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Evaluating the Efficiency of Circular Economies in Persian Gulf Countries in Terms of Municipal Solid Waste Management

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ABSTRACT

In the last few decades, the control of environmental issues, including waste, has been an important part of human duty in maintaining human health, which has a special place in new science and technology according to economic health standards. The use of circular economy practices has been proposed as a new approach for urban solid waste management. The purpose of this study is to provide a data envelopment analysis (DEA) approach to measure the performance of the Persian Gulf countries in the management and exploitation of municipal solid waste (MSW). A careful study of the existing literature shows that there is little knowledge of CE and MWSM, especially in the discussion of improving the circular performance of countries in the field of MSW. Therefore, measuring the performance of countries in this field can be very important. This research is applied in terms of purpose and descriptive survey in terms of data collection. The statistical population is the Persian Gulf countries. In this research, the MSW production per capita and the three dimensions of social progress index "basic human needs", "basics of well-being" and "opportunity" are used as input and recycling as output in the model. Data on MSW generation and recycling rates were obtained from the World Bank and data on the three SPI indicators were extracted from the Essential Social Progress website. The data of this research is for the year 2021. The DEA model was implemented in LINGO Softer.

The results show that the countries of Kuwait and the United Arab Emirates respectively have the highest circular economy performance compared to other countries in the Persian Gulf. Data analysis shows that according to the statistics of the World Bank, these three countries recycle 21% and 20% of production waste, respectively. Of course, they perform well in input indicators compared to other countries. It should be noted that these results can be somewhat influenced by the conditions of the Covid-19 pandemic. For example, Iran will produce more solid waste with more population and compliance with health protocols. This could have caused it to fall to fourth place. Although their performance in these indicators is much lower than some European countries such as Slovakia. According to the results, it is suggested that other Persian Gulf countries improve their performance in recycling.

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1- Introduction

In the last decade, concern about the environment has increased increasingly around the world. One of the serious environmental challenges is urban solid waste, the management of which has been raised as one of the main concerns of human societies. According to the World Bank, by 2025, more than 1.4 billion people will live in cities around the world, and each of them will generate an average of 1.42 kilograms of municipal waste per day. Estimates show that municipal waste worldwide triples every year. The annual generation of municipal waste worldwide has increased from 0.68 billion tons to 2.2 billion tons. Based on available data from countries up to 2012, the World Bank has published a report focusing on municipal solid waste generation. Waste is materials or objects that are discarded or thrown away. Solid waste is waste or discarded materials and objects obtained from industrial, commercial, mining, agricultural, and general daily activities (Ugwu, Ozoegwu & Ozor, 2020). Solid waste is one of the serious environmental issues in developed and developing countries. Solid waste management is a major challenge in urban areas around the world, especially in developing countries. The main reason for this challenge is the rapid population growth along with the expansion of cities, the reduction of financial resources, and the weakness of urban planning. Human activities and changes in lifestyle and consumption patterns have led to an increase in waste production rates (Bovard & ilanloo, 2019). Controlling environmental pollution, including waste, is an important part of human duty in maintaining human health, which has a special place in new sciences and techniques according to economic health standards. Waste production is inevitable in human daily life and population increase will increase it. Municipal solid waste is defined as waste generated by human, commercial, and construction activities that are collected and treated by municipalities (Xiao, Dong, Geng, Tian, Liu, & Li, 2020). The main composition of these wastes is almost the same in different countries of the world. However, the amount of production waste, density, and share of each

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part of it is different from country to country and city to city. This difference is caused by economic development, geographical location, weather conditions, and cultural and social considerations (Afshar Kazemi, Eftekhar & Omrani, 2014). About, 2.01 billion tons of municipal solid waste is produced annually in the world, of which at least 33% is not environmentally managed. Worldwide, waste generated per person per day averages 0.74 kg but varies widely from 0.11 to 4.54 kg. Of course, it is predicted that by 2050, the amount of waste produced in the world will increase to 3.40 billion tons, which is equivalent to 2 times the population growth in that year. The East Asia and Pacific region produces the most waste in the world at 23%, while this number for the Middle East countries is about 6% as shown **Figure 1**. Of course, it is expected that the total waste production in this region will more than double by 2050. It is worth noting that in these areas, more than half of the waste is discarded without reuse. This waste growth will bring many adverse environmental, health, and welfare consequences. Therefore, it requires basic measures.

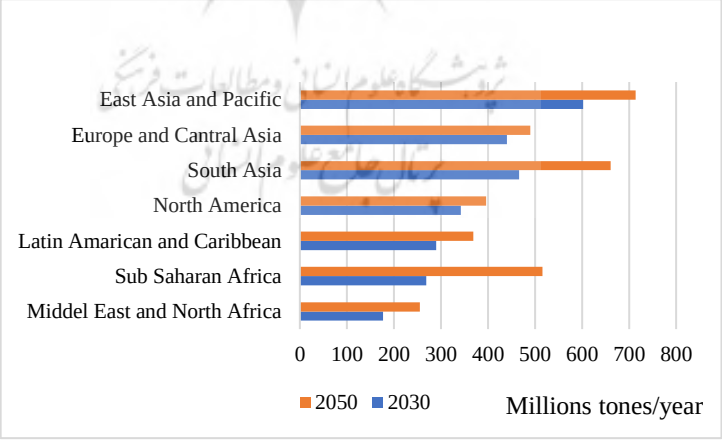

Figure 1. Forecast of waste generation
Source: world bank (2021)

The Persian Gulf region includes the eight coastal countries of Iran, Iraq, Kuwait, Saudi Arabia, Bahrain, Qatar, and United Arab Emirates. The most populous and least populous countries are Iran and Bahrain, respectively. Researchers found that countries such as Saudi Arabia, United Arab Emirates, Kuwait, and Qatar that consume more natural resources tend to produce more waste (Umar, 2020).

Studies show that about 65% of waste in the Persian Gulf region is not managed. Ghayebzadeh et al. (2020) showed that the coastal countries of the Persian Gulf produced about 1634.9 kilotons of plastic waste in 2016, which is expected to increase to 531.6 kilotons by 2030. As a result, the associated cumulative environmental impacts could be more severe. It can be emphasized that all the countries located in the coastal areas of the Persian Gulf need to improve their waste management.

In this situation, there is a need for a model to transition from the traditional linear state of the economy and replace its stable state. A circular economy as an efficient tool can reduce environmental impacts and prevent increased costs, delays, and other consequences. In recent years, the use of circular economy practices has been proposed as a new approach to the management of urban solid waste. Geissdoerfer, Savaget, Bocken & Hultink, (2017) define the circular economy as regenerative and consider it a model that reduces waste production and emissions. This system focuses on reducing the use of raw materials, protecting material sources, and reducing the carbon footprint (Murray, Skene & Haynes, 2015). In the circular economy, various measures such as recycling, use of second goods, etc. are emphasized. If they are followed in the waste management system, they will create many benefits. For example, recycling reduces the pollution from waste incinerators and reduces the pollution of water resources due to leachate. Also, less waste will be buried and burned, and fewer raw materials will be extracted from mines. In developing countries, less than 10% of municipal waste is recycled and only a small amount of these recycled materials have acceptable standards. It is important to promote efficient and environmentally friendly waste

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management. Increasing the rate of recycling and management of the collected waste can contribute to environmental and circular performance in countries, especially developing countries. To this end, it is vital for policymakers and scientists to be able to measure waste management performance and also assess whether the analyzed countries are on the right track to more efficient use of recycled materials. The main question of this research is: How is the efficiency of the circular economy of each of the Persian Gulf countries?

For this purpose, in this research, the research literature and the background of circular economy and urban solid waste have been examined. Then the methodology is stated. In the following, the findings are presented, and at the end, conclusions and research and practical suggestions and limitations are presented.

2- Literature review

In all countries, based on the growth of population and economy, the amount of waste production is increasing annually. Also, the amount of waste produced, its composition, and its origin differ among countries and are related to the structure of the economy and the level of investment in innovation and technologies. In this section, urban solid waste management and sustainable economy as well as the empirical background in the above fields are presented.

2-1- Municipal Solid Waste Management

In the past decades, especially since 1990, the amount of municipal solid waste production has increased according to private consumption costs and GDP. The amount and composition of urban waste in different countries are different according to consumption levels and patterns, urbanization rate, income level, lifestyle, and national waste management practices. Ten years ago, there were 2.9 billion urban residents, producing about 0.64 kg of MSW per person per day (0.68 billion tons per year). The report estimates that today these amounts have increased to about 3 billion people, producing 1.2 kg per person per day (1.3 billion tons per year). By 2025, this amount is likely to

increase to 4.3 billion urban dwellers, who generate about 1.42 kg per person per day of municipal waste (2.2 billion tons per year) (Hoornweg & Perinaz, 2012). MSWM refers to the activities and actions such as storage at source, collection, transportation, treatment, and final disposal that are required to manage MSW from origin to final destination. As a provision of urban governance, the public, environment, and attractiveness of a city depend on it (Wilson et al. 2013).

2-2- Circular Economy

The environment uses resources such as materials, water, and energy. The products and services and waste are produced. The production of waste in excess of the absorption capacity disrupts the ability of the environment to provide input resources and will ultimately cause their reduction(Hosseinpoor & ghorbanpour, 2023). The circular economy will create new resources as a closed-loop system by recycling the produced waste (McDonough & Braungart, 2013). For the first time, the concept of circular economy was introduced by Boulding in 1966. Pearce & Turner(1989), introduced the circular economy under the concept of environmental economy, which promotes competitiveness and sustainable development. Grafstrom &Aasma (2021), the circular economy promotes economic performance through waste recycling and cost reduction. Also, Keulen & Kirchherr (2017), states that in the circular economy, it focuses on reuse of materials, reduction of waste and recycling.

Recently, various researches have been conducted in this field. In 2021, Rafew & Rafizul investigated the capacity of producing, collecting, treating and burying municipal waste with a system dynamics approach until 2050, and the results showed that the per capita waste production will increase to 0.561 by the end of the year. Therefore, it is necessary to increase the budget for the development of wastewater treatment facilities. Bertanza, Mazzotti, Gómez, Nenci,

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Vaccari & Zetera (2021) addressed a topic called circular economy implementation in municipal solid waste management in an average Italian city with the aim of evaluating municipal waste management strategies in the city of Brescia over a 30-year period. The results of the study show that the separate collection is saturated with street containers by about 40%. The creation of incinerators eliminated the direct disposal of waste in landfills. With the introduction of the new collection system, separately collected waste increased by more than 73%, the amount of waste collected per capita decreased from 685.3 kg per year to 579.6 kg per year, a significant decrease in recyclable materials in unsorted waste was gained.

2-3- Social Progress Index

In the field of waste management, in addition to technical, institutional and financial issues, social progress index(SPI) will also be very useful and effective. social progress indicators such as education and public health and advertising will have a great impact on the collection of recyclable waste and thus the recycling rate.

2-4- A review of experimental studies

In the field of this research, several studies have been conducted in recent years, which include:

Marques & Teixeira (2022) in a study evaluated the performance of municipal waste in the European Union using DEA. The results show that policies should focus on environmental awareness through education, strengthening the human development index. Rios et al (2021) studied the environmental performance of European Union-28 (EU-28) members in municipal waste treatment. The results show that there is a positive relationship between environmental performance and the level of economic development. Abou Taleb & Farooque (2021) in research titled Towards a circular economy for sustainable development: using full cost accounting for urban waste recycling with

aim of investigating different accounting approaches and scenarios for sustainable urban waste management were investigated to find the most. The results of this study show that the system used in this study has the lowest waste costs and creates more economic and social incentives for households and brings environmental benefits. These findings have various implications for policymakers, government councils, waste managers, businesses, and communities in adopting plans for cost-effective, profitable, and socially acceptable waste reuse and recycling. Such a valuable addition to municipal solid waste management can contribute to sustainable environmental and social development in emerging markets and move towards a circular economy model. Yeh (2020) studied the dynamic inefficiency analysis of electricity revenue of municipal waste incinerators in Taiwan using data envelopment analysis. The analysis shows that the technical, income and allocation efficiency of public power plants is lower than that of private power plants. Xiao, Dong, Geng, Tian, Liu, & Li, (2020) investigated the issue of policy influence on municipal solid waste management in Shanghai with a system dynamics approach. The purpose of this research is to simulate the impact of different policies on urban solid waste management from a dynamic and complex perspective, and in this research, the entire process of waste production, separation, collection, and final treatment has been investigated in seven scenarios. The results show that economic policy has a great impact on the future municipal solid waste management. If the GDP growth rate decreases by 1%, municipal solid waste generation will decrease by 3.25 million tons in 2035. The municipal solid waste segregation policy reduces the total demand for landfills but increases the demand for food waste treatment facilities. The policy of the treatment method will not play many roles in reducing the total demand for landfill. Finally, the consequences of considered economic and demographic policies, strengthening the capacity of biochemical

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treatment, and comprehensive use of waste are suggested. In this research, it is predicted that this dynamic model and policy implications can help the municipal solid waste management of 45 other Chinese cities that plan to implement segregation regulations soon or even other global cities. In a study, Fatima, Chaudhry & Batool, (2019) evaluated the environmental effects of the urban solid waste management system in northern Lahore. The results of this study showed that about 10% of organic waste is composted by public facilities provided by the government. About 41 percent of the recycled materials are sold by households to junk shops, and 28 percent are sorted by conservation workers at dumpsites. According to the results, it was found that the existing system pollutes the environment in different ways. Bjørnbet, Skaar, Fet &Schulte, (2021), conducted a study to investigate the improvement of the sustainability performance of manufacturing industries through the circular economy. The results showed that circular economy measures can improve sustainability indicators. Grafstrom &Aasma (2021) found in a study that technological, organizational, market and cultural barriers are very important in the transition to circular economy. In their research, Kumar et al. (2021) identified lack of government support and lack of specific policies and protocols as the most important barriers facing the fourth generation industry of Indian multinationals. Moreno et al. (2021), considered the indicators of green purchasing and waste management, recycling and the use of green energy to be the most important performance indicators of the circular economy of Spanish companies. Prada et al. (2021) considered research and development in the environment and energy very important in the transition to a circular economy.In a study, Abokersh et al. (2021) presented a model for evaluating sustainable energy from the point of view of circular economy indicators. The results showed that reuse and recycling should always be pursued in order to meet environmental requirements

and achieve sustainability. Karayılan et al. (2021) during a study, investigated and evaluated circular economy practices in the value chain of plastic industries. The results showed that the observance of circular practices in the value chain of plastic industries can improve environmental performance and finally economic performance.

According to the above, it can be said that there are few studies in the field of combining the two concepts of CE and MWSM, especially in the discussion of improving the periodical performance of countries in the field of urban waste management. Therefore, measuring the performance of countries in this field can be very important.

3- Methodology

The purpose of this study is to evaluate the efficiency of circular economies in Persian Gulf countries in terms of Municipal Solid Waste Management. This research is applied in terms of purpose and descriptive survey in terms of data collection. Its statistical population was formed from Persian Gulf countries. In this research, the per capita value of MSW production and the dimensions of the social progress index "basic human needs", "basics of well-being" and "opportunity" are used as input and recycling as output in the model. SPI indicators show how well society can cover the needs of its members and improve their quality of life. In each of the dimensions, the performance of each country is presented on a scale of 0-100, where a score of 100 indicates the best performance. The use of social dimensions along with the economic dimension indicates the management of MSW with combined indicators such as human development and SPI. which shows the prevailing social and economic conditions, have a lot to do with it (Giannakitsidou et al, 2020). The data of the indicators used in this research were collected from social progress imperative centers and the World Bank. Briefly, the steps of the research are given in **Figure 2**.

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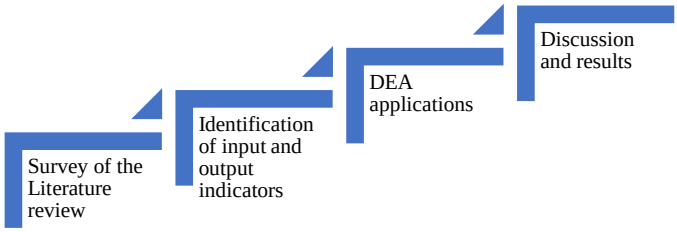

Figure 2 . Research method
Source: Resarch ResultIn

this paper, the circular economy indicators of Giannakitsidou et al (2020) are used. In the next step, the DEA model is used for evaluating the efficiency of circular Economies in Persian Gulf countries. In 1978, this approach was first presented by Charnes et al , which has been used to measure the efficiency and productivity of units due to its high flexibility and adaptability in various economic fields (Abolhasani Hastiani, Amini Milani, Sharif Moghaddasi, & Bayat, 2024). But it was less used in solid waste management (Emrouznejad & Yang, 2017). This approach measures the operational efficiency of decision making units in the form of a linear programming model(Giannakitsidou et al, 2020). The objective function and constraints of this model is as follows(Tsai et al., 2016; Charnes et al., 2006):

$$\text{Max } P_d = \sum_{oc=1}^{n} u_{oc}\, y_{d.oc}$$

$$st$$

$$\sum_{oc=1}^{n} u_{oc}\, y_{d.oc} - \sum_{ic=1}^{m} v_{ic}\, x_{d.ic} \le 0 \quad . \quad j = 1.\cdots.n$$

$$\sum_{ic=1}^{m} v_{ic}\, x_{d.ic} = 1$$

$$v_{ic} \ge 0\,.u_{oc} \ge 0. \quad ic = 1.\cdots.m \quad . \quad oc = 1.\cdots.n$$

In the above model, which is called the input-oriented CCR model, The efficiency of countries is denoted by P_d, and d = 1, 2,...s. $x_{d.ic}$,$y_{d.oc}$,v_{ic} and u_{oc} indicate the input and output and the weight of them in the model, respectively. In this research, the above linear programming model is solved with Lingo version 18.0 software.

4- Finding

In our study, the DMUs are the Persian Gulf countries under evaluation as shown in **Table 1.** The Persian Gulf Countries(DMUs)

Table 1. The Persian Gulf Countries(DMUs)
Source: Resarch Result

Persian Gulf Countries	DMUs
Iran	DMU_1
Iraq	DMU_2
Qatar	DMU_3
Kuwait	DMU_4
Bahrain	DMU_5
United Arab Emirates	DMU_6
Saudi Arabia	DMU_7

In this research, MSW production value per capita and social progress indexs as inputs and recycling as outputs are used as Giannakitsidou et al (2020) as shown in **Table 2**. Indicators of CE performance(CEP)

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Table 2. Indicators of CE performance(CEP)
Source: Resarch Result

Indicators of CEP	Input/output
MSW generated per capita	Input
Basic human needs	
Foundations of wellbeing	
Opportunity	
Recycling rate of MSW	Output

The data related to waste generated per capita and its recycling rate were extracted from the World Bank and the data related to three indicators of SPI were extracted from the social progress imperative website in 2021 as shown in **Table 3**. Data related to indicators

Table 3. Data related to indicators
Source: Resarch Result

	MSW generated per capita (ton/population)	Basic human needs	Foundations of wellbeing	Opportunity	Recycling rate of MSW
Iran	0.207	0.013	0.015	0.022	0.05
Iraq	0.316	0.014	0.018	0.023	0.05
Qatar	0.357	0.012	0.015	0.022	0.03
Kuwait	0.394	0.011	0.013	0.017	0.21
Bahrain	0.637	0.012	0.014	0.024	0.08
United Arab Emirates	0.610	0.011	0.014	0.019	0.2
Saudi Arabia	0.450	0.012	0.015	0.024	0.15

It should be noted that among the input variables, the variable of waste production per capita has a negative nature and the SPI indicators have a positive nature. For this purpose, the values of SPI indices are reversed and included in the model. In the above table, the numbers related to these indicators are reverse values. The input-oriented CCR model has been implemented within the LINGO Softer environment. By solving linear programming problems, the optimal value of the objective function was obtained for each DMU as shown in**Table 4**. Score of DMUs

Table 4. Score of DMUs
Source: Resarch Result

	EC performance	
	Score	Rank
Iran	0.453	4
Iraq	0.296	6
Qatar	0.157	7
Kuwait	1	1
Bahrain	0.353	5
United Arab Emirates	0.952	2
Saudi Arabia	0.654	3

As shown above, the countries of Kuwait (1), United Arab Emirates (0.952), Saudi Arabia (0.654) and Iran (0.453) respectively have the highest circular economy performance compared to other countries in the Persian Gulf. The objective of this study is to analyze DMUs efficiency from the perspective of variable returns to scale(VRS). This means that the decision makers of the countries under study should know that reducing the input of the model does not lead to a proportional change in the outputs. Next, the EC performance of the Persian Gulf countries is shown in **Figure 3**. The EC performance of the Persian Gulf countries

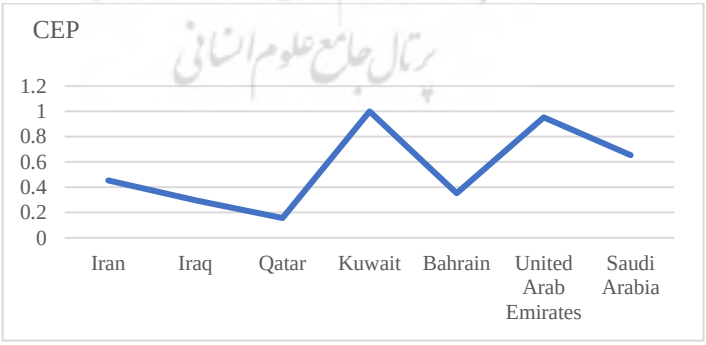

Figure 3. The EC performance of the Persian Gulf countries
Source: Resarch Result

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As shown in the figure above, the countries of Kuwait and the United Arab Emirates respectively have the highest circular economy performance compared to other countries in the Persian Gulf.

5- Conclusion

In the last few decades, some triggers such as global warming, climate change, greenhouse gas emissions, acid rain, etc. have caused governments to move towards a new paradigm of environmentalism in order to reduce environmental degradation. The purpose of this study is to provide a data envelopment analysis approach (DEA) to measure the performance of the Persian Gulf countries in the management and exploitation of municipal solid waste (MSW). This research is applied in terms of purpose and descriptive survey in terms of data collection. Its statistical population was formed from Persian Gulf countries. In this research, the per capita value of MSW production and the three dimensions of the social progress index "basic human needs", "basics of well-being" and "opportunity" are used as input and recycling as output in the model. DEA model is used for evaluating the efficiency of circular Economies in Persian Gulf Countries This technique seeks to maximize the ratio of the weighted sum of the outputs to the weighted sum of the inputs. The data relating to waste generated per capita and its recycling rate were extracted from the World Bank and the data related to three indicators of SPI were extracted from the social progress imperative website. The DEA model was implemented within LINGO Softer. The results show the countries of Kuwait and the United Arab Emirates respectively have the highest circular economy performance compared to other countries in the Persian Gulf. A careful study of the existing literature shows that there is very little knowledge of CE and MWSM, especially in the discussion of improving the periodic performance of countries in the field of municipal waste management. Therefore, measuring the performance of countries in this field can be very important. Studying the data shows that according to the statistics of the World Bank, these countries recycle 21% and

20% of the produced waste, respectively. Of course, they perform well in the input indicators compared to other countries.

This result is consistent with the findings of the study of Alipour & Parnian (2021). In that study, the United Arab Emirates and Kuwait ranked first and second, respectively, in terms of environmental performance. Like this study, Iran ranked fourth. It is worth noting that SPI indicators were not considered in that study. Also, in the study of Nikbakht et al (2022), United Arab Emirates ranked first among other Persian Gulf countries in terms of environmental performance index.

Although their performance is much lower than that of some European countries such as Slovakia in these indicators as shown in Giannakitsidou et al(2020) study. As the data analysis shows, per capita waste generation in Iran is much lower than other countries. Iran has an average performance in terms of SPI indicators. But in terms of circular performance, it has been assigned the fourth rank. The reason for this is its very low recycling rate. Policymakers should use advertising, education, etc. to increase the amount of recyclable waste collection. In order to improve their performance, countries need to reduce waste generation while increasing recycling rates. Education and public investment can help in this regard. Also, they should improve their performance in terms of SPI indicators. Countries also improve access to basic medical care, food, water and housing. Also, they should provide citizens access to basic education and even advanced education for those in the country who wish to increase their knowledge and skills. According to the results, it is suggested that other Persian Gulf countries improve their performance in recycling. The data of these countries shows that they recycle nothing less than 10% of their production waste. It is suggested to evaluate the performance of Persian Gulf countries with European countries in order to better explain their performance. Also, it is suggested to use other indicators such as reuse in calculating the performance of the circular economy. Since the discussion of environmental management and circular economy at the level of the studied countries is new. For this purpose, the data of these countries, especially the recycling rate index and SPI

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indices, in the past years are not much different from the current year and practically will not reach a comparable output. For this purpose, it is suggested that future researchers can study in the same field in different years with a time interval of 5 years and compare the results of different years. However, there is no doubt about the validity and reliability of this study. But more thought is needed in generalizing the results.

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