Recommendations for Sustainable Support Mechanism for Renewable Energy: Efficiency and Capacity Limit Method

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Abstract: Support mechanisms for renewable energy power plants have failed many times in different geographies according to different market parameters. The system being implemented in Turkey has its own problems. The problems of the support mechanism in the study are defined in different planes and a new model proposal based on efficiency and capacity criteria and based on hourly reconciliation are made. In the scenario studies using the generation and cost data between 2012 and 2017, the solution sets that reduce the total cost and increase the earnings of the power plants participating in the support are defined.

Keywords: Renewable support mechanism, Effectivity, Capacity cap.

1. INTRODUCTION

Renewable support mechanisms by incentives are usually found in developing sectors during the first restructuring period in order to call more investment to the host country. However, the support mechanism creates some costs and grid instability in every country; just like Turkey. The fact that Turkey has a large hydro potential, the capacity fed by supporting system and fed by marginal market mechanism should be in balance. Since incentive definition in regulation takes place in USD currency, the currency fluctuation causes dramatic effect on the number and amount of the renewable power plants fed by incentives.

Some of these adverse effects, even if predictable by the models to be built, can reduce the sustainability of incentive mechanisms, resulting from operational problems. The aim of this study is to develop a sustainable mechanism which supports more efficient renewable power plants in a more cost-effective manner.

Current support mechanism is depending on the incentive related to performance (Feed in Premium – FiP). Base-Incentive has been defined as per source through USD in the regulation (Hydro and wind generation: 7.3 USD cent/kWh, geothermal: 10.5 USD cent/kWh, biomass and solar: 13.3 USD cent/kWh (Energy Law, 2005)). Turkish electricity grid is big, well developed and comprehensive with its capacity over 80 GW. Capacity share and generated energy share of resources are not equal because of cost based priority of market mechanism on the grid. Participation to the support mechanism is not an obligation in Turkey. A renewable generation unit has right to make decision between feeding system and marginal market prices. Market calculation requires analytical work according to the climatic forecasts and economic indicators (such as market marginal price estimation of next year, currency). The Electricity Sector Report 2017 represents total capacity change between 2012 and 2017 which participated to support mechanism. The cost of Feed in Tariff is quite high due to the dry season in 2014 and currency fluctuation.

When Figure **1**. is examined, it is seen that the installed capacity of the power plants participating in RERSM (YEKDEM) from 2012 to 2017 is dominated by wind and hydraulic resources. Particularly after 2015, the share of hydro based generation in YEKDEM increased rapidly. While there is no big difference between the capacities in the same resource types, it is seen that the homogeneous capacity element disappears after 2016 and thereafter. It is observed that in 2016 the dam-type HPP, canal-type HPP and wind capacity participated in the support mechanism. Considering the dollar rate increase and market prices in the same period, it is understood that these sources prefer the support mechanism instead of the market structure due to the changing environmental factors and commercial conditions.

Support mechanisms aimed to motivate small capacity resources, while in the end of 2015, large capacity types also benefited from the same mechanism, especially due to the resource capacity type in our country, resulting in an unexpected increase

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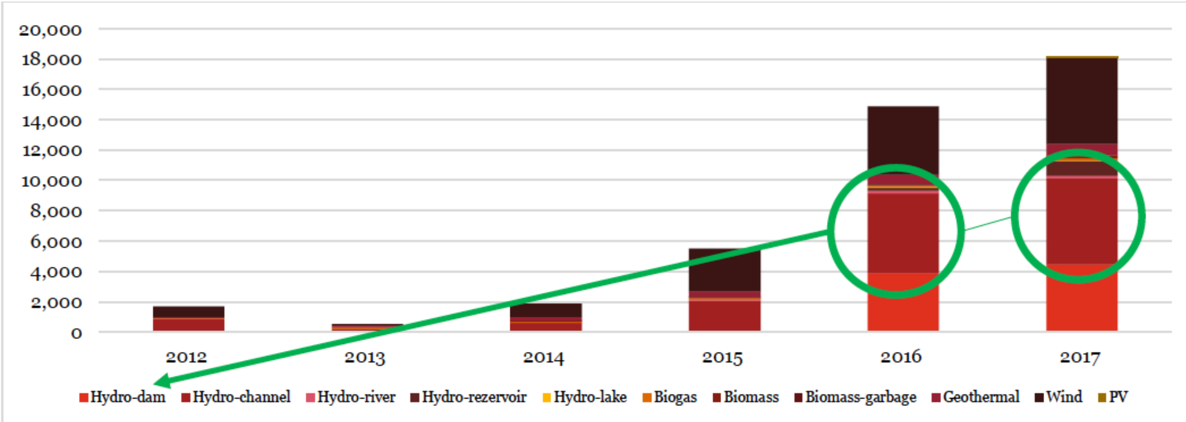


Figure 1: Participation trends to the supporting mechanism (Electricity Sector Report, 2017).

in system costs. This gives clue that the application of the "resource type based model" in the existing support mechanism may lead to undesirable results.

Figure **2**. shows the approximate amount of earnings according to the resource type periodically. As expected, the power plant, which has a large installed capacity with a lot of generation, sees the most support gain. This situation does not conform to the spirit of "support" structure.

Periodical increase in generation indicates that the efficiency of the power plant is low. This is also the most important common feature of renewable energy power plants. These plants are in need of stimulation because of their low efficiency.

Table **1**. shows the average efficiency in 2016 according to the resource type. According to resource types, the highest efficiency plant appears to be geothermal with 37 %. The average installed capacity of this source is 27 MW. The geothermal power plant has a different appeal in our country because of not having global applications in the world. Efficiency of dam-type, lake-type and reservoir-type power plants with an average installed capacity of over 30 MW

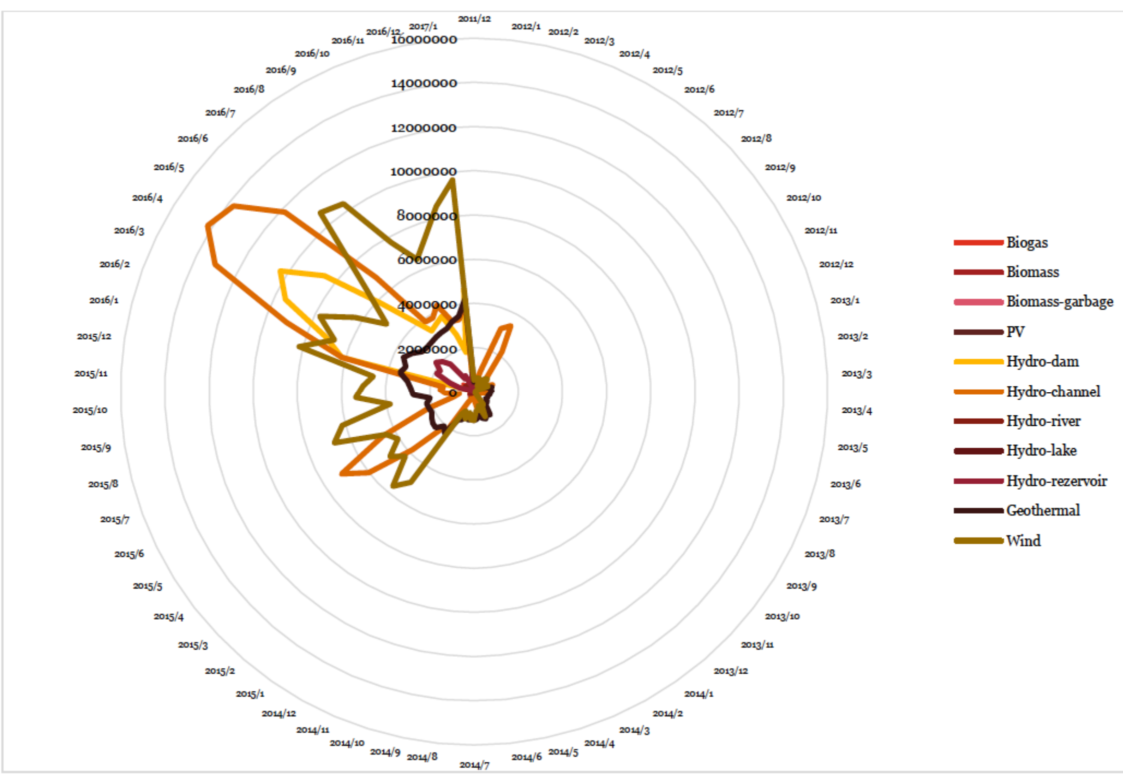


Figure 2: Average revenue of the generators.

appears to be 22%, 10% and 19%. These figures indicate that a large capacity remains idle.

Since the amount of incentive is calculated in dollar exchange rate, there are major disruptive effects on the grid of the power plants operating at maximum level and unscheduled power plants. These disruptive effects can be listed as follows:

- Uncontrolled use of the incentive mechanism of large capacity plants creates technical difficulties with energy transmission in the network. Increased capacity means increased transmission lines and equipment.
- Increase in the amount of imbalance and market prices due to the inability of realized generation quantities through the installed capacity, deterioration of stability.
- The split-up of the cost of the generated YEKDEM to the supply companies in proportion to the amount of absord creates an unpredictable cost item.
- Increase of YEKDEM costs depending on exchange rate.
- Being independent from the composed market prices and not having a signal.

The support mechanism "tailored to the type of resource", increase in renewable resource capacity, commissioning of large plants, etc. cause great additional costs to the market and break the harmony. Given that the relationship between efficiency and installed capacity in Table **1**. is not stable, it is necessary to search for more efficient, less costly and sustainable incentive models based on efficiency and installed power rather than resource type.

Table 1: Average Efficiencies of the Generators as Per Source Type

Source Type	Average Efficiency (%)	Average Installed Capacity (MW)
Biogas	18%	6
Biomass	18%	6
Biomass (solid raw material-garbage)	11%	3
Solar	0%	6
Hydro (dam)	22%	95
Hydro (lake)	10%	37
Hydro (channel)	21%	16
Hydro (river)	15%	12
Hydro (reservoir)	19%	63
Geothermal	37%	27
Wind	22%	40

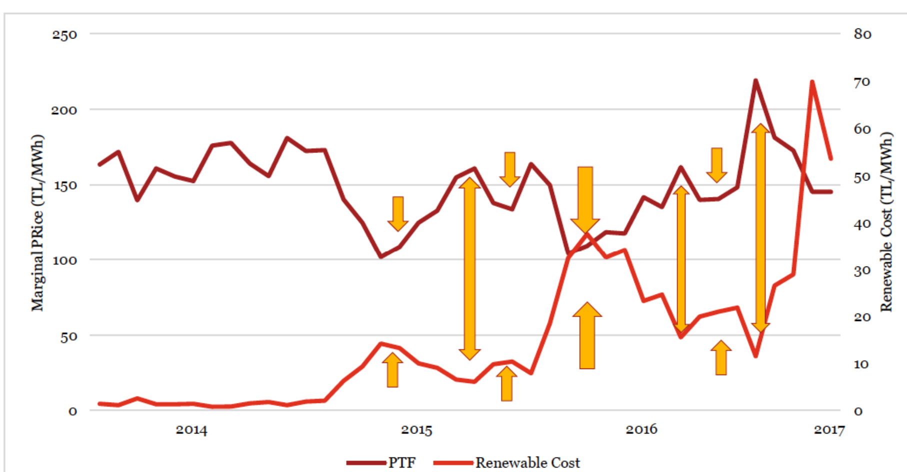


Figure 3: Cost of supporting system participants and the effect of this cost on the marginal price.

Figure **3**. shows the effect of the power plants benefiting from the support mechanism on the market and on the marginal prices. Price drops in the flooding period are a clear indication of this situation. It is also understood from the average prices of the chart that, once a power plant is accepted into support mechanism, it can generate in the desired program and quantity. In any case, it is possible for it to benefit from the incentive at all times. This leads to incentives even for power plants with detrimental effects.

In the light of the above explanations, the problem is not only the installed capacity of the plants participating in the support mechanism but also the capacitors having different generation quantities. In a sustainable support mechanism, a model should be developed that solves both problems.

Due to the existing problems, it is a necessity to define a model which is based on efficiency which reduces the imbalance costs and generates correct signals on the price of the market. It is essential that the costs of the support mechanism can be evaluated on the market price signals in order to establish the competition conditions on the supply side and foresee the risks. The hypothesis in this framework is as follows; "With the efficiency and capacity based incentive mechanism used in the Turkish currency, it is possible to reduce costs, to provide incentives in the desired area and the sustainability”.

2. LITERATURE REVIEW

In the study of Dusonchet and Telaretti (Dusonchet and Telaretti, 2015), they examined the situation of the solar energy system in five European Union countries - France, Germany, Greece, Italy and the UK - and investigated the best method of supporting it. There are three types of support mechanisms in Europe:

1. Feed in Tariff

2. Electricity netting

3. Direct investment incentives and tax deductions. The most recent method of financial reconciliation, the FiT method, is applied as the most advanced "capacity-based" approach (Dusonchet & Telaretti, 2015).

In Ayoub and Yuji's study (Ayoub and Yuji, 2012), the measures to support the RER capacity are divided into two as short and long cycle activities. According to them, short-term measures have a direct impact on investing and investment can stop when absorbed. With long-term measures, there is an investment, and it continues its life as profitable or harmful. Choosing a method in a long-term and sustainable manner allows both the plant and the system to be operated without harm, and this is possible with sensitively designed support mechanisms.

Abdmouleh, Alammari and Gastli in their study (Abdmouleh, Alammari and Gastli, 2015) have argued that the development of power generation based on renewable energy resources should be assessed for the current state of the technology in place, for the budget available, for the target of renewable energy and for the environmental conditions of the country. According to them, it is important not to create a monopoly in terms of resource type or technology while forming the support mechanisms. However, the large dam participation in our present system has been the clearest reason for the system to become unsustainable.

According to Faundez (Faundez, 2008), it is mentioned that the most important aspect of designing incentives is to place targets that can be tracked and followed, because it is not possible to build a stable system based solely on renewable energy. However, generally the development of renewable energy in the models of countries is being prepared according to the fastest growing scenario. It is clear that there is no need for additional motivation to participate in the support mechanism of renewable energy power plants in our country.

Haas and the others (Haas, Panzer, Christian, Resch, Ragwitz, Reece, Held, 2011) have identified the mechanisms for supporting renewable energy in the EU countries one by one and tried to determine which support mechanism is most effective. In a very detailed study, the types of support were categorized in a completely different way. The most successful support mechanism as for the study is the tariff approach, which is always reflected in reconciliation.

Rio and Gual (Rio and Gual, 2007) argued that the efficiency of a support mechanism can be provided by joint evaluation of many components such as network connection criteria and commissioning procedures.

In Chang, Fang and Li's study (Chang, Fang and Li, 2016), they stated that the effect of 5 different variables must be examined in order to establish an evaluation criterion in support of renewable energy. These five variables must be;

- Market structure and targets
- Component of instability
- Efficiency
- Technology
- Financial sources (Chang, *et al*., 2016).

3. METHODOLOGY

In order to the research question to be answered, it is necessary to analyze the power plants participating in the support mechanism in different scenarios. First of all, the behavior and system costs of these plants should be investigated over the years, then the proposals should be tried by scenario-based study and the results should be compared and interpreted. For this reason, between 2012 and 2017, the installed capacities of the power plants participating in the support mechanism and the hourly production quantities were required. Another important aspect of the study is the scenarios. After analyzing the existing data, logical scenarios should be created with the justifications and be subjected to iteration.

During the analysis of the current situation; the monthly generation, imbalances, efficiencies and earnings amounts of renewable resources are determined and evaluated. As a research question, it is planned to consider a sustainable incentive model based on efficiency and capacity size.

3.1. Scenarios

Analysis is required in order to be able to evaluate what variable effect in which manner. Some important findings have been taken into consideration while creating the main scenario to analyze. These are as follows;

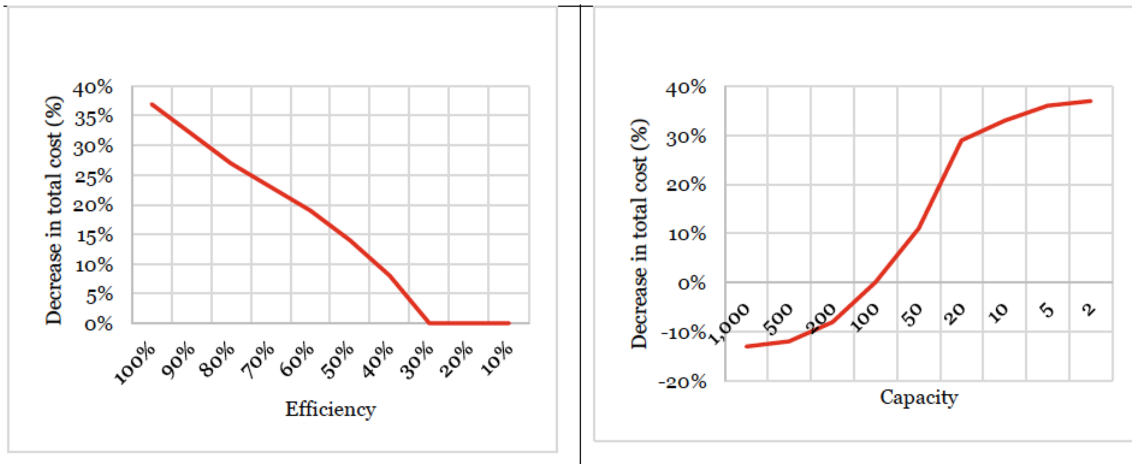
- The fundamental problem of Renewable Energy Incentive Mechanism for Turkish Electricity Market is the possible participation of balancing plants with large capacity into the system.
- When the literature is examined, it has been understood that the best practices in the world are "capacity-based" applications rather than "resource-based" applications. In some countries, as the capacity is reduced, the amount of incentive is increasing.
- A mechanism must be designed to enable renewable energy to be used even more in the future. This capacity should not be discouraged.
- Like roof applications, future developments that may affect the renewable energy market and its financial landscape should be considered and "sustainability" criteria should be determined accordingly.
- An efficient mechanism that allows the elimination of inefficient plants from the system should be designed.

While creating scenarios according to the criteria described above, it should be remembered that renewable energy by nature works at high capacity at active hours but due to the high number of hours that it does not work, the efficiency seems low. For this reason, incentive fiction can be selected according to hourly criteria, just as in reconciliation. Thus, at times when the specified efficiency ratio can not be exceeded, the power plants that will be purchasing at market prices will not cause any additional cost to the system. When making this selection, it will be a strategic and political decision as to where the efficiency criterion will be taken. At the same time, assuming that the problem is formed on two surfaces in terms of capacity and generated energy, the application mechanism, productivity and capacity criteria provide solutions on two surfaces.

Figure **4** shows the result of the analysis made on the effect of efficiency on total cost for the status when incentive is 250 TL/MWh. If the efficiency criterion is selected as 95%, the total system cost is reduced by 32%. If the productivity criterion is set at 50%, the total system cost is reduced by only 14%.

Figure **4** shows the effect of capacity size on total cost, with the incentive being 250 TL/MWh. If the efficiency criterion is selected below 50 MW, the selected incentive price and total system cost are reduced by 11%. The beginning of the curve from the negative value stems from the fact that the selected incentive cost is above the real value.

The efficiency and capacity criteria, which are analyzed independently from each other according to Figure **4**, provide the highest overall recovery (37%) at the best cost. In the analysis of these two schedules, one criterion was applied while the other was not. In this case, efficiency and capacity criteria should be used together to increase total benefit. With the



(**a**) (**b**)

Figure 4: Effect of efficiency (**a**) and capacity (**b**) on total system cost (subsidy selected by 250 TL/MWh).

concern that this application could lead to a response in the market, scenarios under the non-deterrent 50% efficiency factor were studied.

According to Figure **4a**, when the efficiency is greater than 25%, reductions in the total cost begin. While the decrease in the total cost in the section up to %15 of the capacity usage varies between 20-30%, the decrease in the total cost shows a decrease in the capacity utilization above 20%.

In accordance with the hypothesis, the incentive is subject to an analysis as Turkish Lira. Earnings over the 220, 240, 250, 280 and 300 TL / MWh, which are at least 20% above the average electricity market prices, and the total costs to the system are calculated. Thus, 2 parameters over 5 incentive prices of 5 scenarios are calculated for 5 years between 2012-2016.

Searched Scenarios are Given as Below:

- Scenario-1-Efficiency (above average) Capacity (below average)
- If hourly based efficiency is below the average value AND installed capacity is below average capacity size;
- Scenario-2-Efficiency (+30%) Capacity (minus 20 MW)
- If hourly based efficiency is above 30% AND installed capacity is below 20 MW;
- Scenario-3-Efficiency (+25%) Capacity (minus 10 MW)
- If hourly based efficiency is above 25% AND installed capacity is below 10 MW;
- Scenario-4-Efficiency (+20%) Capacity (minus 10 MW)
- If hourly based efficiency is above 20% AND installed capacity is below 10 MW;
- Scenario-5-Efficiency (+15%) Capacity (minus 5 MW)

If hourly based efficiency is above 15% and installed capacity is below 5 MW;

In accordance with the hypothesis, the incentive is subject to an analysis as Turkish Lira. Earnings over the 220, 240, 250, 280 and 300 TL / MWh, which are at least 20% above the average electricity market prices, and the total costs to the system are calculated. Thus, 2 parameters over 5 incentive prices of 5 scenarios are calculated for 5 years between 2012- 2016.

4. RESULTS

4.1. Success Criterion

As the purpose of the study is to reduce the costs of support mechanisms, while preventing participation in this system of giant dams and inefficient plants, the small power plants that are in need of incentive and develop new technology must continue to benefit from the support mechanism.

For this reason, in each scenario, the earnings and costs belonging to the power plants normally participating in the support and the power plants accepted in the scenario are presented. While the success criterion reduces the total system cost, the scenario group moves the earnings of the resources to better conditions.

4.2. Analysis

Five different price scenarios in five categories were tried to be analyzed in detail with the following charts. It is seen that all scenarios reduce the total cost in the first of these schedules (Figure **5-a**). This result is expected due to the fact that large-capacity power plants are disabled when the scenario is provided. The scenario, which reduces the total cost in the largest ratio according to Figure **5-b** (approximately 40%), is the fifth scenario with the highest capacity criterion as expected. In this scenario, incentive was given to those who provided the criterion below 5 MW. Figure **5-c** shows that; the scenario which provides the scenario criteria most and increases its stability most is the

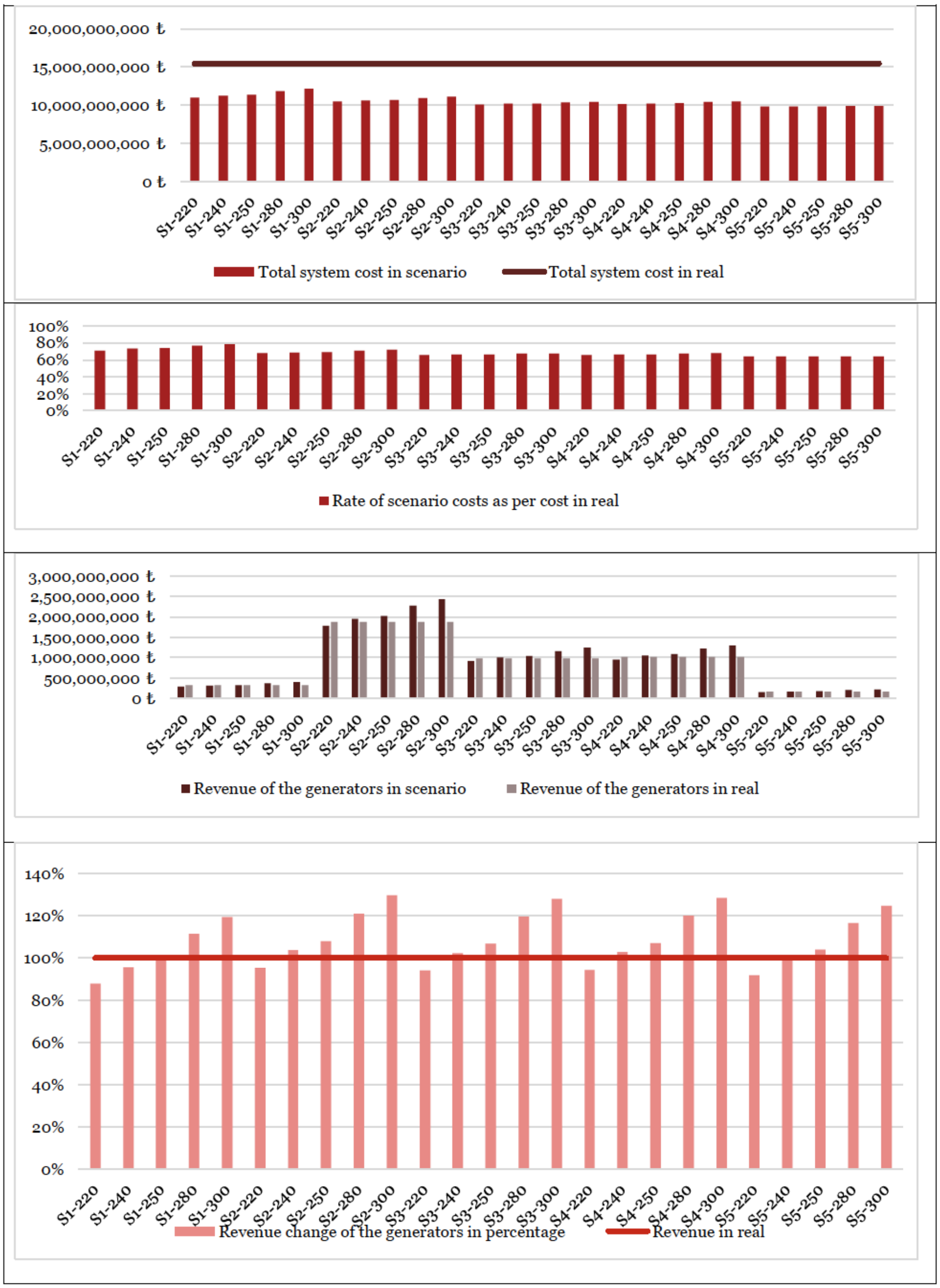


Figure 5: Total cost change (**a**), rate of total cost change (**b**), revenues (**c**) and selling price change (**d**) of the generators through scenarios

Table 2: Success Position as Per Scenarios

Scenario No	S1					S2					S3					S4					S5				
	220	240	250	280	300	220	240	250	280	300	220	240	250	280	300	220	240	250	280	300	220	240	250	280	300
Sustainability	-	-	-	+	+	-	+	+	+	+	-	+	+	+	+	-	+	+	+	+	-	-	+	+	+

second scenario. This result is an expected result. Scenario-2 is the scenario with the smallest capacity criteria. Figure **5-d** shows the change in the selling prices of the plants providing the scenarios. According to these criteria, the starting point is generally around TL 250 / MWh.

Twenty-five scenarios analyzed in accordance with Table **2** were found to be sustainable by exceeding the success criteria (scenario sales price exceeding the incentive sales price). These scenarios, as identified in the previous chart, are scenarios where the incentive price is above 250 TL / MWh.

5. CONCLUSION AND SUGGESTION

This study aims to establish a more sustainable mechanism for supporting power plants based on renewable resources. While the current system gives incentive to all generations regardless of resource type, the proposed system is a model where efficiency and capacity criteria are used together, while in the case where the criteria are met, it benefits from the incentive in the hourly reconciliation, whereas in the unapplied hours it is reconciled from the market prices. Scenario based study results show that while the total cost of the support mechanism is reduced by 30%, the benefits of the power plants benefiting from the support mechanism increase by 40%. This study will pave the way for the two-dimensional studies using efficiency parameters instead of one-dimensional approaches that suggest capacity based model instead of resource based model. The analysis based on average prices will point to more detailed results with elaboration of the studies.

REFERENCES

[1] Abdmouleh Z, Alammari RAM, Gastli A. Review of policies encouraging renewable energy integration & best practices, Renewable and Sustainable Energy Reviews 2015; 45: 249-262. https://doi.org/10.1016/j.rser.2015.01.035

[2] Ayoub N, Yuji N. Governmental intervention approaches to promote renewable energies - Special emphasis on Japanese feed-in tariff, Energy Policy 2012; 43: 191-201. https://doi.org/10.1016/j.enpol.2011.12.056

[3] Chang Y, Fang Z, Li Y. Renewable energy policies in promoting financing and investment among the East Asia Summit countries: Quantitative assessment and policy implications, Energy Policy 2016; 95: 427-436. https://doi.org/10.1016/j.enpol.2016.02.017

[4] Dusonchet L, Telaretti E. Comparative economic analysis of support policies for solar PV in the most representative EU countries, Renewable and Sustainable Energy Reviews 2015; 42: 986-998. https://doi.org/10.1016/j.rser.2014.10.054

[5] Energy Law no: 5346, Renewables, Official Gazette Date and No 18/05/2005 and 25819.

[6] EMRA, Electricity Sector Report, April 2017, (http://www.epdk.gov.tr/TR/Dokumanlar/Elektrik/YayinlarRaporlar/AylikSektor),

[7] EXIST Official web page, transparency platform, (https://seffaflik.epias.com.tr/transparency/),

[8] Faundez P. Renewable energy in a market-based economy: How to estimate its potential and choose the right incentives, Renewable Energy 2008; 33: 1768-1774. https://doi.org/10.1016/j.renene.2007.09.017

[9] Haas R, Panzer Christian, Resch G, Ragwitz M, Reece G, Held A. A historical review of promotion strategies for electricity from renewable energy sources in EU countries, Renewable and Sustainable Energy Reviews 2011; 15: 1003-1034. https://doi.org/10.1016/j.rser.2010.11.015

[10] Rio P, Gual MA. An integrated assessment of the feed-in tariff system in Spain, Energy Policy 2007; 35: 994-1012. https://doi.org/10.1016/j.enpol.2006.01.014

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