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Enhancing Energy Security through Portfolio Thinking: An Analysis of National Energy Portfolios

F. Yazdandoost*, S. A. Yazdani

Department of Civil Engineering, K. N. Toosi University of Technology, Tehran, Iran

P A P E R   I N F O

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A B S T R A C T

Insisting on independently providing energy due to fossil fuel availability and Economic-political purposes has imposed financial-environmental risks on countries. Inefficient obsolete infrastructures and technologies have caused devastating losses causing technical vulnerabilities in the energy sector. Ungainful increasing consumption of water resources has superimposed severe environmental degradation, threatening long-term energy planning. Successively, the energy security debate has turned into a challenging necessity for countries. This study developed a classic approach based on Modern Portfolio Theory (MPT) and Capital Allocation Line (CAL) reinforced with aggregated evaluative measures to deal with the financial-environmental complexities of national energy portfolios. Results prove that countries are not even aware of the risky hidden brittleness of their energy portfolio. Futuristic policymaking should be adapted to gradually change the national energy structure from fossil fuel dependency to portfolio thinking to avoid risks and achieve more security.

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INTRODUCTION

The energy sector as one of the key components of sustainable development (1–4) has been turned into a challenging necessity to ensure economic growth and social welfare for every country (5–8) Some countries with not sufficient amounts of fossil fuel have chosen newer technologies such as nuclear, geothermal, wind, solar and marine to meet their electricity demand (9, 10). However, fossil fuel availability has caused governors' force to intensify conventional electricity production (11–13) depending on highly water consumptive thermal power plants (14, 15). Moreover, CO_2 emissions from thermal power plants has caused huge air pollution and global warming (16). Environmental impacts of conventional energy production in the last decades have become more apparent (17), leading to political, economic and institutional changes for future energy policies (18, 19).

Countries insisting on independently ensuring the availability, accessibility and affordability of energy (20–22) has caused inappropriate origination of the energy sector (1) resulting in the creation of a risky hidden brittleness (23). Severe vulnerabilities such as fuel import constraints (24, 25), electricity black-outs (26–28) and disruptive environmental changes (29) due to independent energy generation at prohibitive cost or by limited obsolete infrastructures and technologies are inevitable (30). That being so, scientists and policymakers started a new debate expressing national energy security vs. energy independence (31). Huge investments in alternative technologies development (32, 33), energy efficiency enhancement (34) and interconnected energy markets (35) are some insights into energy security governance in recent decades.

The Energy Security definition has been severally stated and altered. Primary debates started with supplying adequate fossil fuels (oil and gas) (36, 37), geopolitical concerns (38–42), avoidance of fuel costs, transition and delivery risks (43–45). More details and information could be found in many published works including:1970s the oil crisis (46), the 1990 oil crisis (47), the 2000s oil

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*Corresponding Author Email: yazdandoost@kntu.ac.ir
(F. Yazdandoost)

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crisis (48) and the 2020 Russia and Saudi Arabia oil price war. Moreover, according to IEA reports, the COVID-19 pandemic caused the largest drop in global energy investment from fossil fuels to renewables and efficiency, threatening the global transition to resilient and sustainable energy systems. Energy Security also has been interpreted in political and foreign policy debates (49–51), particularly the European Union (EU) has recognized energy security's role in creating interconnected energy markets (52). In the 21st century, the energy security debate has faced potent environmental discourse due to climate change (53–55) and air pollution (56–58) imposing overwhelming inelegant complexities to the human-environment security (59–62). Successively, more efforts have been made to introduce the energy mix concept and alternative green energy sources to the energy security debate (63–65), leading to gainfully increasing investments in renewable energies (66–68), especially high tech photovoltaic solar power plants (69) and energy efficiency enhancement (70, 71) in global scale (despite the shock caused by COVID-19 pandemic). More information about different aspects of energy security could be found in research done by Wang et al. (72).

Nowadays overwhelming debate on energy security has chosen a more complex path due to the inherent complexity of human-environment systems' interaction with the energy sector. Consecutively, researchers initiated novel multidisciplinary approaches to find the most suitable and satisfying solution to deal with energy security. Complex problems of human-environment systems in the energy sector require complicated convenient solutions to address all aspects of the energy security debate in the 21st century which makes a more environmentally friendly future for the planet earth (73). Considering all aspects of energy security discussed in this section, new holistic portfolio based solutions (74, 75), reinforced with aggregated evaluative measures (76–79) and enclosed with several alternative frontier solutions have helped decision makers to make wise decisions to ensure sustainable development targets in the energy sector which are described in the following:

Goal 7 of the United Nations environment and sustainable development programme includes: Target 7.1: By 2030, ensure universal access to affordable, reliable and modern energy services. Target 7.2: By 2030, increase substantially the share of renewable energy in the global energy mix. Target 7.3: By 2030, double the global rate of improvement in energy efficiency (80).

Reviewing all mentioned above, a mind-boggling question is whether the national energy sector could finally deal with complex human-environment systems conflicts. To pursue this target in this study, our main goal is to take advantage of Modern Portfolio Theory (MPT), Markowitz Bullet and Capital Allocation Line (CAL) (81) shown in Figure 1 -we call it Resource Allocation Line (RAL) in this study- to find a sustainable satisfying National Energy Portfolio. To elaborate more, a sustainable satisfying National Energy Portfolio will not only meet sustainable development targets but will also bring enough complication to the solution of complex human-environment systems problems. Nevertheless, matching the dimensions of a complex problem and a complicated solution is a necessity so that a portfolio based approach may be achieved appropriately.

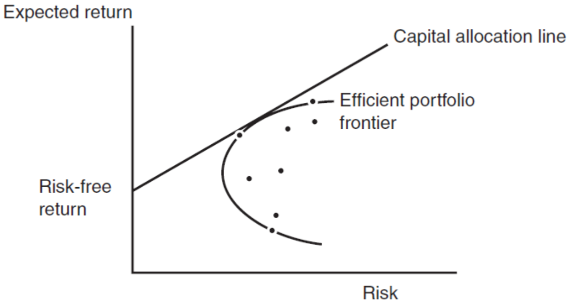

Figure 1. Markowitz bullet and capital allocation line

METHOD

We take advantage of Modern Portfolio Theory (MPT) to demonstrate the necessity of designing a potent diversified national energy portfolio. Interpreting risk and security components of randomly created portfolios leading to a suitable Tangency Portfolio using Resource Allocation Line (RAL) pushed our hopes forward to readily discourse the National Energy Portfolio. In the following, the proposed methodology has been demonstrated in four steps:

Step 1: Development of an aggregated measure called Resource Security Index (RSI) based on ten sub-indices. These indices are: GHG Emission, Water Consumption, Water Withdrawal, Land Footprint, Cost and Social Cost which has been demonstrated in our previous study (78). Also, we added four other indices to widen our aggregated measure's scope. These indices are: Lifetime, Job Creation, Load Factor and Capacity Factor of different technologies. Load Factor can be defined as the ratio of the output produced by a plant in a certain period and the theoretical maximum that it could have produced (82). Capacity Factor can be defined as the ratio of a plant's actual generation to the maximum amount it could generate in a given period without any interruption (83). All indices have been evaluated and aggregated via Entropy and TOPSIS approaches.

Step 2: Infinite number of random energy portfolios have been created and evaluated. Pareto frontier hyperbola of portfolios has been obtained based on the risk and security components of portfolios. 100 finite elements have been considered to represent 100 portfolios on the hyperbola. Modern Portfolio Theory (MPT) assumes that investors or decision makers are risk averse, meaning that given two portfolios that offer the same expected return or security, the decision maker will prefer the less risky one. Thus, a decision maker takes on increased risk only if compensated by higher security (84). Security and Risk of portfolios are calculated by Equations 1 and 2, respectively (77).

$$ESI_p = \sum_{i=1}^{n} W_{E_i} RSI_i \qquad (1)$$

$$SD_p = \sqrt{Var(ESI_p)} = \sqrt{\sum_{i=1}^{n} w_i^2 \sigma_i^2 + \sum_{i=1}^{n} \sum_{j=1_{i \neq j}}^{n} w_i w_j \sigma_i \sigma_j \rho_{ij}} \qquad (2)$$

In Equation 1, ESI_p is the portfolio's Energy Security Index and W_{E_i} is the weight of each resource's security index. In equation 2, SD_p is the risk of the portfolio (Standard Deviation), w is the weight of each resource in the portfolio, σ is the deviation of each resource and ρ_{ij} is the correlation between resources.

Step 3: A new curve has been fitted to obtain a pareto frontier Based on linear regression. We considered equation 3 (which is obtained from MATLAB instructions) to fit a suitable curve. In this formula x represents points on the Pareto frontier hyperbola and $p_1, p_2, p_3, q_1, q_2, q_3$ are constraints. Then, 100 points on this curve representing finite elements of the previous step have been obtained.

$$f(x) = \frac{p_1 x^2 + p_2 x + p_3}{x^3 + q_1 x^2 + q_2 x + q_3} \qquad (3)$$

Step 4: Resource Allocation Line (RAL) has been drawn based on the finite element method. Basic risk free security expectation of decision makers and investors is the most important and effective parameter in drawing RAL and obtaining a Tangency Portfolio. Equation 4 is considered for RAL (85). In this formula, r represents the Return or Energy Security Index (ESI) of Portfolios. p, f and c are representing the Tangency Portfolio, basic risk free security expectation by the decisionmaker and a combination of points p and f, respectively. The intersection of Equations 3 and 4 represents the Tangency Portfolio.

$$r_c = r_f + \sigma_c \frac{r_p - r_f}{\sigma_p} \qquad (4)$$

A finite element method has been utilized to find the intersection of RAL and hyperbola shown in Figure 2. Blue points represent portfolios on Pareto frontier hyperbola, red points represent corresponding Tangency Portfolios of green points representing basic risk free security expectations (for example 30% and 40%). To elaborate more, consider S_{RAL} representing the slope of RAL, S_i representing the slope of each interval between points obtained from the newly fitted curve in step 3 and ε representing an absolute number of differences between S_{RAL} and S_i. A conditional phrase has been set to find matching slopes in Equation 5.

$$\varepsilon = |S_{RAL} - S_i| \quad , \quad \varepsilon \leq 0.0007 \qquad (5)$$

Resource Allocation Line (RAL) is a classic measure to find the most suitable portfolio satisfying decision makers' primary risk averseness and security expectations. However, authors are aware of MPT and RAL's weakness in considering upside risk and downside risk as equal constituents of risk (85). The main target of this methodology is to demonstrate a classic approach to finding a Tangency Portfolio as an aid to finding a target energy portfolio on a national scale and to improving policymaking of the energy sector on a national and regional scale.

CASE STUDY

The Middle East as one of the main players in the energy sector in the world has been submerged in a variety of overwhelming social, political and climatic conflicts, exacerbating the complex situation of the human-environment systems in this region. The energy sector in the Middle East is one of the most turbulent disputes, triggering multi-actor squabbles on a global scale (86–88). Countries' force to independently increase energy production based on economic-political visions ignoring environmental risks and ungainful depletion of natural resources has imposed pernicious risks on nations. Iran is one of the key players in the Middle East dealing with socio-environmental conflicts rather than drastic economic dependence on the energy sector. More than 90 percent of the current energy portfolio of this country is fulfilled by a variety of thermal power plants such as steam, gas and combined cycle technologies leading to a high dependency on fossil fuels and high amount of GHG emissions which made Iran one of the main producers of CO_2 in international scale. Moreover, hydropower plants take second place in the national energy portfolio of this country which is threatened by uncertainties in precipitation and climate change, particularly in arid and semi-arid regions of this country. Nuclear technology

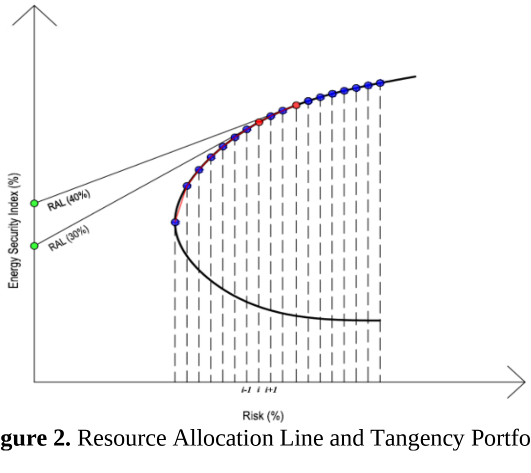

Figure 2. Resource Allocation Line and Tangency Portfolio

takes third place followed by renewable energy production technologies. To put it in a nutshell, the current energy portfolio of Iran mainly consists of Thermal (91.9%), Hydro (5.6%), Nuclear (2.3%) and Wind and Solar Power plants (about 0.2%). In this study, we reviewed the Middle Eastern countries' energy portfolios and applied the proposed methodology to Iran's energy sector to clarify the realities of the energy sector in this country.

RESULT AND DISCUSSION

First of all, an aggregated measure called Resource Security Index (RSI) has been synthesized based on some multidisciplinary indices via Entropy and TOPSIS approaches shown in Table 1. Considering different indices from different disciplines has improved the acceptability of our measure in the evaluation of energy portfolios of countries. The results of RSI are shown in Figure 3. Solar technology gained higher security due to lower environmental impacts and a higher job creation rate. According to Figure 3 and Table 1, biopower plants gained the lowest security (about 40 percent) due to high land footprint (18000 m^2/GWh). Moreover, thermal power plants and hydropower plants gained low security (about 50 percent) due to high water consumption (2 liters/KWh) and water withdrawals (20.21 liters/ KWh) respectively. Wind, Geothermal, Marine and Nuclear technologies gained almost equal security (60 percent) based on all indices. To put in a nutshell, Solar, Geothermal, Wind, Marine, Nuclear, Hydro, Thermal, and Biotechnologies have gained higher to lower Resource Security Index, respectively. The primary conditions of the Middle-East countries energy portfolio are shown in Figure 4.

Results which are shown in Figure 4 indicate that the majority of countries have an energy portfolio with high risk (more than 18 percent) and low security (less than 51 percent) imposing inelegant financial losses to the countries rather than threatening their national energy visions. Moreover, we believe that countries are not even aware of imposed risks to their natural, environmental and financial resources, posing undesired origination of their national energy sector. Losing high number of jobs creation, accelerating high amounts of GHG emissions, high negative effects on climate change and global warming process, unprecedented rate of surface water consumption and groundwater exploitation and imposing technical errors to their power system causing frequent black-outs are only some undervalued indicators that have been missed in national energy planning and policy makings. Based on Figure 4 Turkey (with 53.3% security and 10.8 % risk) could be considered a pioneer country in diversifying its national energy portfolio (Thermal 49.9 %, Hydro 33.5 %, Solar 6 %, Wind 8.3 %, Geo Thermal 1.5 % and Bio Power 0.6 %) in the Middle-East. Energy portfolios of Tajikistan, United Arab Emirates (UAE), Kingdom of Saudi Arabia (KSA), Bahrain, Qatar, Kuwait, Turkmenistan, Oman and Israel are prone to obvious risks (more than 17 %) due to high dependence on one or two energy production technologies with negative environmental impacts such as water consumption, water withdrawal, and GHG emissions.

Energy production in Yemen, Jordan and Afghanistan (with lower negative environmental impacts) is relatively lower than other countries in the Middle East showing unrealistic results in Figure 4. For example, Energy Security Index and Risk for Yemen are about 58.5 percent and 15.5 percent respectively. Russia is one of the biggest energy producers in the world but it does not gain an appropriate security index due to the high share of

Table 1. Sub-indices of Aggregated Evaluative Measure

Energy Source/ Index	GHG (g/KWh)	Water Consumption (Liter/KWh)	Water Withdrawal (Liter/KWh)	Land Footprint (m^2/ GWh)	Cost (€-cent/KWh)	Social Cost (€-cent/KWh)	Lifetime (Years)	Job Per Billion kwh	Load Factor (%)	Capacity Factor (%)	RSI
Index Weighting	**0.15**	**0.12**	**0.17**	**0.19**	**0.03**	**0.11**	**0.01**	**0.17**	**0.03**	**0.02**	
Gas-Thermal	874	2	3	623	6	5	40	10	65	67	**48**
Hydro	17	0	20.210	1700	4.3	3.4	60	247	65	39.1	**50**
Solar PV	55	0.117	0	1200	5.0	0.6	20	3595	20	24.5	**93**
Wind	15	0	0	2300	9.0	0.3	20	383	28	34.8	**65**
Geothermal	70	0.900	0	39.65	6.4	0	40	550	90	74.4	**67**
Nuclear	80	3.024	4.955	78	7.2	0.1	40	75	80	93.5	**59**
Bio-power	113	2.16	3.825	18000	10.9	3.52	30	227	70	80	**42**
Marine (W&T)	60	0	0	250	9	0.2	20	1	4	25	**64**

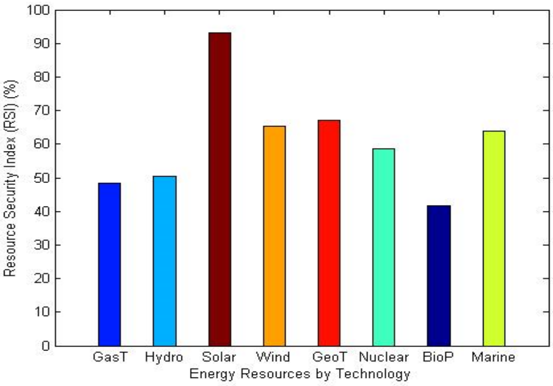

Figure 3. Resource Security Index

thermal power plants (66.5 %) in the energy portfolio. In the following, the energy sector of Iran - with medium risk (14.8 %) and low security (49.2 %) in the Middle East - has been evaluated.

The current energy portfolio of Iran mainly consists of Thermal power plants (91.9%), Hydropower plants (5.6%), Nuclear power plants (2.3%) and also Wind and Solar Power plants (about 0.2%). Due to existing interconnected energy markets, surplus electricity production is being exported to neighbouring countries. As Thermal power plants are the main electricity production sources in this country, fossil fuels are playing a key role in the national energy sector. The energy sector's dependency on fossil fuels combined with economic dependence on fossil fuels have made Iran one of the countries with a high range of GHG emissions posing obvious responsibilities to this country in international discourses, particularly in the climate accord. Moreover, Hydropower plants as the other main electricity source in Iran is threatened by climate change and uncertainties in precipitation. That being so, it could be stated that the energy security of Iran is fairly endangered. Figures 5 and 6 represent some basic information about energy consumption and the energy

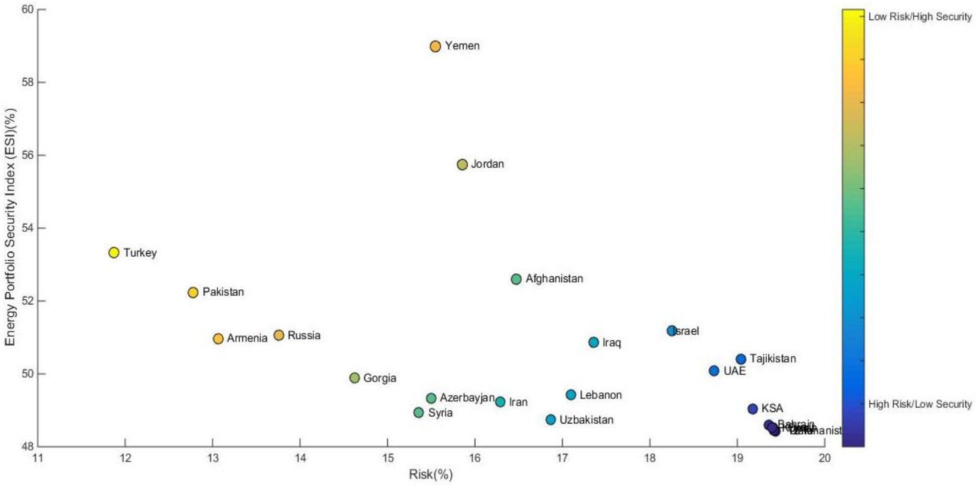

Figure 4. Middle-East Countries Energy Portfolio

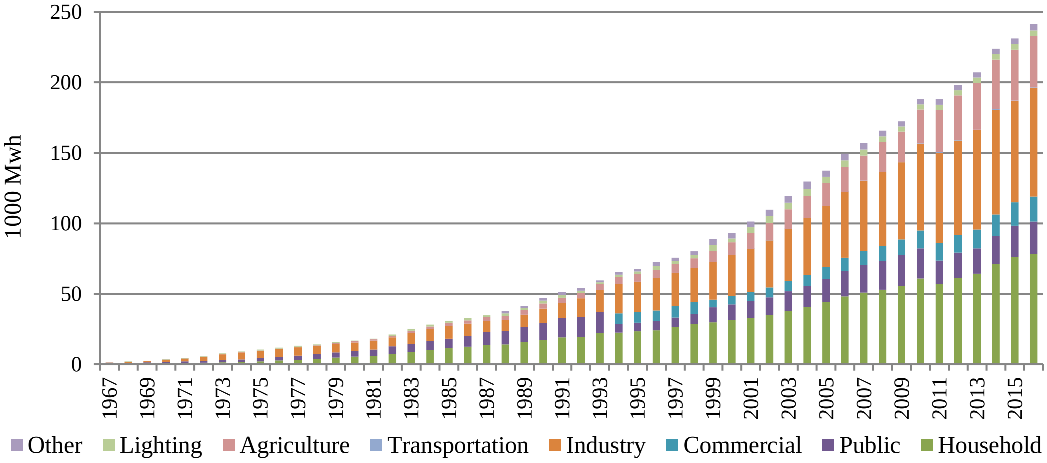

Figure 5. Energy Consumption of different sectors in Iran

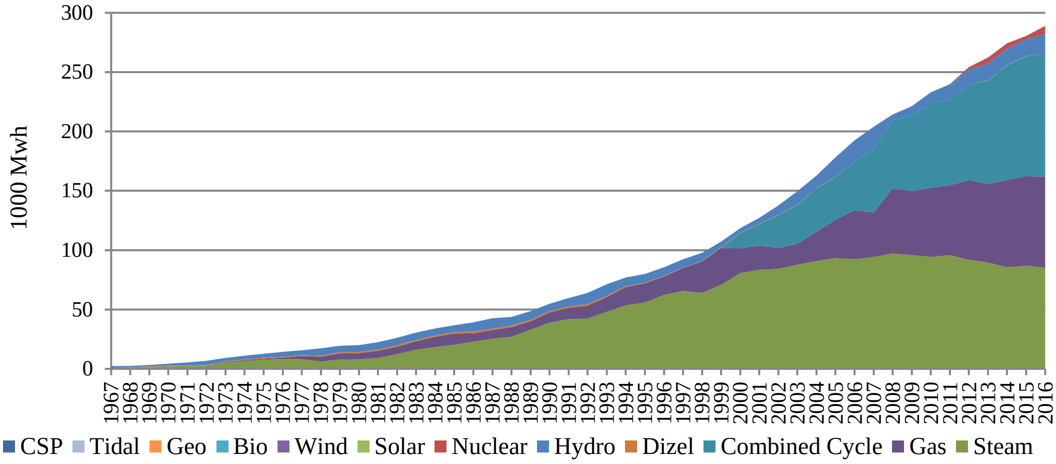

Figure 6. Energy Mix of Iran

portfolio of Iran in recent decades. Figure 5 indicates that from the 1990s to2016 household and industry sectors were the main energy consumer sectors in Iran (the household sector consumed about 78 GWh and the industry sector consumed about 77 GWh and they are followed by the agriculture sector which consumed about 36 GWh in 2016). Figure 6 indicates that more than 250 GWh of Iran's electricity was produced by a variety of thermal power plant technologies in 2016 and it is followed by Hydro power plants. Figure 7 represents the fuel consumption of the energy sector in Iran. High shares of Gas, Mazut (a low-quality heavy fuel oil, used in power plants and similar applications. In the United States and Western Europe, by using FCC or RFCC processes, mazut is blended or broken down, with the end product being diesel) and Gasoline (More than 99 %) in the fuel mix of energy production (mainly Thermal power plants) is indicating the high range of GHG emissions shown in Figure 8. This figure indicates that about 600 million tons of CO_2 were produced in Iran's energy sector in 2016. This amount of GHG emissions plays a serious role in the global warming process.

According to Figure 5, the agriculture sector in the last two decades has experiencing gradual increase in energy consumption, due to development scenarios and food debates in this country requiring similar portfolio based evaluations in further studies.

Figure 9 represents Iran's electricity production, consumption, export, import and loss. Electricity production was about 290 GWh, electricity consumption was about 237 GWh, electricity loss was about 46 GWh, electricity export was about 7 GWh, and electricity import was about 4 GWh in 2016. As stated before, surplus electricity export as a beneficial tradeoff with neighbouring countries has been recently promoted as a national energy vision. However, electricity losses due to obsolete technologies and transition lines have been overlooked in policy making. This is imposing drastic risks to futuristic energy planning and threatening natural, environmental and financial resources. Figure 9 says that

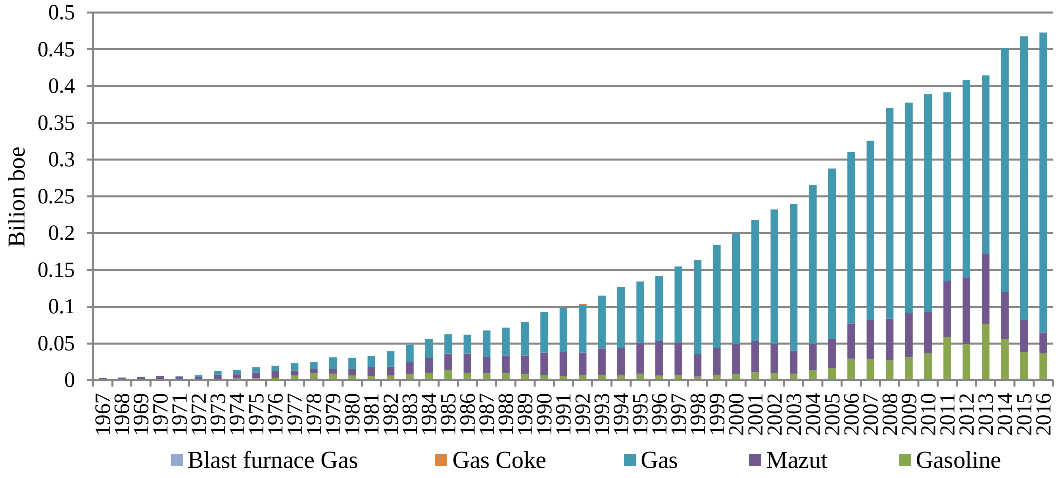

Figure 7. Current Fuel Portfolio of Iran

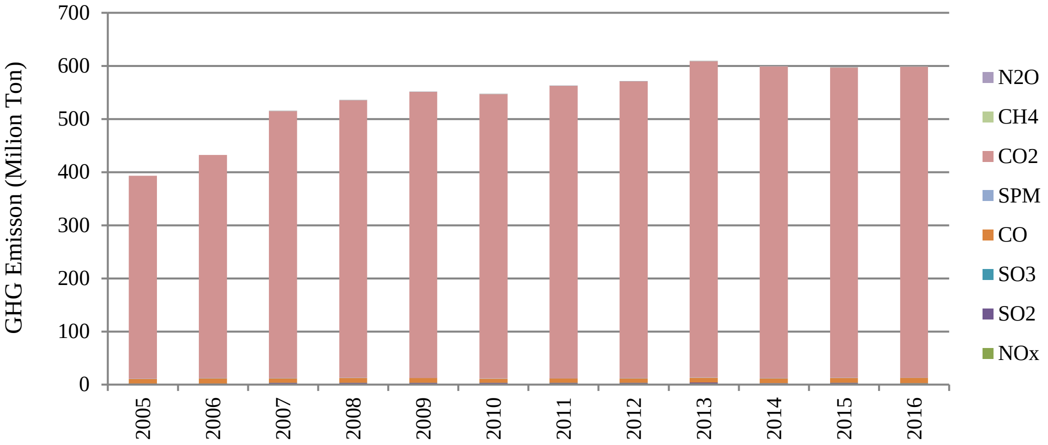

Figure 8. GHG Emission of Iran

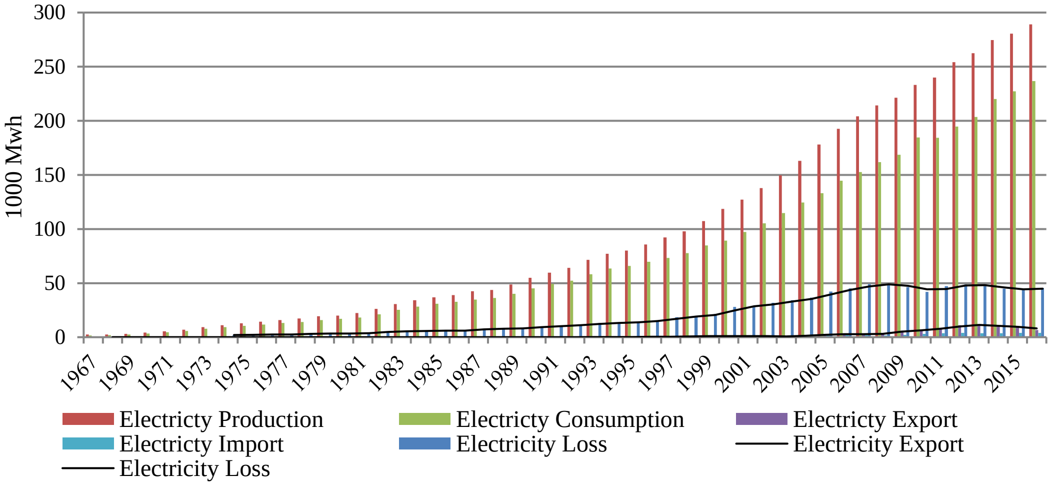

Figure 9. Electricity Production, Consumption, Export, Import and Loss in Iran

electricity loss is 23 times more than electricity export from 1975 to 2016 (in recent decades this ratio has decreased to 5 due to an increase in electricity export and not efficiency enhancement scenarios). According to Figure 9, from 1990s to 2016 electricity production in Iran has increased from about 50 GWh to more than 250 GWh (it means that electricity production has increased more than 5 times), electricity consumption increased from about 49 GWh in the 1990s to about 236 GWh in 2016 (it mean that electricity consumption has increased more than 4 times), electricity loss has increased from about 9 GWh in 1990s to about 45 GWh in 2016 (it means that electricity loss has increased 5 times from 1990s to 2016). Electricity export had its maximum amount (11.6 GWh) in 2013 and electricity import had its maximum amount (4 GWh) in 2016.

Inefficient ungainful obsolete electricity grids, infrastructures and technologies in Iran has imposed severe environmental damage to the country (1.1 m^3/MWh water loss due to energy loss) and unbelievably devastated financial resources ($2\ € - \text{cent}/kWh$ financial loss due to energy loss) averagely in recent decades shown in Figure 10. According to Figure 10, water loss and financial loss have their maximum amounts which are about 2.56 m^3/MWh and $1.41\ € - \text{cent}/KWh$ in 2007, respectively.

Considering the above, improving the national energy portfolio, becomes imperative for decision makers in the country. By improving the national energy portfolio, not only Energy Security of the country will increase, but it will also bring more job creation, positive environmental effects, lower GHG emissions, better load factor and capacity factor of energy systems, and optimized cost to the country. Our proposed methodology as a classic aid could be easily applied to the energy sector of Iran. It will bring more financial-environmental achievements to this country and avoid threatening risks to energy security. To pursue this goal, based on constituents of energy portfolio - Energy Security Index (ESI) and Risk Index - infinite randomly created portfolios have been evaluated and

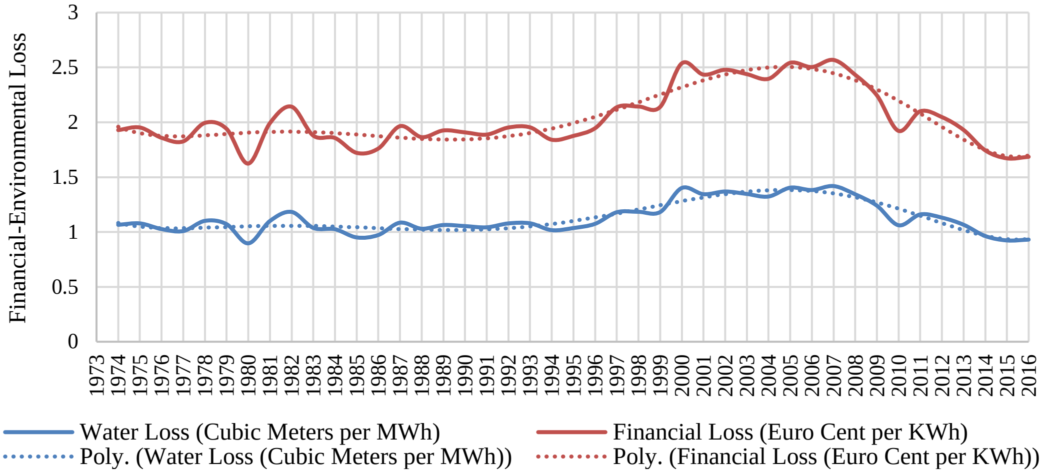

Figure 10. Financial-Environmental Loss Due to Energy Loss in Iran

corresponding Pareto frontier hyperbola is obtained which is shown in Figure 11. Iran's inherent constraints in developing different plant technologies due to consumption hours and water scarcity have been considered as follows. Solar and Hydro power plants share in portfolio has been limited to less than 40% and 10%, respectively. Randomly created portfolios are coloured to clarify risk and security components graphically. Making a comparison between Figure 11 and Figure 4 implies that countries have neglected so many chances to make a better national energy portfolio, as the majority of countries are located in the tail of the portfolio diagram indicating high risk and low security.

To make a drawing of a tangency line to the Pareto frontier hyperbola possible a new curve has been fitted which is shown in Figure 12. The new fitted curve represents all portfolios that could be selected by decision makers based on their risk averseness and risk-free security expectations. Moving to the tail of the curve implies that decision makers are going to face higher risk and also higher security based on MPT's definition. One could claim that willingness to high securities is an intrinsic characteristic of decision makers and the corresponding risk could be logically ignored. It could be controversially claimed that higher risks means that policymakers' visions could be under probable threats causing financial-environmental losses. However, for those policymakers insisting on gaining higher security Post-Modern Portfolio Theory (PMPT) have introduced a new approach called downside risk measurement (Pareto frontier will bring higher profits with lower risks) which is the authors' interest for further studies. Meanwhile, Resource Allocation Line (RAL) as a prevalently utilized method could easily solve the policy makers' conflict on adopting portfolio thinking and selecting a suitable and satisfying National Energy Portfolio. To delineate extra fitted curves, 100 finite elements on the fitted curve, representing each dot with a yellow highlight, have been presented in Figure 12. Drawing tangency lines based on basic risk free security expectations to suitable elements

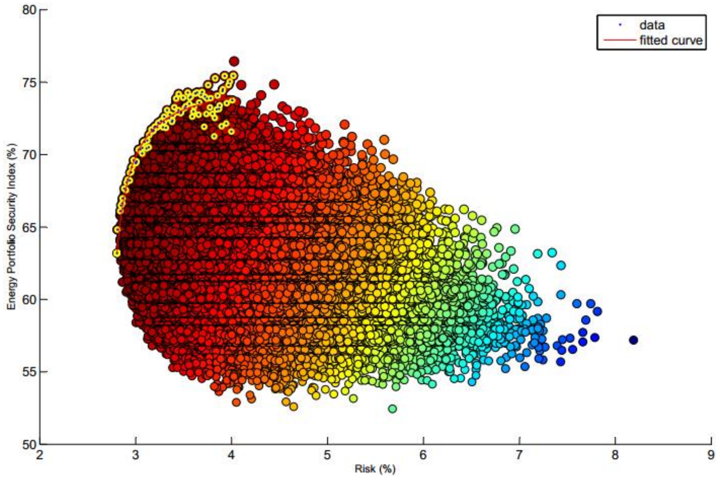

Figure 11. Basic Portfolio Curve

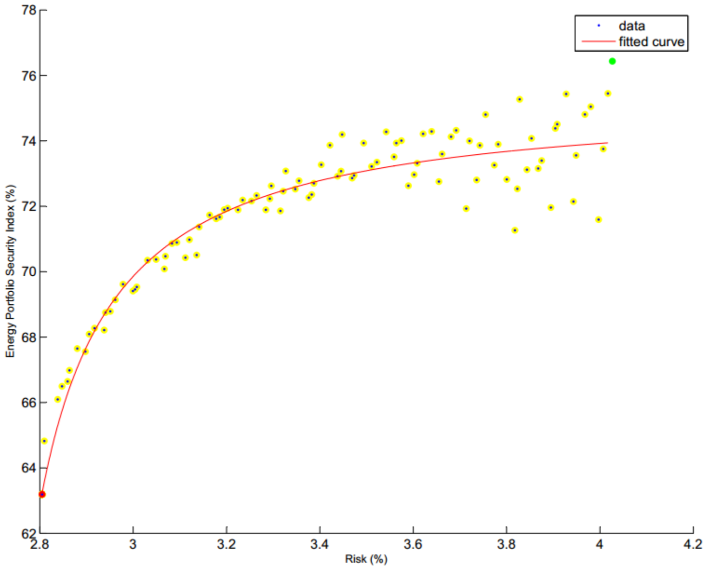

Figure 12. Fitted Curve to Pareto Frontier Hyperbola

will lead us to corresponding Tangency Portfolios. As dots are highly diversified in the tail of the Pareto frontier hyperbola (portfolios which have high security and high risk), we suppose that basic risk free security expectations should not be logically high quantities, otherwise it will lead decision makers to tail of the hyperbola imposing high risks theoretically and technically.

As stated before, the most important parameter in drawing Resource Allocation Line (RAL), is the risk-free security expectations of decision makers and policymakers. To clarify this more, we considered three quantities for this parameter to make it possible to create a decision menu for policy makers claiming different levels of risk averseness and risk free security expectations. Figure 13 represents three tangency lines based on 40%, 50% and 60% risk free security expectations and the corresponding Tangency Portfolios.

Table 2 represents different energy sources' share in tangency portfolios. The set of Tangency Portfolio could be considered as a target portfolio for futuristic energy planning and policy makings. As is clearly shown in Figure 13 there are other portfolios with higher securities and they could have been selected depending on risk free security expectations of authors. Tangency portfolio results indicate that there is a considerable difference between Iran's current energy portfolio and a modified satisfying energy portfolio for this country. The unsustainable development of Thermal power plants has imposed financial-environmental losses on this country. Based on Table 2, the desired pair of risk and security for

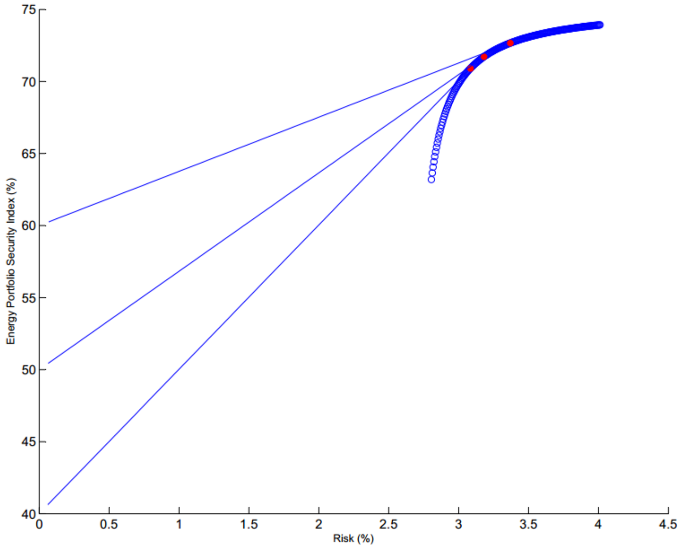

Figure 13. Resource Allocation Lines and Corresponding Tangency Portfolios

Table 2. Energy Resources Share in Tangency Portfolios

Energy Source	**Tangency Portfolio (40 %)**	**Tangency Portfolio (50 %)**	**Tangency Portfolio (60 %)**
GasT	8.2	7.5	2.9
Hydro	4.9	6.0	2.7
Solar	31.9	33.1	36.4
Wind	18.6	19.6	14.9
Geothermal	16.4	19.1	20.3
Nuclear	12.9	6.8	13.9
Biopower	2.7	2.7	5.0
Marine (W&T)	4.5	5.2	3.9
Risk	3.1	3.2	3.4
ESI	70.8	71.6	72.8

Iran's National Energy Portfolio is approximately 3 % and 70 % respectively. It means that Iran's energy managers should increase security by about 20 % and decrease risk by about 12 %. It is expected that saved financial-environmental resources due to energy portfolio improvement will gradually cover the primary costs of energy efficiency enhancement in this country.

To illustrate it more, according to Table 2, the share of each technology in the Tangency portfolio based on 40 percent risk free security expectation are as follows: thermal power plants (8.2 percent, Hydropower plants (4.9 percent), Solar power plants (31.9 percent), Wind power plants (18.6 percent), Geothermal power plants (16.4 percent), Nuclear power plants (12.9 percent), Bio power plants (2.7 percent), and Marine power plants (4.5 percent). Risk and Energy Security Index based on 40 percent risk free security expectation are 3.1 percent and 70.8 percent respectively. The share of each technology in Tangency portfolio based on 50 percent risk free security expectation are as follows: Thermal power plants (7.5 percent), Hydro power plants (6 percent), Solar power plants (33.1 percent), Wind power plants (19.6 percent), Geothermal power plants (19.1 percent), Nuclear power plants (6.8 percent), Bio power plants (2.7 percent), and Marine power plants (5.2 percent). Risk and Energy Security Index based on 50 percent risk free security expectations are 3.2 percent and 71.6 percent, respectively. The share of each technology in the Tangency portfolio based on 60 percent risk free security expectation are as follows: Thermal power plants (2.9 percent), Hydro power plants (2.7 percent), Solar power plants (36.4 percent), Wind power plants (14.9 percent), Geothermal power plants (20.3 percent), Nuclear power plants (13.9 percent), Bio power plants (5 percent), and Marine power plants (3.9 percent). Risk and Energy Security Index based on 60 percent risk free security expectations are 3.4 percent and 72.8 percent, respectively.

However, the current share of each energy technology in 2016 in Iran's energy portfolio are as follows: Thermal power plants (91.9 percent), Hydropower plants (5.6 percent), Nuclear power plants (2.3 percent) and Wind and Solar Power plants (about 0.2 percent), Geothermal power plants (zero percent), Biopower plants (zero percent), and Marine power plants (zero percent). It means that Iran's energy headquarters must move away from conventional electricity production technologies (such as old thermal power plants) to renewable energy production technologies, particularly Solar and Geothermal power plants. Because they have high potential to be installed in different locations in Iran.

CONCLUSION

The energy sector as one of the main components of sustainable development is playing a key role in countries economic, political, and social discourses. Insisting on independently providing energy due to fossil fuel availability and economic-political purposes has imposed financial-environmental risks on countries. This has caused inappropriate origination of energy portfolios in so many countries. The shocking fact is, that energy headquarters in different countries may have not been aware of the risky hidden brittleness of their energy portfolios, leading to severe technical vulnerabilities in their energy sector, alongside unprecedented financial losses due to obsolete inefficient energy infrastructures.

Dynamic meandering energy security debate is going to take a more complex route in human-environment systems to ensure economic growth and social welfare. Our proposed method considering Modern Portfolio Theory (MPT) and Capital Allocation Line (CAL) reinforced with aggregated evaluative measures is trying to propose a secure path to ensure policymakers insist on national energy security, enhancing social welfare, ensuring a high rate of job creation, avoiding technical errors such as frequent black-outs and alleviating environmental degradation simultaneously.

Results proved that, conventional energy production has superimposed financial-environmental losses at the national scale, leading to an unprecedented rate of natural resource depletion. In recent decades, electricity losses in Iran due to obsolete energy infrastructures and technologies are 5 times more than electricity export as a beneficial trade between neighboring countries. This is a hidden threat at the national scale, devastating financial-environmental resources ($2€ - \text{cent}/kWh$ financial loss and $1.1m^3/MWh$ water loss due to energy loss in Iran). Moreover, ignoring alternative energy technologies development by Iranian energy headquarters has prevented high rates of job creation, particularly in the solar power plants industry which have provided high jobs (10 job creation per 1MW installed Solar Photovoltaic power plants in Iran) in so many countries of the world.

The current energy portfolio of Iran contains mainly Thermal power plants (more than 91 percent) and this is because of the availability of fossil fuels such as gas, mazut and gasoline leading to high levels of GHG emissions. Moreover, the current energy portfolio of Iran has a big negative effect on the global warming process. However, considering an optimized satisfying Tangency portfolio produced by Modern Portfolio Theory (MPT) and Resource Allocation Line (RAL) policymakers can finally determine a target portfolio to address all aspects of energy security and long term planning. Moving from Iran's current energy portfolio to the desired Tangency portfolio will require long-term energy planning.

To put in a nutshell, although there are some controversial claims insisting on conventional energy production due to financial and political constraints, authors assert that the more complexity exists in human-environment systems, the more comprehensive portfolio-based approaches will be selected by scientists, decision makers and policymakers. To recapitulate the reasons, not only does it ensure sustainable development goals, but portfolio thinking will untie risky hidden ties of a badly oriented energy sector and prevent undesired financial-environmental losses.

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Persian Abstract

چکیده

پافشاری در تولید مستقل انرژی به دلیل وجود سوخت‌های فسیلی و همچنین مقاصد اقتصادی-سیاسی باعث شده است ریسک‌های مالی-محیط زیستی بر کشورها تحمیل شود. زیرساخت‌ها و فناوری‌های قدیمی و غیر بهره‌ور باعث ایجاد تلفات فزاینده شده است که این امر خود باعث ایجاد آسیب‌پذیری‌هایی در بخش انرژی شده است. استفاده غیر مثمر فزاینده از منابع آب باعث تحمیل آسیب‌های جدی محیط زیستی شده است که برنامه‌ریزی بلند مدت در زمینه انرژی را با اختلال مواجه می‌کند. متعاقبا، مبحث امنیت انرژی به یک ضرورت پر چالش برای کشورها تبدیل شده است. در این مطالعه یک روش کلاسیک بر پایه تئوری پورتفوی مدرن و خط تخصیص سرمایه‌گذاری که با ابزارهای ارزیابی ادغام شده برای چیره شدن بر پیچیدگی‌های مالی-زیست محیطیِ سبد انرژی ملی تقویت شده‌اند. نتایج نشان می‌دهد که کشورها حتی در زمینه شکنندگی و آسیب‌پذیری خطرناک مخفی در رابطه با سبد انرژی ملی خود آگاهی کافی ندارند. کشورها در هرگونه سیاست‌گذاری مربوط به آینده بایستی خود را برای ایجاد تغییراتی در ساختار انرژی ملی آماده نمایند و از تفکر وابستگی به سوخت‌های فسیلی فاصله گرفته و به مرور زمان تفکر بر مبنای پورتفوی انرژی را جایگزین نمایند تا از خطرات و ریسک‌ها فاصله گرفته و امنیت بیشتری را کسب نمایند.