption in Europe belongs to manufacturing and share of industrial activities in GHGs are among 30% to 40%. The electricity production trends show that the proportion of the renewables energy is going to reach to 20% in Europe by 2020 and according to the new energy targets, the minimum use of renewable energy must be 27% by 2030 and decarbonizing by 2050. For the industrial sector as a main energy consumer several elements affect the total energy consumption that start from the mining of the raw materials, transporting the materials to factories, grid network and finally the product to the end users and landfilling/recycling the used products. In this regards, to analyse all factors together a new multi-objective dynamic model has been developed. Moreover, to achieve eco-factories, the main solutions have been provided and dynamically analysed by the model. The results show that, all possible factors must be considered at the same time and applying just some approaches such as solar panels and forgetting the other factors such as end user, life cycle analysis and many other factors will not achieve the sustainability goals. The multi-objective dynamic models can be used as an appropriate approach to check the role of all solutions in achieving eco and sustainable factories.

1. Introduction
There are different ways to achieve eco-factories approach and the solutions and strategies by academic section, industrial section and policy-makers might be different [1]. In this regards, it is necessary to analyse many factors and elements to reach the best result.

1.1. GHGs emissions by sources and different activities
The total emitted CO\textsubscript{2}e from multiple sources in 2008 was about 27 gigatonnes and share of electrical section was 37% equal to 10 gigatonnes [2]. The total GHGs emissions in 2016 reported about 49.3 gigatonnes CO\textsubscript{2}e [3]. The main emitted gas is Carbon Dioxide (CO\textsubscript{2}), counting 76% of total GHGs.
About 65% of CO₂ emitted from fossil fuel and industrial process and 11% from forestry and other land use activation such as agriculture. The second GHGs is Methane (CH₄), counting as 16% and the third is Nitrous oxide (N₂O) counting as 6%. The main sources of these two gases are agricultural activities, fertilizer, and waste management [4].

1.2. Global energy-related CO₂ emissions and the Share of industrial sector
The Global CO₂ and GHGs (CO₂ equivalent) emissions by different sectors between 1990 and 2010 determined that the first one is energy sector that including electricity production, heat, industries, manufacturing, fuels and the second one is transportation. The third one is Industry that contain production of minerals, chemicals, metals and electrical equipment [5]. The study determined that, the energy production causes 72% of total emissions in 2013, that 31% is by electricity and heat, 12.4% by manufacturing, 15% by transportation and 8.4% by other fuels [6]. The analysis of another study in 2014, showed that the main part of GHGs emissions that is 25% belongs to electricity and heat production and the industrial activities counting as 21% of total emissions. The share of agriculture, forestry and other land use activities is 24%, and the share of transportation is 14% [7]. The results of another research shows that about 28.6% of total greenhouse gas emissions are mainly driven from the industrial activities [8].

1.3. The electricity production and consumption and the share of industrial section
The analysis of electricity production by different sections in Europe demonstrated that, during the past two decades, the electricity production by oil and coal decreased but the renewable and gas increased. The use of renewable energy from 13% in 1990 increased to 29% in 2014 and use of oil from 9 % in 1990 decreased to 2% in 2014. Finally, nuclear energy remained the same and around 30% [9]. The global electricity generation increased about 3.1%, (780 TWh) in 2017. However, half of the new electricity generation produced from renewables source and in 2017, the share of renewables from total energy production was about 25% [10]. The trends show that the proportion of the renewables energy is going to reach to 20% in Europe in 2020. According to the new energy targets, the minimum use of renewable energy must be 27% by 2030 and decarbonizing by 2050 [9]. About 36.9 percent of the electricity consumption in Europe belongs to manufacturing and share of industrial activities in GHGs emissions are among 30 to 40% [11].

1.4. The energy flow and energy management in factories
The studies showed that, there are a few energy management systems for factories [12]. One of the standard in Energy Management Systems of organizations is ISO 50001 that was released in June 2011. The major seven components are including general requirements, energy policy, energy action plan, implementation and operation, management responsibility, performance audits and management review [13]. Analysis of the energy flow in the factories will be helpful in better energy management. The energy flow can show the energy supply and consuming sides that can be modelled [14]. Moreover, the energy flow diagrams are suitable for identifying energy waste in a factory and recognizing bad states of processes [15]. Energy management in the factories can be done in different sections including HVAC and lighting, equipment utilization rate, waiting time of equipment, the delay time, the equipment operation time and energy yield of the production [13].

2. Materials and methods
According to the research reviews, there are many correlated factors in sustainability and eco-factories and finding a new solution to achieve sustainable development in the industrial section seems necessary. There are also many parameters in management of energy in the factories such as energy flows, energy consumption by different machines, expecting of consumption in the future, production lines and involved units in the production process, the requirement loads of the various operating sectors, the final uses of energy, the economic impact, and many other similar factors. In this regards, the applied method in this research is to identify the most appropriate solutions and developing of a multi objective dynamic model to be able to analyse all elements and the consequences of choices together. The developed
solutions are based on the combination of the methods presented in literature reviews, using the methods of BEMS in the factories or innovative methods.

2.1. Life Cycle Assessment in different sectors of factories

The life cycle assessment is an important factor in analysis of sustainability in a factory and must be controlled for all factors and all sectors. In electricity production, the emission during the power generation is not the only important factor but also the lifecycle GHGs emissions in different electricity generation methods is important. The Lifecycle GHG Emissions by different electricity generation methods has been shown in Figure 1. As it can be seen, biomass, nuclear, wind, and hydroelectric are among the lowest electricity generation method. Lifecycle GHG emissions of natural gas plants are about 15 times more than nuclear, wind, and hydroelectric plants. The lifecycle GHG emissions of Solar PV range between studies and in some studies estimated near Oil power plant but the average value from the studies is 8 times less than oil power plant and 6 times less than gas power generation plants. The analysis show that, even in selection of the energy supply, if the solar panel with low quality be used the GHGs might be the same as oil.

![Figure 1. Lifecycle GHG Emissions in different electricity generation methods [16]](image)

From the total fresh water consumption, about 11% is used by municipal, 19% by industrial and 70% by agriculture sectors [17]. In 2010, 15% of total water withdrawals in the world, have been used for energy production that is equal to 80% of total water consumption in the industrial section. Predictions show that the water withdrawals will rise about 20% by 2035 and consumption increase more dramatically and about 85% [18]. The analysis showed that energy and water are correlated. The hydropower plants use water directly to produce electricity. In fuel power plants, the water is using in extraction of fossil fuels and in the cooling towers [19]. The correlation between water and energy show that, the methods with optimize use of all resources must be apply. For example, without consideration of the correlation of water, energy and electricity, the energy problem can be solve but the water and environmental problems will be appear.

2.2. The main solutions to achieve eco-factories

The selected approaches to improve the energy efficiency and sustainability in dynamic model are including selected FEMS and BEMS practices, green rating factors, life cycle analysis, energy management in storing the productions and transporting, reusing the raw materials and recycling, total power peak, direct and indirect energy flow, renewable energy (solar, biomass), water management and lid methods, etc.
2.3. Developing a multi-objective dynamic model

There are many dynamic models that one of them is Vensim. The Vensim software is an Industrial strength simulation software for improving the performance of real systems. It can be used for connections of data and it is flexible distribution and contains advanced algorithms.

2.4. The case study for analysis of selected approaches

To show the application of the new method and to illustrate the elements a case study has been selected. The case study is Alfagomma Hydraulic Spa that Founded in 1956. The factory, with various types of industries, will make it available to developed idea. The main productions of Alfagomma Spa is hydraulic productions including Hoses, Fittings, Adapters, Quick Coupling, Swivel Connectors, Valves, Hose Guard, Manipulated Tubes, PVC tubes, etc.

3. Results

3.1. Determining the major energy consume in the factory

The major energy consuming sections in Alfagomma factory have been determined and presented in Figure 2. As it is clear, the energy consume is contains a ranges of sectors including factory environment, manufacturing and production, storing and other indirect energy consumption.

![Diagram showing major energy consuming sections in Alfagomma factories]

3.2. Determining solutions and selected approaches to improve the energy efficiency

The determined solutions to decrease the energy consumption in the factories by consideration of most correlated factors are as follow:

- Solution Number 1: Using selected FEMS and BEMS methods. This solution is mainly including preparation of the energy-saving management plan, establishing the energy dashboard and installing the main systems to the visualization dashboard, monitoring of energy performance and determining the warnings notifications, determining the opportunities and solutions and establishing the client function and communication to obtain the feedback of the implemented solutions [20] & [21].
- Solution Number 2: Green rating systems in decreasing the energy consumption. Analysis of a factory by green and sustainable development approaches and different Green rating methods such as Green Star Rating system of Australia, LEED system by USGBC or ISO 50001, can be a suitable way to illustrate the current condition and to improve the efficiency [13] & [22].
- Solution Number 3: Optimizing the energy management in storing of productions. The storing section is an important unit in any factory and is responsible in total energy. The storing amount,
depends on other factors mainly are the vicinity of stored materials to the end users, the optimum productions in each production line. By considering this solution, the energy for storing for production will be optimized.

- Solution Number 4: Reusing the raw materials and recycling to decrease the energy consumption. The analysis showed that the recycling can boost the circular economy. In the case study, since one of the main element in the Alfagomma factory is rubber, the analysis determined that the cost of using recycled rubber can be half of synthetic or natural rubbers and some of the properties of recovered rubber is better than virgin rubbers and it needs less energy in compared with virgin rubbers. Moreover, the use of recycled rubber will decrease the consumption of petroleum that is a non-renewable material.

- Solution Number 5: Design of a user interfaces for selected production. Through design of a user interfaces that present the energy-related information for end user and all parties the concerns about the sustainability and global warming will increase [14]. Moreover, the relevant stakeholders can share useful data about the environmental impacts and materials and the ways to extend the components lifespan. This decision-making algorithm method will shift the business toward a circular business besides decreasing the wastes amount and increasing the reuse options [23]. In this way, not only the life cycle of the productions can be increase by approving the opinions of the users, but also the availability of reusing used products directly by the main manufacture can be achieved.

- Solution Number 6: Decrease of total power peak. The simultaneous start of machinery systems along with other devices such as hydraulic, cooling/warming systems, air pressure and similar devices can increase the total power peaks [24]. Shift total power peaks on different machines can be done by changing production order at the same time, shifting production start time [25]. The results will decrease the total power peak and it means less installation of solar panel for example, to have the enough load for operation.

- Solution Number 7: Using direct and indirect energy flow in the factory for energy management. Determining the energy flow in the factories will be helpful in better energy management. In this method, at the first all energy usage of the factory for all purposes such as heating and cooling, pumps, manufacturing, maintenance, operation, preparation of the raw materials from mine to factory must be gathered and the direct and indirect energy flow in factory must be determined [14], [26].

- Solution Number 8: The role of water management and lid methods in decreasing the energy consumption. The analysis showed that LID methods can decrease the energy cost in the buildings in several ways. From less required energy for irrigation of the plants by pumps trough rain harvesting to less energy for heating and cooling by green roofs [27] & [28].

- Solution Number 9: The role of other renewable energy resources like biomass in the factory. Producing energy from the organic compounds in sewage sludge can be done in several ways such as of the factories such as Biomass-fired power plant for production of electricity, energy recovery from sewage, production of biofuels, direct production of electricity by microbial fuel cells and producing valuable materials from the inorganics materials inside the sewage sludge [29].

- Solution Number 10: Identifying energy waste in a factory and recycle of the waste energy such as the hot vapour for production of initial materials. By functional software and analysis of the data it is possible to identify the energy waste in a factory and recognizing the bad states of processes [15].

The most of the determined solutions can be extended for all factories. The general suggested analysis trend in the new method prepared and have been presented in Figure 3.
Figure 3. The suggested analysis trend by new method

3.3. Developing a dynamic multi-objective model

According to the provided solutions, a dynamic multi-objectives model has been developed. The developed model by consideration of all determined solutions in Vensim has been shown in Figure 4. As it can be seen, the purpose of all solutions are decreasing the total energy usage in the factory. Some of them directly linked and some of them depends to other factors and indirectly linked.

Figure 4. The developed dynamic model of the selected factory
4. Conclusion
The analysis showed the important role of factories and industrial section in total GHGs emissions and therefore, increase of the efficiency in industrial section will lead to less energy and greenhouse gases emissions as well as less resource consumption. The results show that to achieve the sustainability goals, all possible factors must be considered at the same time. The energy, water and other resources correlated together and with applying the usual approaches such as using solar panels and forgetting the other factors such as end user, life cycle analysis and many other factors the energy in the factory might decrease at the point but the total life cycle energy, GHGs and sustainability not. According to the presented method, it seems that the best way is case by case analysis and determining all energy factors in the selected factory. The suggested solutions that can be considered for analysis are including FEMS and BEMS methods, green rating systems, optimizing the energy management in storing section, reusing the raw materials and recycling, design of a user interfaces, decrease of total power peak, using direct and indirect energy flow analysis, use of water management and lid methods, use of other renewable energy resources like biomass and use of waste energy in the factories. The multi-objective dynamic models such as Vensim can be apply as an appropriate approach to check the role of all factors and solutions together in achieving eco and sustainable factories. In this way, after gathering the required data of each solution by monitoring, the dynamic system will show the advantages of each approach.

5. Suggestions
For further analysis it is suggested that, the climate change elements considered in the modelling. Since, the climate and resources conditions might not be fixed during the life time of a factory, then in some cases even a sustainable design might need to improve and updated based on the new condition.

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