APPLYING MODERN PORTFOLIO THEORY TO PLANT ELECTRICITY PLANNING IN ALBANIA

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Abstract
Resource planning has achieved a great deal of attention from researches these last decades; and energy resource planning has its share of importance. Since the problem of Global Warming, became imminent, researches of all kind are striving to find new, more environment friendly solutions to meet their energy demands. Due to technology limitations, and systemic risks, renewable resources still are exploited poorly and most of the generation depends on fossils. A growing body of literature proves that shortage of energy supply affects directly economic growth, so we face this challenge: "How to produce cleaner energy with maximum reliability?"

Albania generates electricity 100% from hydro resources. Even though there have been a lot of new investments in power generating sector, we believe that we are still exposed to an excessive amount of risk because of lack of diversification. So, this paper addresses issues on planning electric generation supply to achieve maximum reliability for Albania, by analyzing present generation risk from hydro resources and considering diversification effect on Albania's electricity generating portfolio.

We begin by analyzing to day work that support portfolio planning in power sector. Then we address the Modern Portfolio Theory and analyze how it proposes solutions to an optimization problem. After that we take a brief overview of the power sector current situation and its dependence on import. By using a small simulation we will try to demonstrate that adding new generating technologies can reduce risk and improve power generation.

Keywords: Power sector, planning, portfolio, renewable

Introduction
Meeting energy demand requests, especially in developing economies has become an increasingly difficult task. Shortage on energy supply is proven to negatively affect economic growth, and increasing prices of spot import on electricity markets are an ever growing burden on state budget.

In the situation where, energy planning sector is facing insecurity from multiple major factors, it has become imperative to review the approach of electricity generation from "least cost" to generating portfolio.

A growing body of literature has described the benefits of diversification to generating technologies. The current situation in Albania is that we rely 100% on renewable resources, and even though, generating capacities has increased by 20%, they are all capacities exploiting hydropower. Of course, there is some extend of diversification, since hydro resources have different patterns on different areas, but we try to argue in this paper that introducing different technologies can make the supply system more reliable, we can maximize output and keep generating costs to an acceptable level.

An overview of traditional electricity planning methods

There are several approaches to plan electricity generation, such as Levelized Cost of Electricity Generation (LCOE), Screening Curve Analysis, and Degree of System Reliability. Each of these methods focuses on generating costs of a technology, and considers it by itself overlooking the effect of the costs if these technologies are considered in a generating portfolio. We are going to discuss LCOE, on more detail in this paper since we rely on its assumptions to build the model.

Levelized cost of energy (LCOE) is the minimal annual cash flow a generating project should earn in order to break even, or to state it differently to have a NPV equal to zero. To calculate LCOE we need information on Capital Cost[21], Operating and Maintenance cost, Capacity factor and construction schedule and operating economic life. These are the main components to calculate sLCOE but there are several models that take into account capital structure, tax shield, PPA incentives and decommissioning costs. sLCOE formula is given as follows:

$$= \frac{\sum_{t=-N}^{t=-1} I_t (1+i)^{-t} + \sum_{t=0}^{t=n-1} (F_t + O\&M_t)(1+i)^{-t}}{\sum_{t=-N}^{t=-1} Gt(1+i)^{-t}} \quad (1)$$

Where:

LCOE = Levelized cost of energy generation \$[22]/MWh

I_t = Investment cost in year t in \$

F_t = Fuel cost in year t in \$

O&M = Operating and Maintenance cost in year t in \$

G_t = generation in year t in MWh

N = Construction Schedule in years

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[21] Include overnight costs, which are costs incurred during the project development and investment costs in technology

22 We are refering to dollar as a measurement currency

n = operating life
i[23] = discount rate
$(1+i)^t$ interest factor

If we choose new generating capacities based on LCOE, fossil generating technologies would have priority, due to their lower investment costs; and renewable exploiting technologies would be avoided to some extent, due to high investment costs. But, in a market where fuel costs are highly volatile, adding more expensive but fixed cost technologies can improve generating performance in output levels and reduced risk.

Modern Portfolio Theory

Portfolio theory was first introduced in 1952 by H. Markowitz, who later won the Nobel Prize for this achievement. In substance, Markowitz explained that it was possible to reduce risk of financial investment, if we combined financial assets with no or negative correlation with each other. If we considered a portfolio with F_i financial assets, where i=1, 2…n, portfolio performance would be measured by expected return E (R) and variance σ^2.

$$E(R_P)= \sum_{i=1}^{n} w_i \, E(R)_i \quad (2)$$

$$\sigma^2\big[r_p(t)\big] = \sum_{i=1}^{n}\sum_{j=1}^{n} w_{i,p}\, w_{j,p}\,\sigma[r_i(t)]\sigma\big[r_j(t)\big]\rho\big[r_i(t),r_j(t)\big] \quad (3)$$

By combining these assets we can achieve efficient portfolios that have higher performance in output and lower risk level than stand alone assets, or some of their combinations. This is called the efficient frontier and we can chose among these combinations with respect to our risk and output preferences.
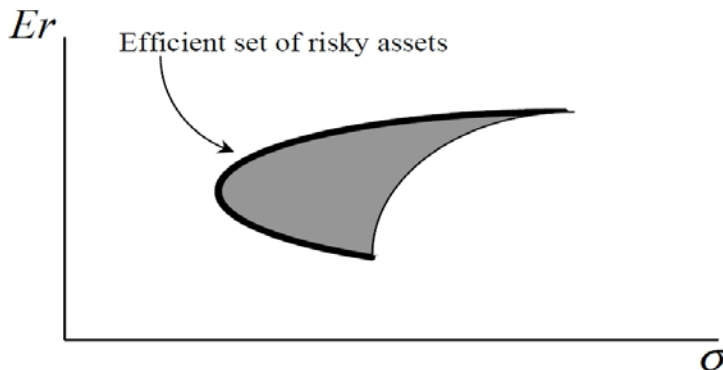
The efficient frontier

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23 Generally the discount rate is fixed to 10% and operating life is considered between 15-20years. Construction Schedule may take 5-10 years depending on the generating technology.

Portfolio Selection for generating Assets

Shimon Awerbuch and Martin Berger in 2003 argued that Modern Portfolio Theory could be applied successfully to generating assets. In their work they measured implications to total generating assets for US and EU generating portfolios. Nevertheless, we consider it is nearly impossible to account the diversification effects in state level, due to information inadequacy and limitations for Albania power sector. The approach we have chosen is to illustrate these effects in a small scale project.

The key assumptions to sustain the following logics are:

Renewable technology risk is determined by the specific site construction place. Studies like (S. Waterbuck & M. Berger 2003) suggest that renewable energy is site sensitive. When researched is conducted locally site characteristics matter since they are the key determinants of expected capacity factor. LCOE probability distribution is driven by output/capacity factor probability distribution which is site sensitive.

We import technology from a specific country, since we suppose we have zero technology capacity building domestically. So technology performance and construction costs are considered exogenous variables.

Capacity factor is not considered fixed over time

Precipitation and river flow are highly correlated in specific location

Standard deviation of meteorological phenomena is transposed to standard deviation of LCOE to the extent that hydro, wind turbine and PV have their power curve function, and input who is a stochastic variable determines standard deviation of technology's LCOE in site.

Technology	Capacity[24] Factor	Capital Cost[25]	O&M Fixed	Fuel Cost	LCOE[26]
Hydro	53%	78.4	4.1	6.4	84.5
Wind	37%	181.2	22.8	0	204.1
PV solar	25	118.6	11.4	0	130

Source: IEA December 2013, DOE/EIA-0383ER(2014).

These costs are derived from International Energy Agency (IEA) dataset. By defining the reliability risk as the risk that weather conditions are not supported for a technology to generate and hence make the excepted output zero. The LCOE are calculated for expected output at present location, and since output is considered the main component of LCOE calculation we try to derive LCOE probability distribution from capacity factor distribution.

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[24] This is the expected capacity factor in site, given that weather phenomena have normal distribution

[25] Besides levelized capital cost we have included transmission investment as well, on the assumption that

[26] Free of subsidy

By using EXCEL Solver and the data from meteorological station for upper Osum river flow region, we have achieved the following results. The Approach we have chosen is to study LCOE behavior for minimizing risk for different given levels of Output.

By studying the results above and the graph below, we can get to the conclusion that diversification of generating technologies can reduce risk of shortage for a desired level of output, and at the same time is keeping portfolio cost at minimum levels for desired system performance. This is the result of combining renewable technologies with negative correlation with each other. Since precipitation and river flow are considered strongly linked to each other, and hydro turbines are working run of river, in summer where precipitation and river flow is lower, we can maximize output by exploiting solar radiation and wind power.

Hydro	Wind	Solar	LCOE	Risk
0.1098901	0	0.8901099	125	0.4443
0.0087939	0.0053998	0.9858063	130	0.1279
0.0024322	0.0689699	0.9285979	135	0.1351
0	0.1349528	0.8650472	140	0.1747
0	0.2024292	0.7975708	145	0.2331
0	0.2699055	0.7300945	150	0.2996
0	0.3373819	0.6626181	155	0.3699
0	0.4048583	0.5951417	160	0.4422
0	0.4723347	0.5276653	165	0.5156
0	0.5398111	0.4601889	170	0.5898
0	0.6072875	0.3927125	175	0.6644
0	0.6747638	0.3252362	180	0.7394
0	0.7422402	0.2577598	185	0.8146
0	0.8097166	0.1902834	190	0.8900
0	0.877193	0.122807	195	0.9655
0	0.9446694	0.0553306	200	1.0412
0	1	0	204.1	1.1033

Limitations of this analysis are:
- Efficient frontier is not a continuous line for generating assets
- Generation assets are limited by cardinal conditions as minimum capacities and power curve function and transactions round lots
- Building efficient frontiers is possible for high capacities power plants and diversification effects are more visible when considered in country level

Efficient Frontier
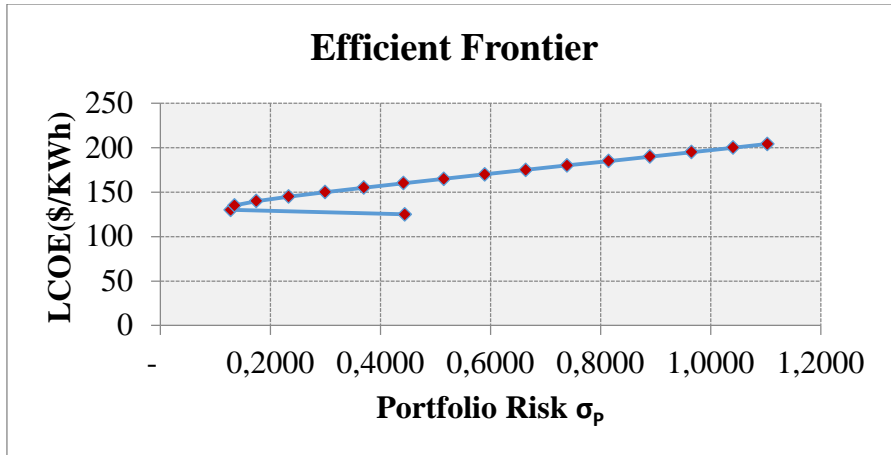
Conclusion

1.   When planning power sector we should switch from traditional least cost methods to assessing efficient generating portfolios

2.   In Albania should be conducted further studies to asses locations that can develop alternative renewable generating technologies other than hydro

3.   Modern Portfolio Theory suggests that by combining different generating technologies we can achieve more efficient results than adding capacities based on their LCOE

4.   Applying MPT, to generating assets has it limitations like cardinal and transactions round lot constraints, but it still suggests more efficient alternatives than "least cost" planning methods.

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