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An integrated multi objective decentralized energy planning model with focus on minimizing the net present value of costs on renewable energy sources

Masoud Rabbani[1,*] , Iman Shokr[2], Amir Farshbaf-Geranmayeh[3]

[1,2,3]*School of Industrial and System Engineering, College of Engineering, University of Tehran, Iran*

*Corresponding author's E-mail: mrabani@ut.ac.ir

ABSTRACT

Renewable energy sources (RES) are known as a tool to meet the energy demand more economic and sustainable, especially in rural and remote areas. There is a research gap around mathematically modeling for investment on renewable energy source and decentralized energy planning (DEP) by considering supply and demand side simultaneously. The aim of this paper is to find an optimum solution for planning RES according to minimize the net present value of demand side management (DSM) costs, operation and maintenance and installation costs and the cost of producing energy during the time horizon. Thus an integrated multi objective decentralized energy planning model is presented in both the deterministic and stochastic demands and the TH method is exploited to solve the multi objective programming. Also the chance constraint method is utilized for entrance the uncertainty for the demand in mathematical models. To validate the proposed models, the sensitivity analysis is implemented and impacts of life cycle of technologies and the coefficient of compensation in TH method are investigated.

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Renewable energy sources (RES), Decentralized energy planning (DEP), demand side management (DSM), energy planning, Multi objective programming (MOP)

1.Introduction

Renewable energy sources (RES) are powerful tools to supply the energy demand, especially in rural and remote areas which includes of hydro power, solar, wind, geothermal, biomass, photovoltaic and marine energies. The sustainability of these technologies is a major factor which makes RES more valuable. Less greenhouse gas emission and less pollution are the advantages of using RES also. Despite of the advantages of renewable energy sources, there is lack of exploitation of RES because of the high cost of installation and operation .

It is worthy to define demand side management (DSM). DSM includes the activity which should be implemented to reduce the use of energy demand [1] which needs to invest and consume budgets to achieve its goals .

The Energy planning attempts to utilize sources of energy in an optimal way. There are two different levels of energy planning: the centralized and decentralized level [2]. Centralized energy planning (CEP) is a conventional energy planning in urban. The amount of producing energy will distribute to urban and make span the entire network. On the other hand the decentralized energy planning (DEP) implements, especially in rural and remote areas which there are natural sources of energy. Decentralized energy planning is a concept to plan limited energy sources to meet energy demands. Rural is influenced by using DEP and it ceased to saving, cost reduction and increase supply reliability in rural. Herran et al. (2012) Expressed that decentralized electrification can reduce disparity in rural because there are much more opportunities to use RES in rural and remote areas than urban [3].

Privitera et al. (2004) modeled the problem in order to find an optimal mix of renewable energy technologies need to be installed and how much is the capacity for each renewable energy technologies [4]. Mirzaesmaeeli et al. (2010) proposed a mixed-integer linear programming in order to planning electric systems. The Objective function is planned for minimizing the net present value of costs. Constraints are set to satisfy the annual electricity demand, capacity for existing power stations, lead time and capacity for new power stations, capacity in the capture process, fuel selection and shutting down plants, selection of CO2 capture process and carbon dioxide emission [5]. Cristóbal et al. (2012) presented a goal programming which it finds an optimal solution for mix and location of renewable plant in Spain. The goal is defined as maximizing the number of plants that are matched with comparable locations and locate one plant in each place. Some attributes are considered to be controlled such as Power (Gw), Investment (I), Tons of emission, of CO2, O&M costs, Jobs (J), distance between plants (D) and Social acceptance (S) [6].

Münster et al. (2011) presented a model which focused on waste in a future system. Their objective function is to minimize cost which is based on annualized investment cost, the O&M costs, and the operational costs of the units [7]. Senjyua et al. (2007) implemented genetic algorithm for providing an optimal solution for energy planning. The objective function of Generic Algorithm (GA) is the total cost which is sum of initial and operating costs per year [8]. Kaviani et al. (2009) effort for designing energy systems is using of PSO algorithm [9]. Arnette et al. (2012) proposed a multi objective linear programming (MOLP) model for Specify an optimal mix of renewable energy sources. This model allows a decision maker to balance annual generation costs against the corresponding greenhouse gas emissions. The first objective is about minimizing costs. Costs include annual generation costs that are related to wind and solar power. The second objective is set for minimizing emissions. Constraints are employed to indicate the total amount of generating electricity. The other constraint is for satisfying the amount of capital investment allowed [10]. Banos et al. (2011) reviews on optimization methods applied to renewable and sustainable energy also [11].

Chatzimouratidis et al. (2009) used AHP to evaluate power plant such as Hydro, Wind, PV, Geothermal and etc. by technological, economic and sustainability aspects. They claimed that Operation and maintenance costs (O&M) include wages of the employees, operating costs and maintenance activities. External costs are every cost related to health and environment and quantifiable [12]. Koo et al. (2011) Expressed that total costs of RES are equal to CC+FC+VC+EC which CC is capital costs, FC is fixed costs, VC is variable costs and finally EC is externally costing. They proposed a new approach which considers uncertainty at present in the evaluation and comparison of costs that is an important role in implementing renewable energy plans under different technologies [13]. Stein (2013) studied RES with multi criteria decision making to find the most sustainable RES. Their results show that wind power is the most suitable RES [14]. Evans et al. (2009) Is studied renewable energy sources based on sustainability indicators and ranked technologies based on sustainability indicators. The most important sustainability indicators are price of generating electricity, greenhouse gas (GHG) emissions, water consumption, land requirement, availability of renewable sources, efficiency of energy conversion and social impacts. Based on their research the second ranking is from hydropower, third is photovoltaic and fourth ranking is for geothermal technologies [15].

Economic evaluation in different areas of RES is a challenge able problem. Boomsma et al. (2012) analyzed the system under different support schemes such as feed-in tariffs and renewable energy certificate trading. The other approach which is employed, have introduced uncertainty under multiple sources from each support scheme and uncertainty under any change of support scheme. It is concluded that wind power is more attractive to investment [16]. Owen (2006) expressed in addition of costs is implied for installing and operating renewable energy source, externality costs should be considered also. Externality costs include of costs which impact on health and the environment by pollutant emissions other than climate change and the costs caused by climate change by greenhouse gases [17]. Also the cost analysis in which considered capital expenditures, operating and maintenance expenditures (fixed and variable) of each system, and appropriate discount and inflation rates are investigated by Blum et al. (2013) [18]. Pricing of decentralized energy planning is the other issue in the energy area. Thiam (2011) investigated on price supports for using more of renewable energies are investigated in purpose of penetration in the market for these sources of energy. Renewable energies play an important role in developing countries. The proposed methodology is integrating different stakeholders such as producers, investors and consumers in the planning phase [19]. Yuan et al. (2011) expressed there is an increasing level of concern at the high initial cost associated with the renewable energies. The high initial cost associated with the renewable energy development is one of the most significant barriers to the further development and shows that the pricing mechanism plays a critical role in improving the affordability of renewable power [20].

In this paper, it is focused on wind, hydro, solar and geothermal sources and the aim of the designed models are minimization net present value of annualized cost over its 20 years of operations in order to find the optimal solution for running renewable energy sources in time horizon (20 years).

2. Material and Methods

In this section proposed models are presented. Assumption, indices, parameters and variables which are used in models are as follows:

Assumptions:

- It is assumed that there are i technologies which some of them should be installed during the time horizon (20 years) in order to meet the energy demand. The cost of installing, operation and maintenance are assumed to be constant for each technology and the net present value of costs should be minimized during the years. There are the costs of producing energy for any technology in different years and it is desirable to minimize the net present value of producing energy costs.
- Specific budget is assigned to each period, which can consume for installing and implementing technologies. Savings from each period is considered to invest at one period and will transmit to the next year`s budget .
- It is considered to utilize DSM for decreasing the demands in each year. But the cost of DSM plans should be mentioned. Also the model attempts to minimize the net present value of DSM`s cost.
- Minimizing the cost of installing, O&M and producing energy (first objective function in models) is more preferable than minimizing the cost of DSM (Second objective function in models), because DSM costs have profits and can modify the use of energy demand and decrease them.
- The demand of energy is not constant during the years and could be deterministic or stochastic.

- Demand-side and supply-side, both should be integrated into models.
- The interest rate is assumed as a constant rate during years and all of the calculations for the net present values is based on this rate: 10 percent.

Indices:

- i = Set of RES technologies
- t = Set of periods (yearly)

Parameters:

- D_t = Demand of the period t
- C_t = Cost of generating electricity from technology i
- OM_i = Fixed and variable O&M cost related to i-th technology
- LC_i = i-th technology`s life cycle
- $INST_i$ = The cost of installation i-th technology
- $CDSM$ = Cost per unit of SDSM
- B_t = The available budget for period t
- P = Maximum reduction in demand at period t by DSM
- $SOBJ$ = Minimum reduction in demand at period t by DSM

Variables:

- x_{it} = Optimal amount of produced energy by i-th technology at period t
- y_{it} = 1 if technology i is operational during period t ; otherwise equal to 0
- m_{it}= The number of i-th technology should installed at period t
- S_t= Slack variable which denotes the remaining budget from period t
- $SDSM_t$= The amount of the energy which is reduced by DSM in period t
- F_t = The future time value factor which calculated by the discount rate k and is variable during periods (years).

2.1 Deterministic Model

Model 1:

$$Min\, z_1 = \sum_i \sum_t \frac{C_i}{F_t} x_{it} + \sum_i \sum_t \frac{INST_i}{F_t} m_{it} + \sum_i \sum_t \frac{OM_i}{F_t} y_{it} \quad (1)$$

$$Min\, Z_2 = \sum_t SDSM_t CDSM_t \quad (2)$$

$$\sum_{i=1}^{m} m_{i0} \geq 1 \quad \forall t = 0 \quad (3)$$

$$x_{it} \leq m_{it} CP_i \quad \forall i,t \quad (4)$$

$$SDSM_t \leq p \quad \forall t \quad (5)$$

$$SDSM_t \geq SOBJ \quad \forall t \quad (6)$$

$$\sum_{i=1}^{m} x_{it} \geq D_t - SDSM_t \quad \forall t \quad (7)$$

$$\sum_{i=1}^{m} m_{it} OM_i + \sum_{i=1}^{m} m_{it} INST_i + \sum_{i=1}^{m} x_{it} C_{it} + S_t + CDSM = B_t + S_{t-1}(1+k) \quad \forall t \quad (8)$$

$$m_{it} \leq M y_{it} \quad \forall i,t \quad (9)$$

$$\varepsilon y_{it} \leq m_{it} \quad \forall i,t \quad (10)$$

$$y_{it} \leq y_{i(t+1)} \quad \forall i \text{ and } \forall t = 0,\ldots,LC_i - 1 \quad (11)$$

$$\sum_t y_{it} \leq LC_i \quad \forall i \quad (12)$$

$$F_t = (1+k)^t \quad \forall t \quad (13)$$

$$y_{it} = 0 \text{ or } 1 \quad (14)$$

$$m_{it} \text{ is integer} \quad (15)$$

$$x_{it} \geq 0 \quad \forall i,t \quad (16)$$

Equation (1) signifies the cost of power generation of i-th technology at period t and transforms their value to period 0 by considering the time value of money. Also, it denotes the cost for installation i-th technology at period t, operation and maintenance cost and Equation (2) minimizes DSM costs respectively. Equation (3) signifies at least one technology should be installed at period 0. Equation (4) shows the maximum amount of produced energy by the technology i at period t. It is obvious that the maximum produced energy is equal to the number of technology i which is installed at period t multiple the capacity of technology i. Equation (5) Illustrates that the amount of the energy consumption, which is reduced by DSM in period t should be less than the maximum reduction in demand at period t by DSM and Equation (6) is for showing the amount of the energy which is reduced by DSM in period t, should be greater than the minimum reduction in demand at period t by DSM. (7) Ensure that the amount of producing energy should be greater that demand subtracted by energy consumption saving by DSM program. Equation (8) is the budget constraint which costs are equal less that budgets. S_t Denotes the saving of budget at period t. Equation (9) and Equation (10) are set to mention if i-th technology is installed at period t, then y_{it} =1, and if it is not installed then y_{it} =0. Equation (11) Signify that if one technology is installed at the period t then it could run in the next years. According to (9), Equation (10-11) y_{it} is set for showing if technology i-th is installed and operational, so it needs to consume some of budgets for maintenance and operation costs. Equation (12) ensures that the total years, which every technology could run should be less than its life cycle. Equation (13) is the factor which model is able to transmit cash flows due to the other years. Equation (14) defines y_{it} as binary variable. Equation (15) Define m_{it} as integer variable and (16) denotes x_{it} is positive variable.

2.2 Stochastic model

In this section we presented the stochastic model and it is assumed that demands are stochastic variables which follow of normal distribution with the mean $\bar{D}$ and the σ^2 as variances. For achieving this goal the chance constraint is utilized [21, 22] and the constraint (7) is reformulated as follows:

$$pr\left(\sum_{i=1}^{m} x_{it} - \hat{D}_t + SDSM_t \geq \beta\right) \geq 1-\alpha \quad (17)$$

The equation (17) ensures that the produced energy should meet the demand of energy with the confidence level of $1-\alpha$ and β is a small number like 0.01. According to assumption of the normal distribution of $\hat{D}$ equation (17) can be rewritten as follows ($\hat{D}$ follows of normal distribution with the mean $\bar{D}$ and the standard deviation σ):

$$pr\left(\frac{\hat{D}_t - \bar{D}}{\sigma} \leq \frac{\sum_{i=1}^{m} x_{it} + SDSM_t - \beta - \bar{D}}{\sigma}\right) \geq 1-\alpha \quad (18)$$

Now the probability follows as a standard normal distribution with the mean 1 and variance equal to zero:

$$pr\left(Z \leq \frac{\sum_{i=1}^{m} x_{it} + SDSM_t - \beta - \bar{D}}{\sigma}\right) \geq 1-\alpha \quad (19)$$

Now we are able to inverse the Eq. (19):

$$\frac{\sum_{i=1}^{m} x_{it} + SDSM_t - \beta - \bar{D}}{\sigma} \geq F^{-1}(1-\alpha) \quad (20)$$

So the final model with considering demand as stochastic variable is as follows:

Model 2:

$$Min\, z_1 = \sum_i \sum_t \frac{C_i}{F_t} x_{it} + \sum_i \sum_t \frac{INST_i}{F_t} m_{it} + \sum_i \sum_t \frac{OM_i}{F_t} y_{it} \quad (1)$$

$$Min\, z_2 = \sum_t SDSM_t CDSM_t \quad (2)$$

$$St: (3)-(6)$$

$$\sum_{i=1}^{m} x_{it} \geq \bar{D} + \sigma F^{-1}(1-\alpha) - SDSM_t + \beta \quad (21)$$

$$(8)-(16)$$

2.3 Solution methodology

The proposed model in both deterministic and stochastic form is able to solve with the software GAMS in high dimensional by CPLEX solver. Model is a multi-objective programming (MOP) so the interactive fuzzy method which is proposed by Torabi et al. (2008) (TH method [23]) is exploited to solve multi objective models.
The fuzzy approach model is as follows:

$$Max\ \lambda(v) = \gamma\lambda_0 + (1-\gamma)\sum_i w_i \mu_i(v) \quad (22)$$

st:

$$\lambda_0 \leq \mu_i(v) \quad \forall i \quad (23)$$

$$v \in F(v),\ \lambda_0\ and\ \gamma \in [0,1] \quad (24)$$

$\mu_i(x)$ demonstrates the satisfaction level of *i*th objective function for the given solution *v*. λ_0 Denotes the minimum satisfaction degree of objectives. w_i Denotes the relative importance of *i*th objective function by considering $\sum_i w_i = 1$ and γ signifies the coefficient compensation. In other words, γ controls the minimum degree satisfaction degree of the objective functions as well as weighted satisfaction degrees of objectives. Membership function μ_i is shown in the Figure1 for the minimization objective functions:

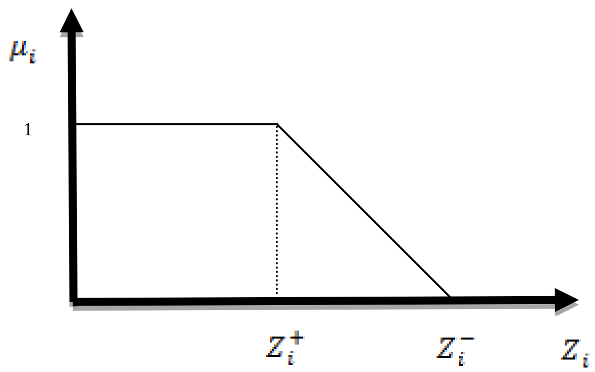

Figure.1 the membership function for minimization objective functions

For the objective functions in the minimization form, linear membership function defines as equation (25):

$$\mu_i = \begin{cases} 1 & Z_i < Z_i^+ \\ \dfrac{Z_i^- - Z_i}{Z_i^- - Z_i^+} & Z_i^+ \leq Z_i \leq Z_i^- \\ 0 & Z_i > Z_i^- \end{cases} \quad (25)$$

Z_i^+ Signifies the optimum value (ideal) of *i*th objective function and Z_i^- denotes the non-ideal value of the objective function.
According to the minimization form of the objective functions which is defined in both model 1 and model 2, the above membership function is utilized.

3. Results and discussion

3.1 Deterministic Model

The deterministic model is run for the time horizon 20 years. For preparing the multi objective programming to solve with the TH method, the model is solved by every function separately for obtaining the optimum value for each objective function. The results are shown in the Table 1:

Table1. The optimum value of functions separately when applying Model 1

Function	Optimum value
1	8.0788E+6
2	2.8350E+6

So for finding the efficient solution of the MOP problem the following model mentioned in the section 2.3 is run:
Model 3:

$$Max\ \gamma\lambda + (1-\gamma)(w_1\mu_1 + w_2\mu_2)$$

$$St:(3)-(16)$$

$$(22)-(23)$$

It is worthy to mention that parameters of model 3 are described in section 2.3. Coefficient of compensation (γ) is assumed 0.5. Also, minimizing the cost of installing, O&M and produced energy (first objective function) is more preferable than minimizing the cost of DSM (Second objective function). For this purpose the weight of first objective function w_1 is assumed to equal to 0.7 and the weight of the second objective function w_2 is 0.3.
The model is solved for 20 years and with the hypothetical data of technologies. The results are obtained as reported in Table2.

Table 2. The amount of energy should be produced in time horizon (Efficient solution of the MOP)

Year	Wind	Solar	Geothermal	Hydro
0	350	0	0	0
1	450	0	0	0
2	0	780	0	0
3	0	1030	0	0
4	0	1130	0	0
5	0	0	730	0
6	830	0	0	0
7	930	0	0	0
8	0	1030	0	0
9	0	0	1130	0
10	0	0	730	0
11	0	0	830	0
12	0	0	930	0
13	0	0	0	1030
14	0	0	0	1130
15	0	0	0	730
16	0	0	0	830
17	0	0	0	930
18	0	0	0	1030
19	1130	0	0	0
20	730	0	0	0

Also the savings which are remained from budgets are shown in Table 3.

Table3. Saving from budgets during the time horizon

Year	Saving	Year	Saving	Year	Saving	Year	Saving
0	5.00E+11	6	6.03E+12	12	1.66E+14	18	4.26E+14
1	6.65E+11	7	7.42E+12	13	1.96E+14	19	4.95E+14
2	1.57E+12	8	1.34E+13	14	2.30E+14	20	5.74E+14
3	2.60E+12	9	6.45E+13	15	2.69E+14		
4	3.49E+12	10	7.90E+13	16	3.14E+14		
5	4.81E+12	11	1.40E+14	17	3.66E+14		

It is worthy to find optimal solution when solving model separately by objective function. The result of the model under objective function 1 is shown in Table4.

Table4. The amount of energy should be produced in time horizon (under objective function 1)

Year	Wind	Solar	Geothermal	Hydro	Year	Wind	Solar	Geothermal	Hydro
0	350	0	0	0	11	0	0	450	0
1	450	0	0	0	12	0	0	550	0
2	550	0	0	0	13	0	0	650	0
3	0	650	0	0	14	0	0	0	750
4	0	750	0	0	15	0	0	350	0
5	350	0	0	0	16	0	0	0	450
6	450	0	0	0	17	0	0	0	550
7	550	0	0	0	18	0	0	0	650
8	0	650	0	0	19	0	0	0	750
9	0	750	0	0	20		0	0	350
10	0	0	350	0					

Results are also reported in Table5 when objective function 2 is optimized separately.

Table5. The amount of energy should be produced in time horizon (under objective function 2)

Year	Wind	Solar	Geothermal	Hydro	Year	Wind	Solar	Geothermal	Hydro
0	0	0	0	1.00E+06	11	0	3.27E+06	0	0
1	0	0	0	1.00E+06	12	0	0	0	1.00E+06
2	0	0	0	1.00E+06	13	0	3.27E+06	0	0
3	0	0	0	1.00E+06	14	0	3.27E+06	0	0
4	0	0	0	1.00E+06	15	8.00E+06	0	0	0
5	0	0	5.55E+06	0	16	8.00E+06	0	0	0
6	0	0	5.55E+06	0	17	8.00E+06	0	0	0
7	0	0	5.55E+06	0	18	8.00E+06	0	0	0
8	0	0	5.55E+06	0	19	1.13E+03	0	0	0
9	0	0	5.55E+06	0	20	8.00E+06	0	0	0
10	0	3.27E+06	0	0					

3.2 Stochastic model

When demand is not deterministic and is a stochastic variable, the model 2 should be implemented. Under this assumption we consider that demand follows of normal distribution with the mean 1250 and the 100 as its standard deviation. Also the model is solved by considering α=0.25 which the confidence level is 0.975 and β=0.01.

Now we are able to solve model for the time horizon (20 years). Again, we mention, the model is a multi-objective programming (MOP) so it solved by the TH method which is introduced in the section 2.3. For this purpose the model is solved with objective functions separately and then results are utilized in TH method to find the efficient solution. The results are shown in Table 6:

Table 6. The optimum value of functions separately when applying Model 2

Function	Optimum value
1	1.1308E+7
2	2.8350E+6

Now for obtaining an efficient solution we run model 4.

Model 4:

$$Max\ z_3 = \gamma\lambda + (1-\gamma)(w_1\mu_1 + w_2\mu_2)$$

$$st:(3)-(6)$$

$$\sum_{i=1}^{m} x_{it} \geq \bar{D} + \sigma F^{-1}(1-\alpha) - SDSM_t + \beta \qquad (21)$$

$$(8)-(16)$$

$$(22)-(23)$$

The results of the stochastic MOP model are as Table7.

Table7. The amount of energy should be produced in time horizon (Stochastic MOP model 2)

Year	0	1	2	3	4	5	6	7	8	9	10
Wind	796	0	0	1176	1176	0	1176	0	1176	0	0
Solar	0	796	958.6	0	0	1176	0	0	0	1176	0
Geothermal	0	0	0	0	0	0	0	1176	0	0	1176
Hydro	0	0	0	0	0	0	0	0	0	0	0

Year	11	12	13	14	15	16	17	18	19	20
Wind	0	0	1176	0	0	0	0	0	0	0
Solar	0	0	0	0	0	0	0	0	0	0
Geothermal	0	0	0	1176	0	0	0	1176	1176	0
Hydro	1176	1176	0	0	1176	1176	1176	0	0	1176

Also savings during time horizon are as the same as the savings of deterministic model 1 which is demonstrated in Table3.

3.3 Sensitive analysis

For validation of the proposed models the sensitivity analysis is implemented. The impact of the parameter γ in the fuzzy model which is introduced in section 2.3 and the life cycle parameter (LC_i) in the model 1 are investigated. The results are obtained by considering the deterministic model 1.

The model is solved in the presence of different γ values. This analysis is implemented by w_1=0.7 and w_2=0.3. Thus minimizing the first objective value is more preferable than second objective function.

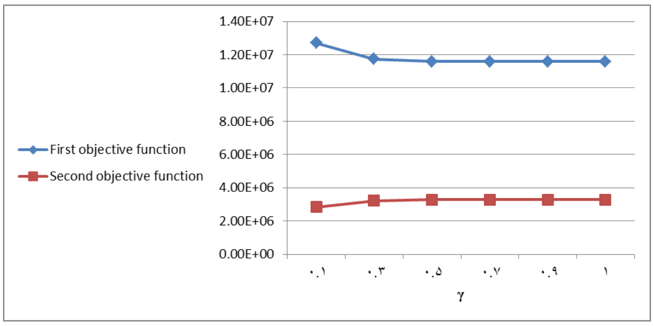

Figure2. The trend of the objective function values by altering the parameter γ

When γ increases, the objective function values get closer together and demonstrated in Figure2. Also the amount of produced energy under these conditions is as Figure3:

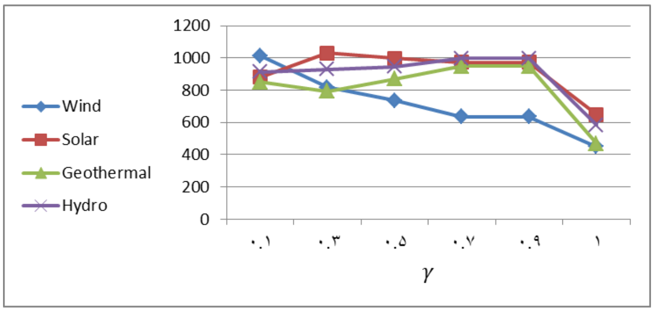

Figure3. The trend of the energy production by altering the parameter γ

When γ is at its minimum value (equal to 0.1) the average amount of produced energy in time horizon and different technology plants is high and when γ takes its maximum value (equal to 1) the average is at least.

Also life cycle parameter of technology plants LC_i is analyzed. The results are considered by w_1=0.7 and w_2=0.3

and γ =0.5. The default life cycle parameters are assumed to multiple of two by considering the other life cycle technologies as constant value, and then the trend of produced energy is investigated. For example the wind technology`s life cycle assumed equal to 6 and 12 and other technology life cycles is not changed. The results are shown is Figure 4-7:

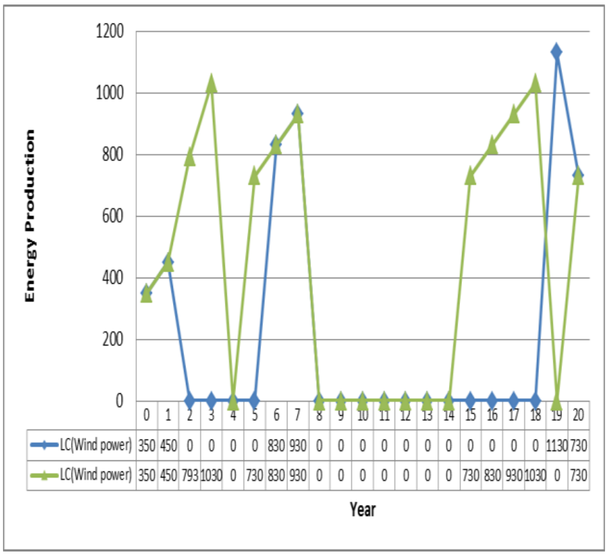

Figure4. Amount of producing energy from wind power

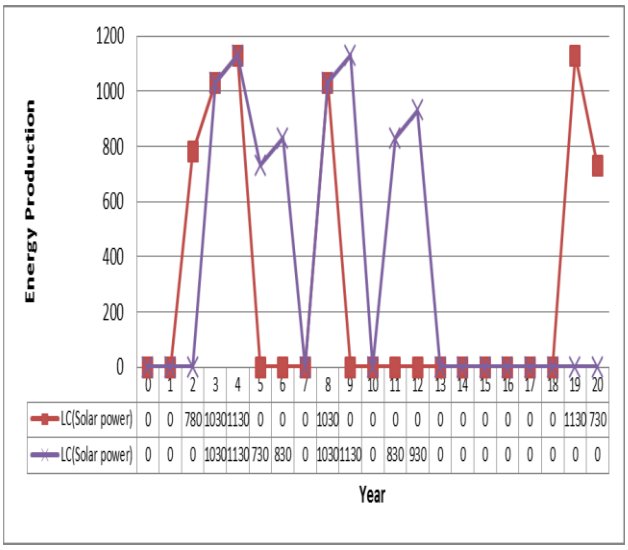

Figure5. Amount of producing energy from solar power

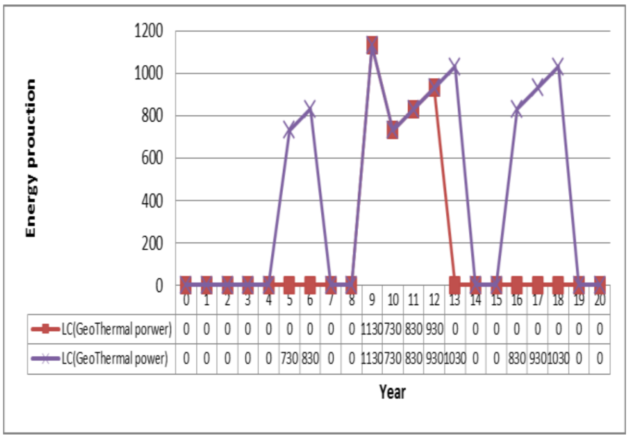

Figure6. Amount of producing energy by geothermal power

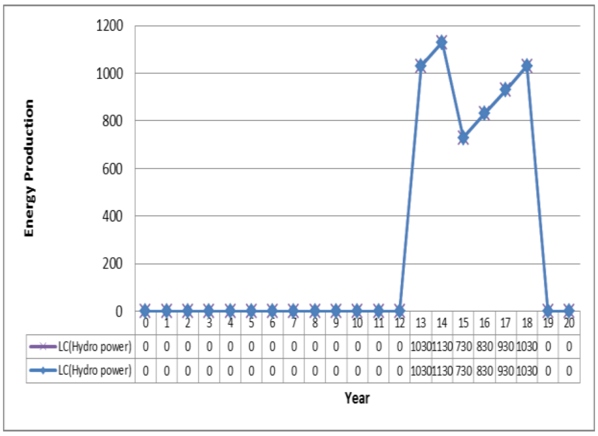

Figure7. Amount of producing energy by hydro power

The wind, Solar and Hydro powers are produced more than during the years when implementing more life cycles. But Hydro power is not changed in producing energy on the time horizon. On the other hand the install cost of the Hydro power is assumed to be higher than the others, thus it is not reasonable to install more than a certain number of this kind technology during the time horizon to produce more energy. Finally, it can be concluded that if a technology plant, implement with reasonable install cost and higher life cycle, it is more economical to produce energy and install them during the time horizon.

4.Conclusion

In this paper a model is presented to find the optimal amount of energy which should be produced during 20 years by considering minimizing the net present value of the costs, i.e. cost of installing RES technologies, O&M costs, energy production and DSM costs. Model is presented for both the deterministic and stochastic energy demands during the years. For entrance the demand as uncertain parameter in the stochastic model the chance constraint method is exploited. Models are multi objective programming (MOP) so the TH method [22] is utilized to find an efficient solution with considering two objective functions simultaneously. Also one might be not desired to consider two of the objective functions in models. So for this purpose the deterministic model is solved by each objective function separately to make it sensible in comparison between results .
Models are solved in the existence of four technologies such as wind, solar, geothermal and hydro power. The time horizon is considered equal to 20 years. Also sensitive analysis is implemented on the parameter γ in the objective function to show the impact on the final results. Coefficient of compensation (γ) depends on the decision maker opinion and results may differ when it alters. Also, because of the importance of the life cycle parameter of RES technologies, this parameter is analyzed too. The results show that the higher life cycle of a specific RES technology results in higher energy production of that technology but at a reasonable installing cost. In other words, to make a decision about implementing two technologies, it is crucial to analyze both the life cycle and installing costs simultaneously .

Future research may be proposing a model which considers sustainability indicators to implement the technologies to produce energy. Also proposing a model which helps decision maker to invest in savings during years is worthy.

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