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## INTERNATIONAL WORKSHOP ADVANCES IN CLEANER PRODUCTION

“CLEANER PRODUCTION TOWARDS A SUSTAINABLE TRANSITION”

## **Cleaner Energy Production and Sustainable Investments: A Portfolio Analysis in the Italian Electricity Market**

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### **Abstract**

The recent climate change, global warming, environmental disasters and the economic crisis are only the first signs of the failure of an economic system that, for too long, shows an uncontrolled utilization of the planet wealth. The Italian electricity market, which is strongly dependent on hydrocarbons, only in recent years has seen a first attempt to change towards renewable resources for electricity production aimed at self-consumption and for feeding into the grid. This paper presents an economic analysis whose purpose is to evaluate the sustainability of investments in renewable technologies for the production of electricity. Each renewable source has its own profitability dependent on a number of factors and subject to market fluctuations, cost and frequent changes on the incentive policies. Applying Portfolio Theory is it possible to select the right mix of renewable energy sources to be included within the renewable energy balance and simulate its evolution. Moreover the presented analysis can be useful for energy planners to select future green scenarios finalized to the reduction of emissions and energy imports through the increasing use of renewable energy.

**Keywords:** *Renewable Energy Sources, Portfolio Analysis, Sustainability, Sharpe Index.*

### **1. Introduction**

Unbridled exploitation of planetary resources as infinite source and disregard of the environmental impact of human works in various fields have been the driving forces of world economies and the basis of the recent environmental disasters, the increase in pollutant emissions and failed policies related to the lack of resources and the lack of supplies. In this scenario Green Economy represents not only a simple ecological branch of the economy but a real economic model. Only in the last thirty years it is possible to observe the first steps towards an energy policy and sustainable development; the European Union has laid the foundation for a post-Kyoto protocol (expiring in 2012) with the formalization of the package "climate-energy 20-20-20" (in force since June 2009 and valid from January 2013) which has three main objectives to be achieved by 2020: 20% reduction compared to 1990 levels of emissions; reaching the renewable share of 20% compared to the gross final consumption and improving energy end-use efficiency of 20%. To each member State is also assigned a binding target (with deadline 2020) that in the case of Italy is:

- a reduction of greenhouse gases by 14% compared to 2005;
- a renewable energy share of 17% of gross final consumption (in 2005 it was 5.2%).

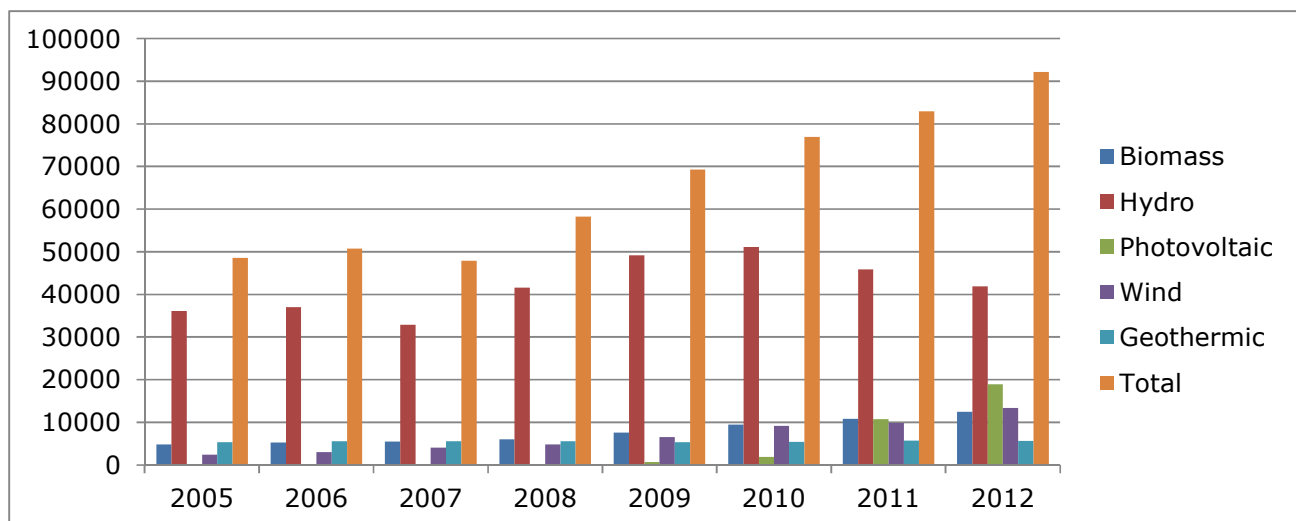
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The guidelines of this strategy, both at European and national level, ranging from the need to address the alarming climatic tasks to the end-user awareness, focusing on renewable sources such as keys to energy efficiency and technological development towards a "growth green" (Popp *et al*, 2011). The implementation of incentive policies is favouring the spread of so-called renewable energy that can be considered almost inexhaustible resources and ensure a practically zero environmental impact when compared to traditional sources such as fossil fuel. The electricity from renewable energy sources (Solar, Biomass, Wind, Hydroelectric and Geothermal) is in Italy 30.8% of the total production in the year 2012 [GSE Statistical Report 2012-Electric Power]. The paper aims to present a financial and strategic analysis focused on the renewable energy sector, in particular related to the Italian electricity market, in order to get concrete suggestions to the needs of investors and useful results in the field of sustainability. The paper is organised as follows. After this brief introduction in Section 2 an overview on the situation of Renewable Energy Sources in Italy (RES) is presented. In Section 3 we introduce the model utilized in this paper based on the Portfolio Theory; starting from the returns and risks of individual activities involved (RES), it is simulated a large number of case studies which correspond to cost scenarios and different sizes (range 10kW-10MW) of different RES combinations; such model is able to obtain a set of efficient portfolios maximizing the Sharpe ratio (the excess of return for unit of risk deviation in an investment asset) evaluating the economic sustainability of investments in renewable technologies for the production of electricity. In Section 4 it is analyzed the current renewable Italian electricity balance (mix) and finally the results are discussed in the conclusions.

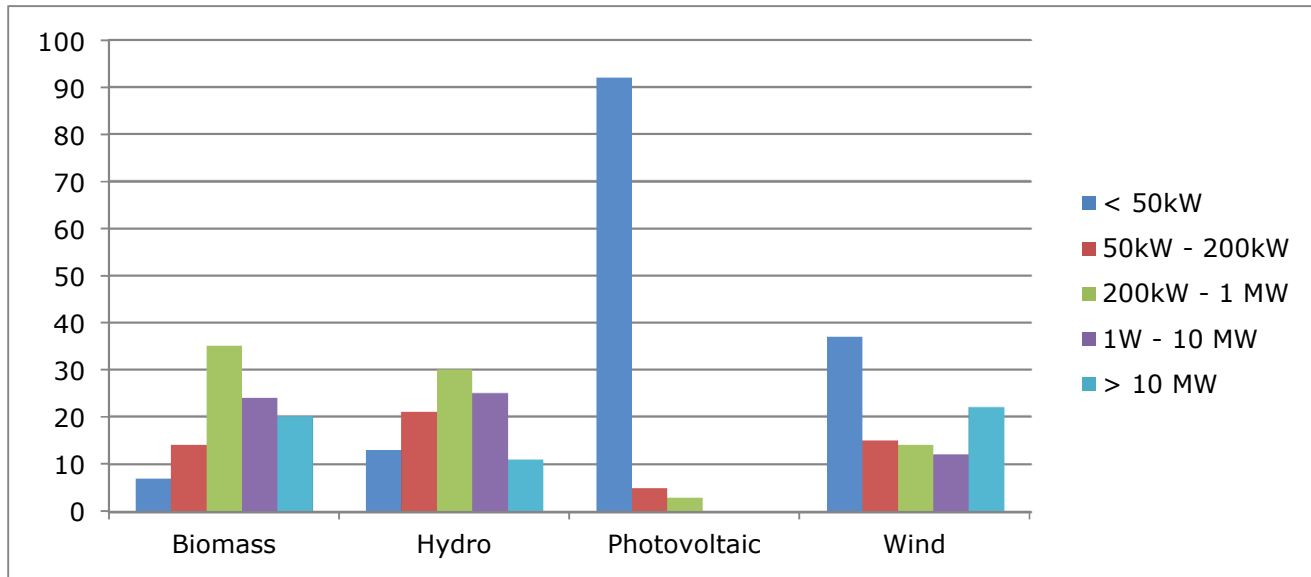
## 2. The Italian electricity market

In 2012 the total gross production of electricity (not purified of energy losses and the energy absorbed by auxiliaries), amounted to a value of 299 TWh, showing signs of recovery following the decline suffered in the period between 2008 and 2010 in conjunction with the economic crisis. The share of RES total production earns about 3.4% compared to 2011 (27.4% of the total gross) continuing the growth of the share of electricity from renewable sources in the period 2000-2012 in Italy. Contrary to what is happening to the "new" renewable sources (solar, wind, bioenergy), the electricity produced by hydroelectric plants is undergoing a modest reduction in the overall national scene. Fortunately this deficiency is filled by the rapid growth in the last five years of the "new" renewable led by the photovoltaic still guarantee a more than positive overall trend that has achieved record production of electricity from RES in 2012 amounted to 92 222 GWh (Figure 1). This paper considers only the shares of energy produced by hydro, wind, solar and biomass (bioenergy) for which, excluding the geothermal, the overall balance in the total gross production amounted to 86 630 GWh of renewable energy as well divided: Hydropower 41 875 GWh (48.33% of total production), Solar 18,862 GWh (21.77%, Wind 13,407 GWh (15.48%) and Bioenergy 12,487 GWh (14.41%).



**Fig. 1.** Electricity generation from renewable sources in 2005-2012 (GWh)

In Section 4, these shares represent the weights of RES in the actual renewable energy Italian portfolio. The size of the plants of RES installed in Italy ranges from power below 50 kW up to powers greater than 10 MW (Figure 2).



**Fig. 2.** The size of the plants of RES installed in Italy (%)

### 3. The Portfolio Theory in the Renewable Market

The model proposed in this section is based on the Portfolio Theory (Markowitz, 1952; Bodie *et al.*, 2004; Roques *et al.*, 2008; Westner and Madlener, 2010; Shen *et al.*, 2011) applied to RES (Biomass, Water, Solar, Wind). The portfolio approach is a method used for strategic selection and use of energy sources for public managers or businesses. It is based on the financial principle of Modern Portfolio Theory which focuses on diversification. According to this approach by diversifying a portfolio of financial assets, the overall risk can be lowered compared to the risk of the individual assets. Finance theory divides total risk into two components: the first one - unsystematic risk - affects principally the prices of an asset (this risk can be reduced through diversification) and systematic risk that affects the prices of all assets. Systematic risk cannot be diversified and is related to the risk common to all securities. When a portfolio is efficient, the unsystematic risk is eliminated through the diversification and, accordingly, the market portfolio risk (standard deviation) is equal to the systematic risk. When the portfolio theory is applied to renewable sector, it is to be considered another relevant point (Muñoz *et al.*, 2009; Janczura, 2010; Gökgöz and Atmaca, 2012). Some renewable sources (such as wind, photovoltaic, and other passive) are capital-intensive and characterized by operating costs that are fixed, or riskless, over time. Unlike with financial assets, it is unrealistic to assume negative correlations among the costs of different electricity generating technologies. Instead, the correlations among the technologies can be very high, especially among those derived from fossil fuels. Thus, the effect of diversification is usually lower in energy portfolio with respect to financial one.

In the energy market, since the returns and standard deviations of individual activities (RES) are organized by class of power (in the range of 10 kW-10 MW) and cost scenario (High, Medium, Low Cost), the first step of the analysis aims at identifying three energy portfolios each of them presents a scenario of identical cost for the activities and a single class of power for each technology (Cucchiella *et al.*, 2012). In the second step is carried out a more realistic analysis in order to identify all the possible mix of RES representing the spectrum of solutions that an investor faces in the Italian electricity sector: three power classes for each technology and three cost scenarios for each power class. Considering only the four considered technologies, 6,561 combinations are obtained where each renewable source can assume any one of three cost scenarios and belong to any of the three power classes. This approach can better reflect the variability of the renewable energies market due to the

mutability of available incentives forms and the level of costs. For each mix of RES resulting from this analysis is detected optimal portfolio and the results are compared with the solutions obtained in the first step with fixed cost by focusing on the portfolio weights of the sources and on the Sharpe ratio attributable to each of them. In order to apply the model it is essential to define the risks and returns of the sources held in the portfolio, as well as the correlation between the activities themselves. The "Return" of each activity is defined by the net present value compared to the power generation (power production) and is expressed in €/W (Euro on Watt) to allow a cross comparison between technologies of different size. The risk however is simply calculated as the standard deviation of activity returns (random variables) and is also expressed in €/W and the correlation coefficients between the various technologies are those reported in the literature (Awerbuch and Yang, 2007). As mentioned before, each technology has three different power classes (Poor, Average, High, see Table 1) varying between 10kW and 10 MW.

<b>Technology Power</b>	<b>Biomass</b>	<b>Hydro</b>	<b>Photovoltaic</b>	<b>Wind</b>
<b>Poor Power</b>	100 kW	100kW	10kW	10kW
<b>Average Power</b>	1 MW	1 MW	100kW	100kW
<b>Elevate Power</b>	10 MW	10 MW	1 MW	10 MW

**Tab. 1.** Power Classes for Renewable Technologies

In the first step the cost scenarios are 3: High, Medium and Low (Cost) and significantly influence the returns and risks of each activity as reported in Table 2. For each scenario we observe 12 activities belonging to four renewable technologies and the three power classes; this implies that the identification of the optimal portfolio results in the definition of a set of renewable consists of four activities selected from the 12 available, each with a different weight but still belonging to the scenario of cost analyzed. So, following the portfolio theory we can proceed with the analysis identifying the efficient frontier and then the optimal portfolio for each scenario. We are thus able to define three optimal portfolios with a corresponding Sharpe Index values for scenarios High, Medium and Low.

	<b>Biomass</b>			<b>Hydro</b>			<b>Photovoltaic</b>			<b>Wind</b>		
	100 kW	1 MW	10 MW	100 kW	1 MW	10 MW	10 kW	100 kW	1 MW	10 kW	100 kW	10 MW
	<b>Return €/W</b>											
<b>High</b>	-2.83	-0.74	-1.07	-1.9	- 1.47	0.15	-0.9	1.13	0.27	-0.02	2.7	-0.19
<b>Medium</b>	0.12	1.75	1.03	0.78	1.87	1.09	1.9	2.43	1.57	0.96	3.44	0.43
<b>Low</b>	3.63	4.19	2.67	3.11	3.02	2.61	2.75	3.5	2.64	2.23	4.02	1.05
	<b>Risk €/W</b>											
<b>High</b>	2.05	1.74	3.24	0.38	0.68	1.46	1.3	0.96	0.9	0.96	0.55	1.34
<b>Medium</b>	1.61	1.37	2.94	0.19	0.32	1.43	0.89	0.77	0.7	0.81	0.44	1.25
<b>Low</b>	1.09	1.01	2.7	0.14	0.21	1.35	0.76	0.61	0.55	0.62	0.35	1.16

**Tab 2.** Returns and risks of renewable sources

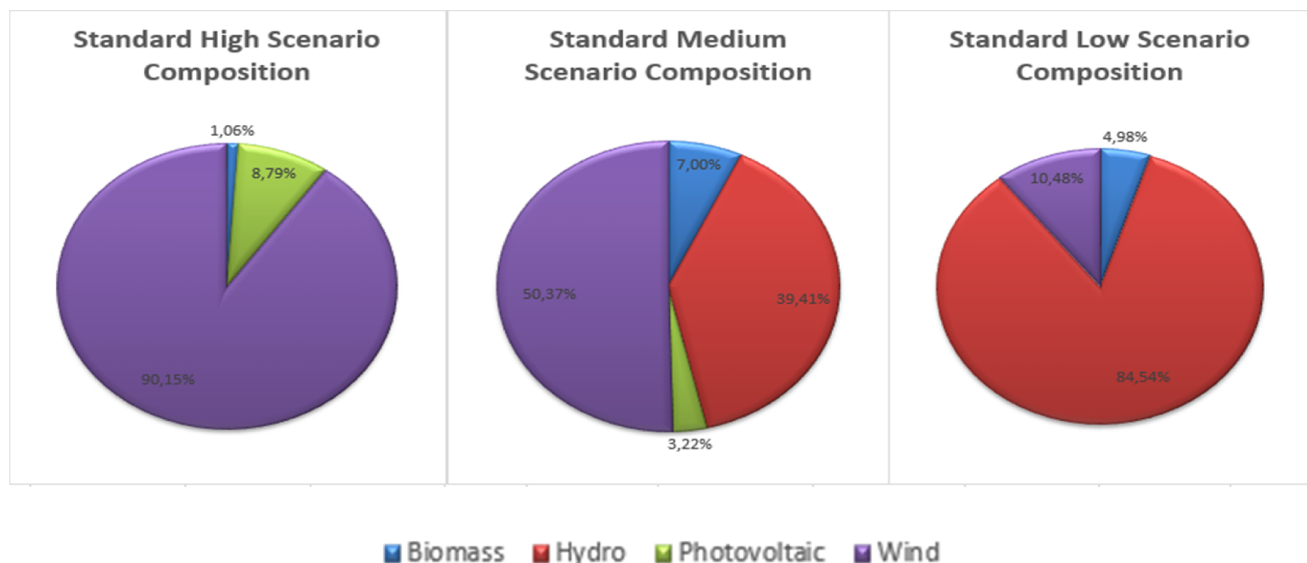
The composition of the optimal portfolios for the three standard scenarios is the following:

*High Cost scenario:* Biomass, 1 MW, 1,06%, Photovoltaic, 100 kW, 8,79%, Wind, 100 kW, 90.15%, Hydro absent.

*Medium Cost scenario:* Biomass, 1 MW, 7%; Hydro, 1 MW, 39.41%; Photovoltaic, 100 kW, 3.22%; Wind, 100 kW, 50.37%.

*Low Cost scenario:* Biomass, 1 MW, 4.98%; Hydro, 100 kW, 84.54%; Wind, 100 kW, 10.48%; Photovoltaic absent.

As evident from the results shown in Figure 3, standard cost scenario drastically influences the composition of the optimal portfolios: in the scenario High wind technology of medium size (100 kW) is the leader with a 90% of the portfolio, leaving the remaining 10% to photovoltaic and biomass (only 1%). Note the absence of hydro source that is, with dimensions of 1 MW, the second technology of the optimal portfolio of the Medium cost scenario (39.4%) and the largest share in the scenario Low (100 kW) with 84.5%. Moreover in the medium cost scenario, the PV reduces its presence by switching to a paltry 3.2% leaving to biomass a share of 7% remaining in the class of 1 MW. It is interesting the constant reduction of the wind share within portfolios that moves from 90% of the scenario High to a 10.5% in the scenario Low with the same type of plant (100 kW). A similar but not identical process can be noted for photovoltaic even absent in the scenario Low. This technology is just appealing in scenarios with high cost and very unsustainable in the low cost scenario unlike wind energy that is still the best choice in the high cost scenario. This is clearly derived from the state of maturity of wind technology with respect to the still low efficiency of photovoltaic panels. Reverse process is instead for hydro that in the transition from the scenario Medium to Low reduces the size of the plant but doubles its weight within the portfolio. Portfolios must be analyzed considering the Sharpe Index; the values range from 5,008 (High Cost Scenario) to 9.289 (Medium Cost scenario) and to 24,576 (High Cost Scenario). This means that from a financial point of view the portfolio related to the Low Cost scenario is the most convenient in terms of profitability and sustainability. This arises primarily from the its low value of the standard deviation (0.1317 €/W) compared to a return of only € 3.2552/W (Table 3); these values do not differ too much from those of hydro with a small power class (100 kW) whose return and risk are respectively € 3.11/W and 0.14 €/W. Infact this activity assumes larger weight in this scenario.

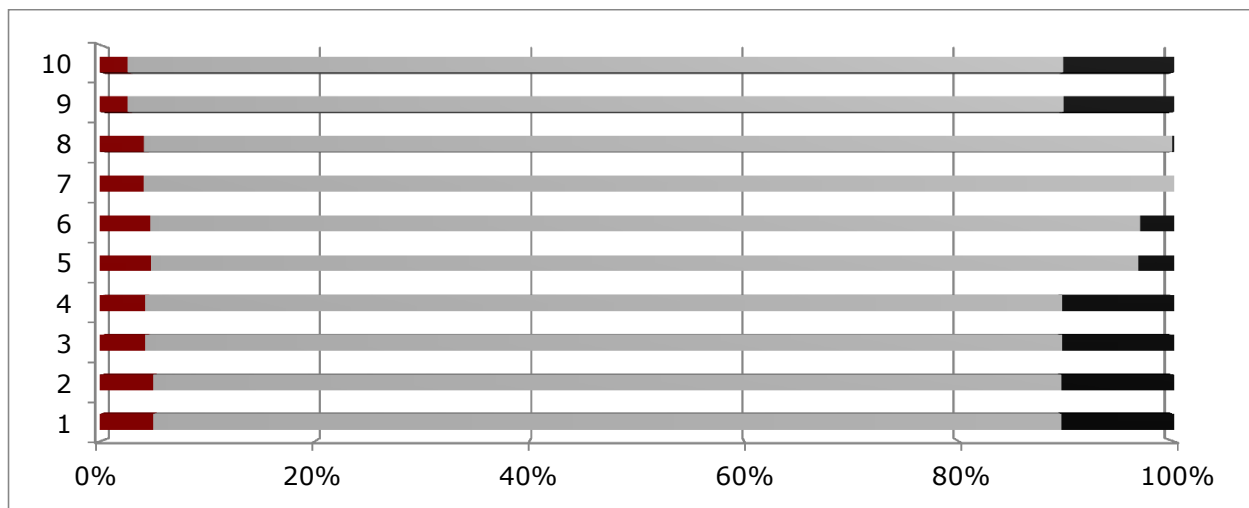


**Fig. 3.** Optimal portfolios composition

	High	Medium	Low
<b>Return</b>	2,5221	2,6358	3,2552
<b>Risk</b>	0,5031	0,2805	0,1317
<b>Sharpe</b>	5,008	9,289	24,576

**Tab. 3.** Returns, risks and Sharpe Index for optimal portfolios in the different cost scenarios

In the first step of the analysis the cost was the same for the different renewable sources. This is a simplified approach that do not consider several phenomena such as the technological evolution of the sector, the number of firms in the market, the different levels of incentives and the development of the sector. So simply evaluate the quality of an investment only based on the three standard scenarios previously proposed is insufficient. So it is necessary to consider a larger number of possible combinations of the activities so far considered, in order to enclose all the opportunities in the Italian renewable electricity sector. For this reason the second step of the analysis starts by the creation of the 6,561 possible combinations of activities with their returns and risks. Each combination contains four activities, each belonging to a different technology (Biomass, Hydropower, Photovoltaic or Wind). Each source can vary among three power classes (Poor, Average, High) with different cost scenarios (High, Medium, Low Cost). In this way we get exactly 9<sup>4</sup> combinations where the mix of RES depends from the size of the installed system and/or the different market cost scenario. Once all the possible activity combination have been obtained we can proceed with the construction of optimal portfolios with the best Sharpe Index and individuate the weights of the activities associated with each of them. Only 12 portfolios assumed negative returns; for this reason these portfolios are excluded from the analysis so based on 6,549 combinations. The returns of portfolios ranging from a minimum of 0.117 €/W to a maximum of 4.039 €/W while the standard deviations moving in a range between 0.1326 and 2.94 €/W. The Sharpe index allows to combine the above parameters by providing a measure of the sustainability of the investment. The 10 portfolios that provide excellent profitability and low volatility marks the highest Sharpe Index values as shown in Figure 4. It can be observed in fact a predominance of hydro technology in all 10 portfolios with weights ranging from 84,5% to 95,9%. A modest share is left to wind technology that is present in eight of the ten optimal portfolios (in the eighth portfolio assumes a value of only 0.17%), but only six of them exceed 10%. Still less is the presence of biomass that, despite being an integral part of all 10 mix, never exceed 5%, with a minimum of 2.6% in the ninth and tenth portfolio. Absent is the photovoltaic technology except for the sixth portfolio with a very low share (0.0042%). In order to justify the obtained results it is necessary to evaluate the cost scenarios related to the sources constituting the portfolios and at the same time the size of the systems installed (table 4). RES belonging to optimal portfolios have been selected in the Low cost scenario with some exceptions for biomass (the last two optimal portfolios) and wind (four portfolios). Moreover, considering the capacity of the installed power, the general trend shows the total absence of installations of large dimensions in favor of smaller sizes between 10 and 1000 kW. The composition of ten selected portfolios maximizing the Sharpe Index represent a range of investments proposals able to consider financial sustainability. For example, the first portfolio selects the more profitable renewable sources; infact the 100 kW hydro plant presents return-risk values extremely positive in the low cost scenario, respectively 3.11 and 0.14 €/W. The effect of diversification allows to involve in the portfolio composition the returns and risks of the other two sources: biomass plant with a capacity of 1 MW and wind with a power of 100 kW both belonging to the Low cost scenario. With the application of the theory of Markowitz and therefore the determination of the weights to be assigned to the sources involved, it is possible to select a portfolio assuming a couple return-risk of 3.259 and 0.133 €/W with a Sharpe index of 2.3 points higher than that recorded by the only hydro source.



	1	2	3	4	5	6	7	8	9	10
<b>Biomass</b>	4,98%	4,98%	4,25%	4,25%	4,78%	4,70%	4,13%	4,14%	2,61%	2,61%
<b>Hydro</b>	84,54%	84,54%	85,30%	85,30%	91,90%	92,14%	95,87%	95,69%	87,08%	87,07%
<b>Photovoltaic</b>	0%	0%	0%	0%	0%	0,004%	0%	0%	0%	0%
<b>Wind</b>	10,48%	10,48%	10,45%	10,45%	3,32%	3,15%	0%	0,17%	10,31%	10,33%
<b>Sharpe Hindex</b>	24,58	24,58	24,28	24,28	23,84	23,83	23,69	23,68	23,65	23,65

**Fig. 4.** Weights of portfolios with high performance

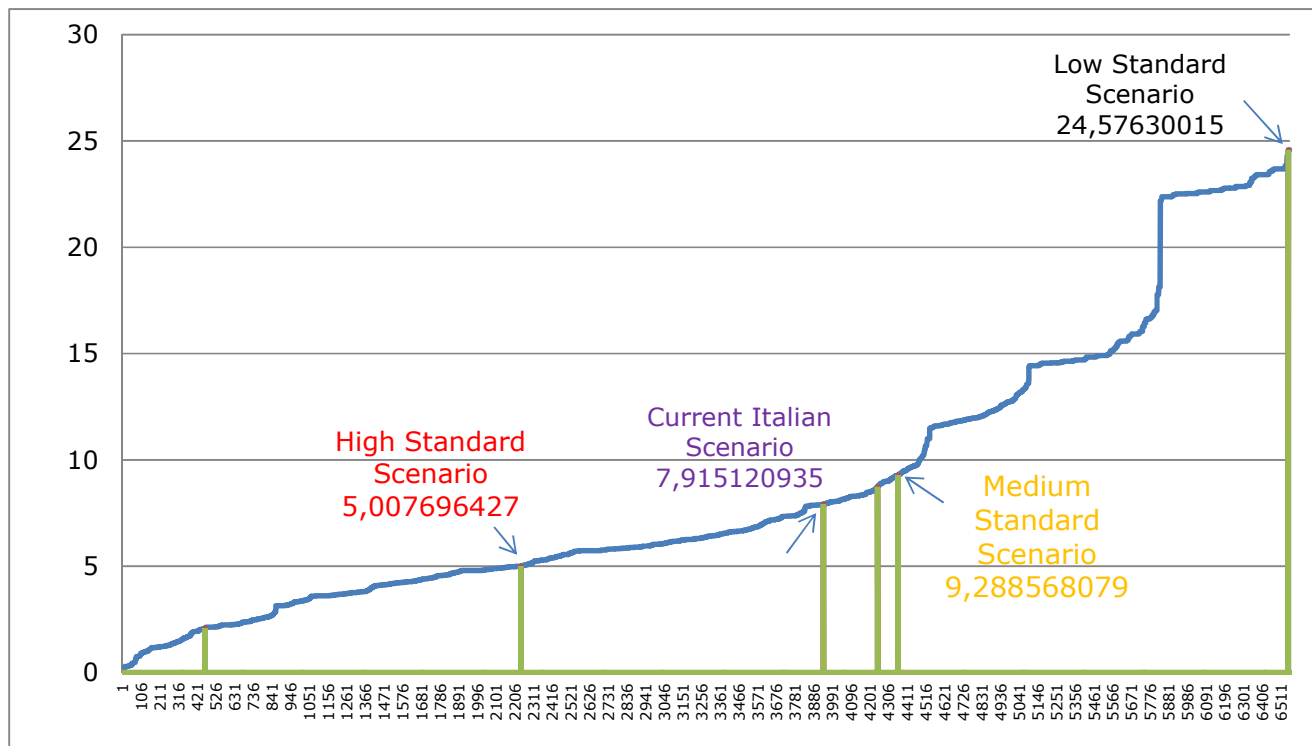
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
<b>Biomass</b>	L 1000	L 1000	L 100	L 100	L 1000	L 1000	L 1000	L 1000	M 1000	M 1000
<b>Hydro</b>	L 100	L 100	L 100	L 100	L 100	L 100	L 100	L 100	L 100	L 100
<b>Photovoltaic</b>						L 100				
<b>Wind</b>	L 100	L 100	L 100	L 100	M 100	M 100	H 10	H 100	L 100	L 100

**Tab.4.** Cost Scenario and power of the ten portfolios with high performance  
[Cost Scenario (L – Low, M – Medium, H – High) and Power (kW)]

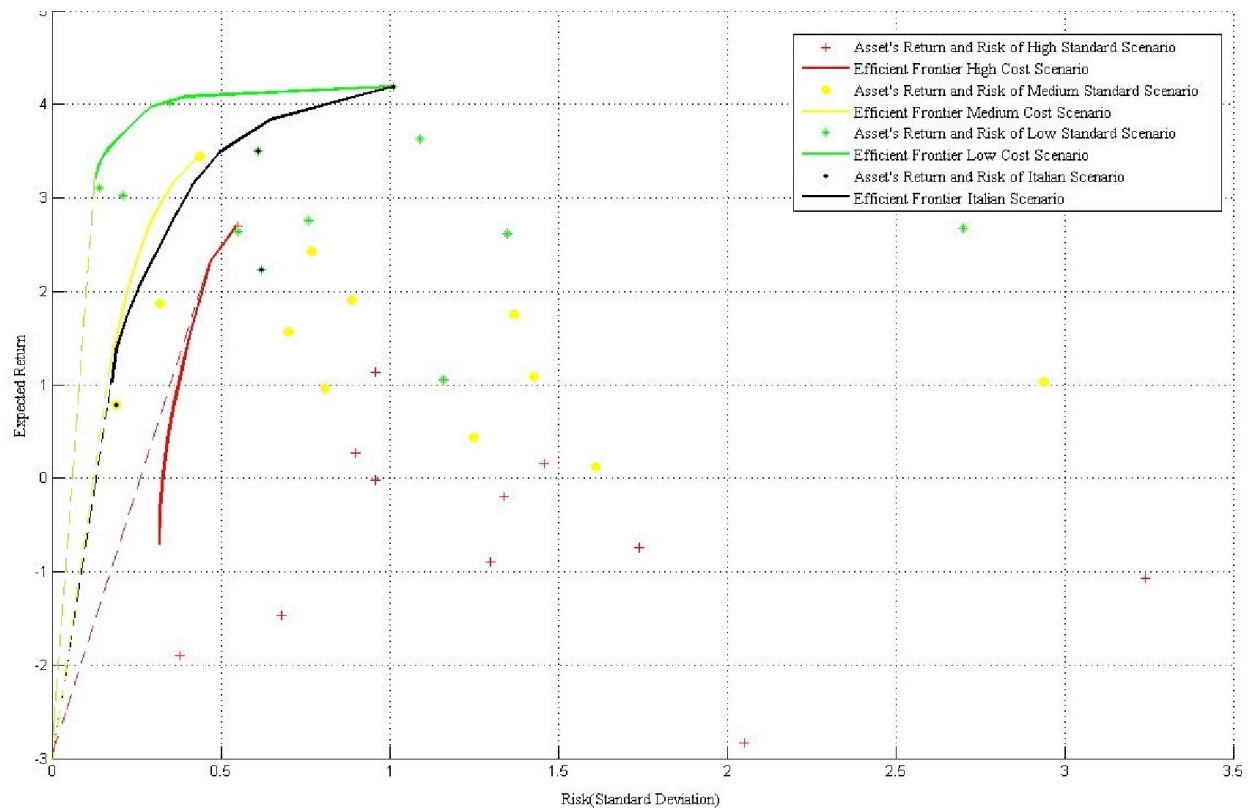
#### 4. The Italian Renewable Market

This section presents the current situation of the Italian electricity market. By observing Figure 5, we can see how the real energy portfolio located on the Italian territory presents a value of the Sharpe Index (7.92) between the corresponding values obtained for optimal portfolio with scenario Medium (9.29) and High (5.01) cost. This is due to the strong weight of hydro technology in the Italian energy mix. The difference among the examined cost scenarios are even more evident looking at the efficient frontiers (see Figure 6).





**Fig. 5.** Sharpe Index for the Italian Renewable market



**Fig. 6.** Efficient Frontiers



As can be expected, the curve representing the efficient frontier of the scenario Low is located in upper-left side of the plan, confirming the profitability of efficient portfolios that are in that scenario (high return and low volatility). The Capital Allocation Line (dashed line), tangent to the efficient frontier, allows the identification for each cost scenario of the three optimal portfolios and provides, being the portfolio without risk-free assets, an estimate of the associated Sharpe Index (the slope of the CAL). Moreover, the slope of the dashed lines shows the upward trend of the Sharpe Index from High scenario to Low scenario. Finally, as expected, the efficient frontier related to Italian market is among those associated with Medium and High Cost scenarios; it shares with the efficient frontier related with the Low Cost scenario only portfolios with high efficiency and high volatility that not guarantee an efficient Sharpe Index.

## 5. Conclusions

The development of cleaner energy sources is a central policy of national government for addressing alarming climatic tasks. However the investment in renewables are becoming increasingly risky due to the dependence on uncertainties of energy market. At the same time, these investments are necessary to reach the aims of environment protection plans (Cucchiella *et al.*, 2013, 2014 and 2015). Using a portfolio approach, it is possible to define and diversify the renewable energy production optimizing the economic and environmental performances (Kienzle *et al.*, 2007; Allan *et al.*, 2011). The realization of an optimal portfolio of RES, in the Italian electricity sector, is significantly influenced by the level of costs registered on the real market. The results show that the worst renewable mix is that consisting primarily of large systems, in medium and high cost scenarios, which are usually associated with good returns but at the same time a large margin of risk that does not allow to reach considerable values of Sharpe Index. On the other hand the choice of installing small power systems seems more interesting and sustainable, especially investing in mature technology like hydro and wind.

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