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Renewable energies And Energy saving Scenarios and Opportunities

con il patrocinio di

Fondazione Silvio Tronchetti Provera

MINISTERO DELL'AMBIENTE E DELLA TUTELA DEL TERRITORIO E DEL MARE

Rubbettino

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Preface

When more than a year ago we decided to create, together with the Agency for innovation technology and the support of Luigi Bocconi Milan University, Politecnico di Milano and the Milan-Bicocca University, an observatory on renewable energies and mini energies, we thought that such an issue would have a growing interest. Now, after Fukushima and the results of the nuclear referendum, this interest has grown even further.

The collaboration with the Agency for innovation reflects the effort since long carried on by the Foundation, dedicated to my father, in supporting research in the economics, science, technology and management fields, with particular attention to the training and specialization of skilled young people.

There is no future without research; there is no development without new technologies; all the most advanced societies have put research and products at the center of their development.

Research is even more fundamental in the energy industry, as a great innovative effort has to be powered if traditional energy sources want to be substituted, within a reasonable time, by renewable sources.

Bringing the solution to the energy problem nearer, means affecting life's quality and protecting future generations.

In our Country in this respect a lot is said and too little is done; the countries that today have a competitive advantage are those that have made a systematic effort, those that have defined a sustainable energy planning with a close collaboration between political institutions and the industrial world and that are implementing it . This book wants to be a contribution in this sense.

Marco Tronchetti Provera

President

Silvio Tronchetti Provera Foundation

Foreword

By Davide Giacalone

The Italian debate on the Energy issue, that we consume and that we should produce instead, predicts a reasonable disposition to fundamentalism. It is about an issue that deserves detachedness and not a great deal of attention to numbers. It should deserve, furthermore, to be read not only under a profile of complexities, but also under one of opportunities.

A new national energy plan should be presented by the end of the year. This has been awaited for, since twenty years and it shouldn't be excluded that drafters will be struck, in the hope that one day it will see the light, also to help one and others to speak about real issues and not ideals.

Contribution of renewable sources was 5.7% of the energy consumed in 1999 and it is only 9.5% in 2009. The European average (at 27%) is, respectively, of 5.4% and 9%. We are slightly above average, therefore, but this should not comfort us, as almost all the other countries integrate their production with sources that have been abandoned by us (I won't say the name to avoid radioactive effects).

In the meantime the new is discussed and the old progresses. The cost of imported oil, calculated on the GDP, is of 1.8% in 2010 and it was of 1.3% the year before. We have to keep in account obviously both the price and the GDP trend in the same way as we shouldn't forget that it was 4.6% at the beginning of the '80s. It is a fact that oil remains the first energy cost, covering 52% in 2010, while it arrived up to 48% the previous year. We buy oil in the same way as we buy gas and the total cost to buy energy sources (and energy directly) abroad amounts to 54 billion, against 42.4 in 2009, with a growth of 27%.

Ours, whichever way we look at it, is a condition of weakness. What safeguards our economic and political safety is diversification. This applies for technologies in the same way as for Countries from where we import. Italy's political class might lose most of Its control without a proper diversification, but not by a virtuous donation in favor of supranational organizations.

It is not enough, therefore, to have increased the energy share produced with gas, we need not to depend exclusively on what we import with pipelines.

The building of re-gasification terminals is needed to raise the number of potential suppliers, decreasing the political weight of each of these.

The production share from renewable sources can grow significantly. The field in which we should put our efforts is not only that of production, but also that of technology that makes it possible. There are different opinions on the importance that these sources will have in the future of energy, but what is certain is that it's an interesting growing market in which we can't limit ourselves to being spectators and consumers. We have to produce it, obviously, but we have to produce what needs to be produced. The global market has penalized us in the race for production cost restraints, but only we can penalize ourselves for giving up racing on a ground where we should excel: innovation, quality, safety to have a leading role in the global market, for offer and not only demand.

As far as concerns about contributions for the production from renewable sources we have to look out that they don't become disincentives for the more serious investors. To produce a megawatt (MW) of electricity from fossil sources has a cost that depends on market trends, last year it was approximately about 50 euro. To this direct cost, an indirect pollution of CO_2 cost has to be added. It's an external diseconomy that should weigh on who pollutes, while the benefit should go to who produces energy without polluting. "Green certifications" testify this diseconomy. The value of these certifications depends on real taxation on polluters: if many are exempt from such a cost, to avoid that polluting companies become non competitive, the value of these certifications is low. If we make all polluters pay, the value of these certifications increases by far because they are a scarce good. Let's say that an abstract fair value could be of 20-30 euro per MW.

Therefore renewable energy produced at a cost of 75-80 euro per MW is already competitive and considering that, differently from the fossil one, it doesn't depend on uncertain imports and doesn't risk incurring in out of control in rises the future, up to 100 euro per MW renewable sources have a good sense in economic terms. Beyond this level, production is artificially subsidized.

Eolic fares, in Europe, are fixed between 65 and 100 euro per MW and are reasonable in a market logistic. Italy is an exception, where the eolic fare until last year arrived up to 180 euro per MW, but differently from the other countries, this fare is not linked to the inflation index and it is not guaranteed for 15 or 20 years. This being the reason that who invests in Italy in eolic is doing real good business at the moment, but with the risk of losing a fortune it in the future, which doesn't help to select the best.

There is also a neglected or not fully read chapter: that on energy saving. It would be worth calling it in a different way, entitling it in the name of efficiency. It's not only about our mothers' good advices to avoid waste, but in the way in which we conceive and invest in energy consumption. This concerns not only the way in which we build our cities, but also how we live in our houses. I repeat, it's not only about common sense, unknown to those who abuse of heating in Winter and air conditioning in Summer, but also about the business model to which inspires the energy market. Today, for example, the drive of who sells energy is addressed to regulating a private contract based on consumption peaks. A housewife in Voghera and a lawyer in Milan notice that the electricity meter switches off and they deduce that they have too little energy supplies. If energy consumption would be regulated in a way that avoids energy peaks due to cumulus which could be deferred in time, those same people would have contracts at lower and more balanced prices.

If plugs would be e intelligent so that refrigerators and washing machines could work in alternation: while one is on the other is off, we would have created a saving system in the name of efficiency and not poverty. We would continue having all the modern benefits but limiting wastes. The most important thing is that by reasoning in this way, we would be cultivating a very rich ground on which fruits of great economic interest would grow and at the same time it would be hungry for technology and innovation. From home automation to digital healthcare there are entire worlds that travel in search of new ways to conciliate safety, efficiency and wealth. For us Italians these are opportunities. We have what it takes to play an important role, if not leading. Even because quality of life and environmental respect despite our not few superficialities are homologous and coherent with the made in Italy. All this can be done harmonizing the goals of an energy plan with incentives for what can be produced and exported, putting an end to energy masochism.

Introduction

By Lucio Pinto

The new European energy policy, that tends to the development of energies from renewable sources and to the subsequent reduction of the green house effect, places our Country in the position of reducing dependence from fossil fuel energies, which we are lacking.

Nevertheless, at the moment, renewable sources aren't yet competitive and therefore, to speed up the availability of innovative solutions, technological evolution and incentive tools take on great importance.

This book relates these issues in depth and takes inspiration from the conference held in Milan June 20 2012 in Pirelli's auditorium, titled "Renewable Energies and Energy Efficiency, Scenarios and Opportunities". This conference was organized by the Agency of technological innovation and the Silvio Tronchetti Provera Foundation. The Agency and The Silvio Tronchetti Foundation are side by side in promoting initiatives for technological transfer , for enhancing the competitive ability of small and medium enterprises and industrial districts, by widening the horizons towards new technologies and their respective industrial applications.

The agreement between the Agency and the Foundation contemplates important synergies both in the fields of high managerial training activities and in the enhancement of public research. This collaboration in particular, allows to share the promotion and organization of events, conventions and seminars on one side and postgraduate courses and training activities on the other.

Of significant importance was the activity of the "Observatory for Renewable Energies" carried out in collaboration with the Bocconi University, the Milan Politecnico and the University of Milan-Bicocca has been of particular relevance. From this, the book takes its various contents.

The observatory came to life to create a point of reference on the conditions of renewable energies in our Country and to give a starting point to consider these new technologies as areas in which to invest in research.

To give an example of the need, Italy is the second European Country in terms of installed gigawatts in fotovoltaic, whereas all standard technologies are developed outside our Country.

So broadening the mind towards these new technologies is essential to then generate innovative companies with innovative products.

In this book the most essential technologies in the area of renewables are dealt with: the part of fotovoltaic and biomasses is carried out by Vittorio Chiesa, Professor at the Politecnico of Milan where he is Strategy and Organizational Research lecturer and Director of the Energy and Strategy Group; the part on eolic, the minieolic and solar thermodynamic is carried out by Francesco Strassoldo, who has a long industrial experience in multinational energetic companies; the hydroelectric and the mini hydro is carried out by Giancarlo Giudici, associate Professor of the Milan Politecnico. Massimo Beccarello, Professor of the Business School at the University of Milan-Bicocca, Responsible for the energy field in the Confindustria, took care of the part on Energy Saving; and lastly Claudio Ferrari – President of FEDERESCO Italy – develops the issue on Strategic tools for the development of the energy efficiency field. Attached you will find a disclosure of Clara Poletti, former Director of IEFE, the center of studies on energy and environment at Bocconi University, on Global Energy Scenarios.

1. The Photovoltaic

By Vittorio Chiesa

1.1 Photovoltaic in Europe and in the World

The Photovoltaic as a whole, reached in 2010 about 38.4 GW of installed power, 39%of which (about 14.9 GW) were installed in that same year: 2010. The progress of the photovoltaic market is even more impressive if we consider that Europe has exceeded the threshold of 25.5 GW as a total installed power at the end of 2010, of which the majority were installed in that current year (12 GW, equal to 47% of the total). In spite of the economic crisis, therefore, the growth rate of the European photovoltaic has been of a “three digit” figure (+103% if we examine the installed power in 2010 in respect to 2009 in Europe, +93% if we consider the same data at a worldwide level).

Europe, as a whole, remains without any doubt the geographical area *leader* for its photovoltaic installments, accounting for about 67% of the total installed built up worldwide and for 80% of new plants which started operating in 2010. The data regarding the 2010 growth of installments reported before, are more over a sign that this *leadership* didn’t undergo standstills, and in fact got stronger in the course of the last year.

Signs of growth of the other geographical areas though must not be underestimated. Japan – at the third place in the classification by Country – has more than doubled (from 480 MW to about 1 GW) photovoltaic plant installments in the course of 2010. The USA has pulled off a sign of a slightly inferior growth (+95%), but have finally widened their base for installations: not anymore only in California (that is anyway still responsible alone for 30% of the total of the new installations in 2010), but also to other States , for instance to New Jersey (167 MW in 2010, against 57 in 2009) or in Nevada (61 MW against 3 MW).

Countries	**Power 2010 (MW)**	**Power 2009 (MW)**	**Cumulated Power 2010 (MW)**
Germany	7.250	3.800	17.150
Spain	100	80	3.700
Japan	1.000	480	3.650
Italy	2.100 (6.050*)	720	3.276 (7.226)
USA	880	450	2.560

Czech Republic	1.360	470	2.400
France	720	200	1.025
Europe	11.950 (15.900*)	5.900	25.650 (29.600*)
World	14.850 (18.800*)	7.700	38.350 (42.300*)

* values including installation following the "Salva Alcoa" Decree

Table 1.1 – Annual power installed in the main Countries in the World

We have to underline Spain's decline that, although holding "nominally" the second place in the world ranking by Country, has installed in the last two years less than 200 MW. This is an example, in a negative way, of a too "sudden" change of course in the incentive policy, with the introduction of a too low "roof" for installments and significant cuts in the incentive rates, that in only two years' time have substantially set to zero the growth perspectives and development in a market that until 2008 was considered to be amongst the most promising in the world. Germany, despite a drop of 10% in the average rates in the course of 2010, has installed new plants for a power of around 7.3 GW (+91% compared to 2009) has brought the cumulus to overcome 17 GW (over 45% of the world's total).

The main innovations in 2010 at a European level are ascribed to France and the Czech Republic. In the first case what was installed in the course of 2010 has overcome the rate of 750 MW, a growth of 300% in respect to the previous year. For the Czech Republic – where in fact the market is in part largely made up of small and medium plants (4.2 MW is the size of the largest plant achieved in 2010) – the 2010 installed is of 1.360 MW (against 470 MW in 2009), a goal that has almost enabled to reach the USA as far as concerns power installed overall.

The appearance of new European Countries such as Greece that, after only 59 MW achieved in 2009, installed in 2010 about 150 MW bringing to over 200 MW the total installed, or (broadening the horizon to the Mediterranean) Israel and Turkey, "strong" of the introduction of a new incentive system in the course of 2010.

1.1 Photovoltaic in Italy

The trend of new installments and of the total photovoltaic power cumulated starting from 2007 (or rather from the "genesis" of the Italian photovoltaic market) up to today, is reported in figure 1.1. The progress we have seen is impressive. If we look at the new installments, year after year growth has been that of +382% in 2008, +112% in 2009 and +192% (or +743%, if we consider also the dotted area) in 2010, with a market therefore that has more than doubled each year in respect to the value registered in the previous period.

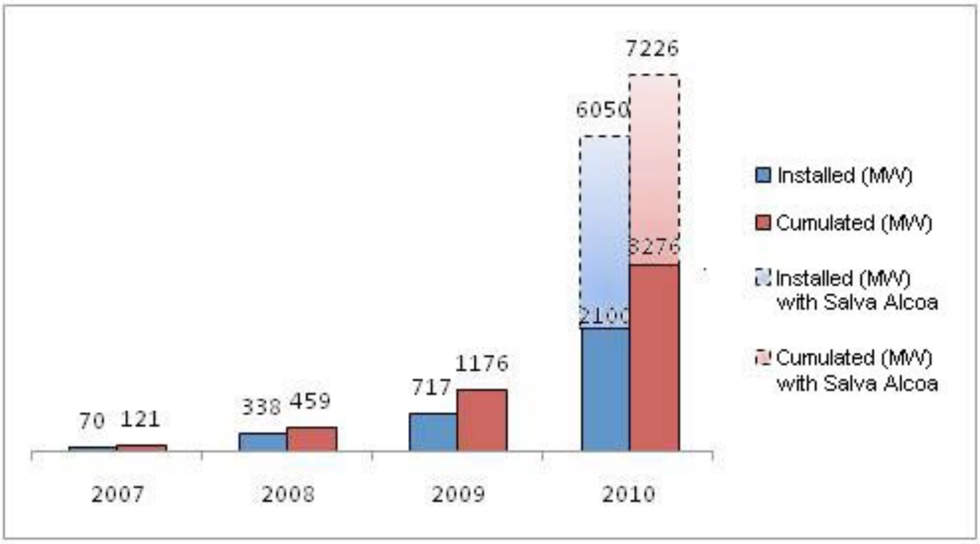

Figure 1.1 Annual and cumulated power installed in Italy from 2007 to 2010

During 2010 about 138.900 new plants started operating, with a total power of 2,1 GW, and another 3.95 GW of almost 55.000 “finished” plants by December 31st 2010, are waiting to be installed by June 2011.

The total power installed in the approximate 210.000 working plants at the end of 2010 was equal to 3.276 MW, over 64 times the value registered in Italy in 2007, before the entry into force of the “New Energy Bill”. The multiplier goes up above 140 times if we take into consideration also the ready plants and the ones that are awaiting to be connected to the network. There is a possibility that a certain number of these plants (15-20% according to GSE estimates) will never be actually connected to the network. This variability in numbers, nevertheless, doesn’t modify the considerations and the “importance” of the photovoltaic phenomena in Italy.

Figure 1.2 shows the market’s photovoltaic segment in Italy from 2007 up to today. Also in this case the contribution of the “Salva Alcoa” Decree was isolated.

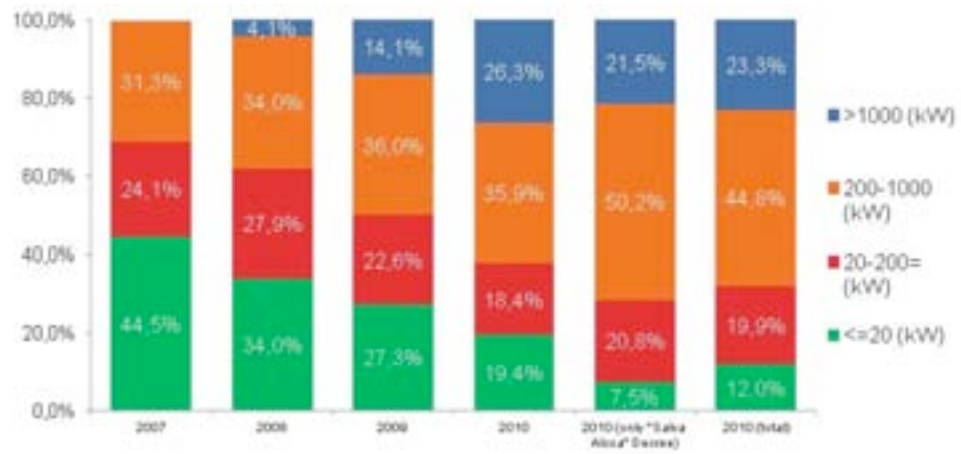

Figure 1.2 – Segmentation of cumulated and installed power in Italy

In particular:

- Residential plants (1-20 kW) have more than halved their "weight", passing from 44.5% of "007 to 19.4% in 2010. Although the absolute value (over 407 MW against 28 MW in 2007) has grown and even significantly, in relative terms, small plants have really left place to more consistent sizes. The typical customer for these plants has definitely evolved, both in terms of technological knowledge and in terms of alternatives available for the achievement, and mainly in terms of "contractual power" in regards to the installers;
- also the segment of 20 to 200 KW has shown a drop, less significant than the previous one, in the overall "weight" of the Italian market, going from 24.1% in 2007 to 18.4% (corresponding to 426 MW) in 2010. Many times, although the attempt has been made - even at a normative level thanks to the grant of January 1st 2009 (unique in its kind in respect to other European countries) to admit under the so called "scambio sul posto" regime of all energy plants up to 200 KW – to push development in this market segment, the Italian market has not proven sufficiently "mature" for this type of installment, that instead well suits the ideal of a distributed generation of energy, allowing to directly balance electricity consumptions there where they are mostly concentrated. It is to be noted that in the course of 2010 the increment in this market segment of the role of public administrations, that have been able to seize the opportunity (both financial and mainly of image) and have invested in photovoltaic plants to satisfy the electricity demand of municipal sport centers, schools and other public buildings.
- there was instead an increase from 31.3% to 35.9% of "big plants", so to speak those from 200 KW up to 1 MW. Although it is mostly made up of "ground plants" (the medium size recorded in 2010 is of 670 KW) that haven't received incentive fares equally enticing in respect to the

previous ones, this market segment earned since 2009 the *leadership* for percentage of installed power;

- the segment concerning the plants (plants with sizes higher than 1 MW), that practically didn't exist in 2007, has instead registered an "exponential" growth, reaching 26.3% of the total installed in Italy in 2010 and almost doubling the share (14.1%) of 2009. If until 2009 they were only exclusively investment funds or (but in few cases) *utility* the actors to ask for the installment of photovoltaic plants, during 2010 the importance of private customers grew. We are speaking of local entrepreneurs and wealthy families who use the photovoltaic plant as a purely financial investment, thanks to good revenues at low risk that allow to obtain gains (mainly in a period of economic crisis such as the one we are going through now). The investment funds, especially English and Israeli ones (but with some Italian exceptions) have taken on a behavior in the course of 2010 that operators judge as more "aggressive", with tighter timelines for the *due diligence* (that force the *EPC Contracter* to a harder preliminary planning job) and price policies that aim to maximize yields. It can even happen that "less enlightened" foreign investment funds overshadow the qualitative aspect of the plant, focalizing only on revenues in the first 4-5 years of life. Lastly, during 2010, there have also been cases of "plants" built on roofs of warehouses and commercial or industrial buildings. For example, in Padua, at the Intermodal -Magazzini Generali -, Solon built a photovoltaic plant of 15 MW on a total surface equal to 250.000 m^2, corresponding to all of the roofs of the Intermodal and to the shelters that are used in the car park.

  If a market "disturbance" is introduced following the approval of the "Salva Alcoa" Decree, the frame changes furthermore, even though not in a significant way. The industrial plant segment is the one that benefits most in relative terms, going from 35.9% to 44.8% of the total in 2010. The phenomena can be explained in two ways: (i) on one side, the "Salva Alcoa" Decree has accelerated the installments of those industrial plants of which the process of evaluation on behalf of possible customers was put on hold in order to understand what would happen in 2011 and that instead tried to take advantage of the unexpected "window" provided by the Government; (ii) on the other side, those bigger plants with finishing timelines (mainly for connection problems to medium and high tension networks) that would have gone beyond December 31st 2010 have been "downsized", and in respect to which was privileged an anticipated closing of the works to be able to exploit even more the New Energy Account fares.

1.3 The Italian photovoltaic chain

1.3.1 Turnover and margins

The high "uncertainty", introduced by the so called "Salva Alcoa" Decree, makes the real turnover in Italy in 2010 generated by the photovoltaic difficult to be estimated.

In 2010, the photovoltaic in Italy generated a turnover between 7.6 billion euro (lower bound) and 21.5 billion euro (upper bound). The photovoltaic field in Italy grew in 2010 of about 162% in respect to 2.9 billion euro in 2009 (or, actually, of seven times more if the upper bound is considered).

Figure 1.3 – Main business areas in Photovoltaic value chain and 2010 business values (the data with asterisk refer to the estimates "Salva Alcoa" included)

The registered analysis of the turnover in the different market segments (figure 1.3) offers some elements of observation:

- the residential segment, that of plants up to 20KW, recorded a doubling in respect to 2009, reaching in the whole 1.95 billion euro, that would become even 3.45 billion euro if all the requested plants by December 31st 2010 had been built. The growth in this segment is without any doubt a positive sign, as it is quite unlikely to think of any speculative phenomena here, and also the end of the year acceleration was largely due to a commercial action aimed to small installers, present and active on the territory and determined to take advantage of photovoltaic as a "flywheel" to come out of the crisis;

- the industrial segment, that of plants of size between 20 and 200 KW used - in the mode of self-consumption – by small and medium industrial and commercial realities, have marked a relatively more limited growth, with 1.47 billion euro (+160%) of turnover, in respect to the 562 billion euro of 2009. But if the plants whose connection is under the "Salva Alcoa" Decree are considered, then 4.56 billion euro are reached, with a leap of more than 3 billion euro;
- the big plant segment, that of photovoltaic installments of sizes between 200 and 1.000 KW, in the course of 2010 has seen connected to the network a counter-value of 2.6 billion euro, almost four times in respect to the same data in 2009. The plants that have applied within the "Salva Alcoa" Decree by December 31st 2010 and those which are attending an approval could however make the overall turnover in this segment leap to about 9.4 billion euro. It is without any doubt the most significant difference in terms of value registered in this field and it's symptomatic also in the will to exploit as a primarily financial investment the opportunity offered by the Italian system of incenting. In a speculating way of speaking, in respect to the residential it is appropriate to say that it is exactly this segment, together with the following one, the one in which Italian businesses that produce cells and modules, that operates the most, namely that supports the National production of the key components of photovoltaic plants;
- the plant segment, lastly, reached third place in the course of 2010 in this particular ranking with a counter-value of 1.6 billion euro (and an upper bound that comes close to 4 billion euro). So 2010 has been for Italy, the year of great photovoltaic plants and it has clearly catalyzed attention also of funds and investors interested in the possibility of a financial return more than to the characterization of "renewable" energy produced. Also in this case however, it must be mentioned how the plant segment is that with the lowest cost per KW in the industry and in fact the one that has experienced the most significant drop (over 9%) in respect to 2009.

With regards to the distribution of turnover along the different phases of the chain (figure 1.3) one can observe what follows.

Silica and wafer producers, in reference to the Italian market, have generated a turnover equal to 1.4 billion euro, in growth of 37% in respect to the precedent year 2009. If we consider also plants waiting for connection such a value goes up to 4.7 billion euro. If we associate this with the fact that in the course of 2010 the average price of silica has dropped by approximately 4-5% (following a rise in the first months of 2010) we obtain an increase of the turnover that – in real value and keeping into account the upper bound of installations – reaches even 240%. Cell and modules producers have marked, for their part, a turnover increase of 125% in respect to 2009, settling at approximately 3.2 billion euro, that goes up to over 9.3 billion euro if we also consider plants not yet connected, but whose works have been completed by the end of 2010. The fall of the average price of modules, equal to 13% in the course of 2010, has also in this case influenced the final result, that in any case well represents the extraordinary growth experienced by the Italian market. Overall, the increase recorded by these two segments was about equal to 120% in respect to 2009, up to a maximum of 300%. In respect to the early stages in the chain, tensions in prices have been less obvious for these components and in the case of the inverter, just as with the modules, we have assisted to a temporary rise in prices in the Summer months (in particular in June and July), for a peak of partially unsatisfied demand due to the absence of a suitable production capacity. Distributors and installers, that is the last link prior to the final customer, complete the chain and "see" therefore a turnover equal to the total of the market.

- Moving to a few comments on margins, figure 1.4 shows three data (the "historical" figures of 2008 and those of 2009 and of 2010) accompanied by an indication about the variance in the observed results.

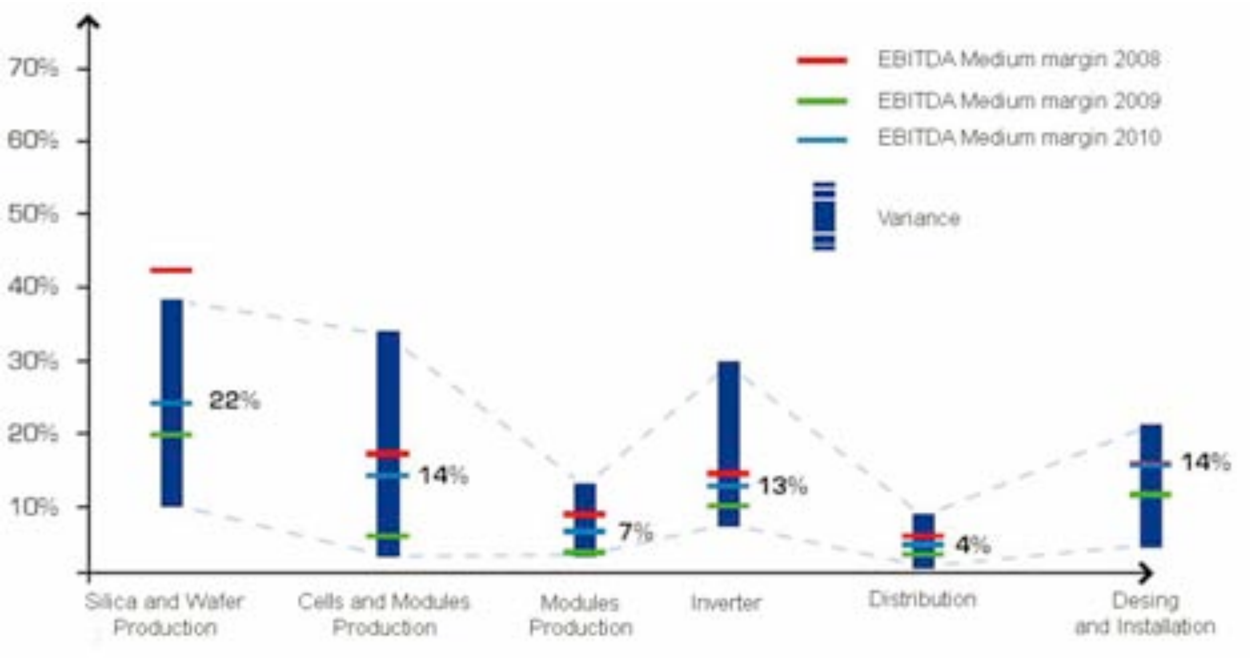

Figure 1.4 – EBITDA Average margin of operation companies in the different phases of the photovoltaic chain.

It is possible to underline two general trends:

- the increase in the course of 2010 of the average margins that in some cases, after a meaningful bending in 2009, went up to levels comparable to those of 2008. The drive to efficiency, that brought companies to invest mainly in the processes of innovation (not only at early stages but also in later ones, for example enhancing skills in *project management* or of the project of installments), and the *stretch* on the chain by an increasing level effect in Italian and foreign competitors, have added a "positive" effect on generating operating profitability. This notwithstanding the decrease that in the course of 2010 has affected prices of the various components and the "finished product" and the significant reduction of incentives provided for the production of photovoltaic energy. In other words it triggered a virtuous phenomena that, to the drop in incentive fares, a drop of prices and margins increase was followed;
- the reduction, mainly in the central phases of the chain, of the variance of the results between companies of the sample. If in the course of 2009 we assisted to a rise of the variance that drove to a reduction of the margins, 2010 marked a trend reversal. The consolidation of some phases of the chain – in particular production of cells and modules and distribution – and the assertion of some of a sort of standardization level in the productive processes has allowed companies, despite the explosion to the market's demand, to maintain their level of profitability *range* within the values. Nevertheless the two extremes of the chain, silica and wafer production and the activity of project and installment, remain extremely "in the air". Reasons for this are diametrically opposed. In the first case, variability is linked to the impact of competition mainly by Asian operators and of the consequent difficulties for some operators even "traditional" ones to saturate their productive capacity. Instead, in the second case , the difference is to be attributed to the characteristics of the market segment in which different companies operate, with relatively "richer" plants and residential plant.

1.3.2 The player of the Italian chain

Plants operating along the entire photovoltaic chain in Italy in 2010 were about 800. To these are added several thousands of local operators, that deal with the phase of plant installment in the residential and small commercial segment, and 430 banks and active credit institutions in plant financing. With respect to the previous year, growth, measured in the number of companies, was about 7%.

The photovoltaic chain evolution in the course of 2010 was also characterized by an increase in the attendance of Italian companies. It is evident that, although at a slow pace, Italian operators are conquering a more important role also in the earlier phases of the chain.

If we translate the "numeric" presence of Italian companies or at least those with head offices in Italy in an economic indicator, so to say in the share of total gross marginality generated by the field that stays in our Country, we discover it arrives near to 72%. If only Italian operators are considered the percentage drops to 42%, nevertheless marking an important increase in respect to the 2008 value (28%).

This data should make us think for a number of reasons. The first, linked to the dispute usually made on photovoltaic, so to say that of "financing" mostly the growth of foreign companies, is that, if silica production is left out (but in which industrial sector does Italy have basic raw materials?) the path undertaken by Italian operators is a virtuous one of development along the chain; the fact that it took time is linked to a "delay" with which we started off with, in respect to the other countries, that forced our companies to be "followers". The second, linked to the market trend, is that the margin share deemed by Italian companies is growing in terms of percentage just in the same moment in which "absolute" figures of installments are becoming important. The third, on a wider vision of the Italian industrial system, regards the impact of the ability to generate income and growth of employment in companies that operate in this field and have head quarters in our Country, in a general context where "traditional" sectors seem to be showing some signs of wearying. Total employment (that is of about 18.500 direct equivalent employees and that increases to 45.000 if we consider also the induced) is a relevant data for a sector that until 2005 counted only a few hundred employees.

1.3.2.1. Cells and modules business area

The Italian situation definitely deserves some study, also because the presence of Italian companies (43%) or that however have branches in Italy (30%) are very important in this *business* area. Among the foreign companies present in Italy, Solon, that has a production site in the province of Padua – with a capacity equal to 100 MW – and that represents the company with the most important module production in our Country thanks to its 70 annual MW stands out.

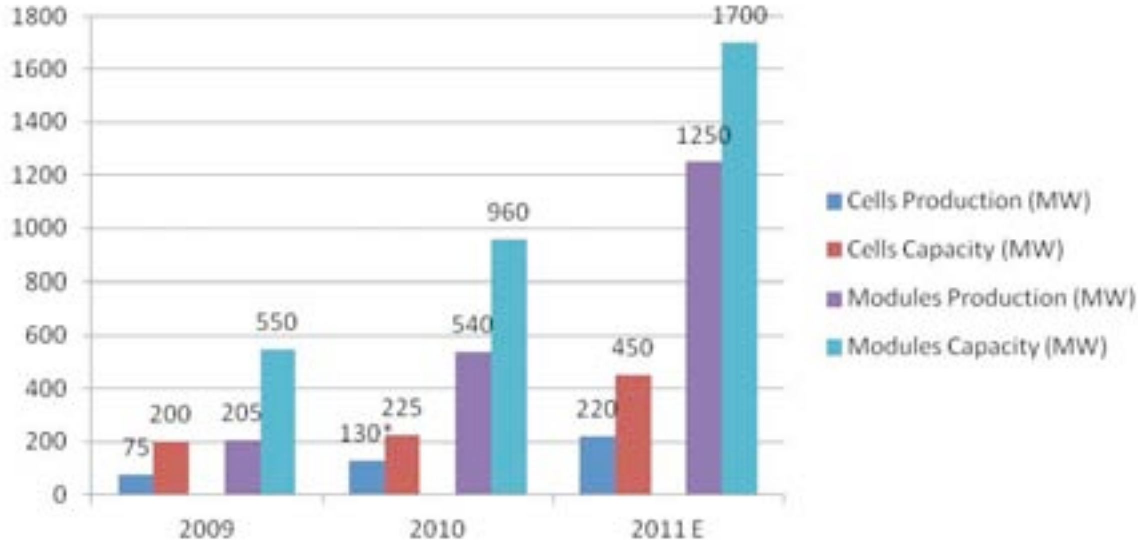

Figure 1.5 – Productive capacity and production of cells and modules in Italy in 2009 and 2010 and forecasted for 2011

Figure 1.5 shows that productive capacity of cells has grown by 12.5% in the course of 2010 reaching 225 MW, whilst production stopped at 130 MW (+70% in respect to 2009). As far as modules are concerned, the total capacity available reached 960 MW, (+ 75% in respect to 2009), saturated in average by values over 55% and peaks of 80-90% for the smaller operators, that found themselves to manage the "peaks" of the 2010 market.

It appears clearly that the productive capacity of cells represents a marginal fraction at a global level (approximately of 0.85%) and has growth rates definitely "lower" in respect to the *trend* registered at a worldwide level (+47% in 2010). The saturation level grew sensibly during 2010 and is in line with the average values (55-60%) reached at a worldwide level, but levels of production are very far from the final installed in Italy (110 MW, against 2.1 GW or &.05 GW, if we consider the effect of the "Salva Alcoa" Decree, of photovoltaic plants installed in 2010). It has to be further more underlined that we assist to a concentration of operators towards "traditional" silica (mono and poly-crystalline), that is in that arena where the European ones are in more difficulty in respect to Asian competition. An interesting case, in this respect, which inter alia puts three industrial realities together (two of which Italian) of absolute relief like Enel, STMicroelectronics and Sharp, is represented by the 3Sun project for the construction in Catania of a plant for the production of thin-film modules of 160 MW. The trend observed in regards to modules is instead definitely more encouraging and mainly it proves how a non marginal share of the Italian market (around 25% if the lower limit of installments is considered) could be served by companies born in Italy in the last few years. Notwithstanding that the rhythm of the growth of the productive capacities of modules is superior to that of cells –and this represents an exception to what has been measured at a global level – it seems that even in Italy the business model of "integrated" producer is emerging, that is seen as "dominating" on the international scene. The main Italian producers, in fact, have among their activities both cell and module production, even if the ratio among capacities (except for the Helios Technology and EniPower case) is anyway unbalanced in favor of the latter.

The main Italian integrated producers of cells and modules and the main module suppliers are presented in tables 1.2 and 1.3.

Company	Manufacturing capability 2009 (MW)	Manufacturing capability 2010 (MW)	Production 2010 (MW)	Revenues2010 (mln €)
Solsonica	25 cells 50 modules	35 cells 70 modules	35 cells 64 modules	100
Helios Technology	60 cells 55 modules	60 cells 55 modules	n.d.	61
X-Group	90 cells 30 modules	90 cells 55 modules	55 cells 45.modules	57
EniPower	30 cells 30 modules	30 cells 30 modules	1 cells 10 modules	6,5

Table 1.2 – The main integrated Italian producers

Company	Production capacity2009 (MW)	Production capacity 2010 (MW)	Production 2010 (MW)	Revenues 2010 (mln €)
MX Group	60	90	48	83
Solarday	60	90	42	73
Renergies (Gruppo Afin)	30	40	37	60
Brandoni Solare	20	40	28	43
Vipiemme Solar	20	25	21	32
El.Ital	10	40	20	25

Table 1.3 – The main Italian module suppliers

1.3.2.2 Business area of distribution and installation

The *business* area of Distribution and Installation is no doubt one of the most "urged" by the great growth that the Italian market has experienced in the course of 2010 and it is also the one where the presence of Italian companies prevails. Reality appears, as it often happens, faceted when dynamics that have interested the two "souls" of this business area , that is distribution and installation, are analyzed in depth. The first three Italian distributors have contributed in putting products on the Italian market for about 200 MW, which correspond yet to less than 10% (in the conservative assumption of 2.100 MW complexes installed) or even to 3% (including all the "Salva Alcoa" plants). All this despite a growth in turnover, that for example in the case of Tecno Spot has tripled between 2009 and 2010, and the entrance of new operators, for example Galeo Energy, that has become operative in September 2009 and that has reached a turnover in 2010, so to say in the first year entirely operative, of almost 20 billion euro. It has to be underlined that "pure" Italian distributors have put numerous actions in place, aimed at increasing their business volume: through the widening of brand ranges available, that passed from 5 in average in 2009 (they were 3 in 2008) to over 10 last year, to satisfy the market's needs; through an increase in service supplies at value-added, as for example supplies in *ad hoc* support services for certain types of accomplishments, or the assistance to project activities ; through ventures abroad, in Europe (in France and Germany), but also in the USA (with Tecno Spot, for instance, that opened a branch in Los Angeles) and Asia.

In reality, Italian distributors complain about the scarce competence of the installers, mainly in smaller and medium segments. This issue isn't entirely groundless, considering that the number of installers – for whom no professional qualification is expected – active in Italy, has gone up five times in 2010 and 80% of these have installed photovoltaic plants as a first exactly in the course of the last year. The picture presents itself differently if *system integrators* and *EPC contractors* are examined, engaged respectively in medium-big size plants and in and great buildings. The main Italian operators are reported in table 1.4.

Company	**Business Model**	**Head quarters**	**2009 Revenues (mln €)**	**2010 Revenues (mln €)**	**MW sold/installed during 2010**
Enel.si	System integrator	Roma	178	320	150
Enerpoint	Distributo EPC contractor	Desio (MB)	82	235	120 (105 distribuzion; 15 plantss)
Ecoware (Gruppo Kerself)	EPC contractor	Padova	110	220	80
Enerray (Gruppo Maccaferri)	System integrator EPC Contractor	Bologna	55	190	68
Terni Energia	EPC contractor	Terni	45	170	80
Enerqos	EPC contractor	Sesto San Giovanni (MI)			50
Tecno Spot	Distributor	Brunico (BZ)	45	150	55 (115 inverter)
Coenergia	Distributor	Bondeno di Gonzaga (MN)	10	92	33 (43 inverter)

Table 1.4 – Main Italian *player* in distribution and installment

As far as the *system integrators* are concerned, the consolidation of the position of Enel.si must be underlined that from 2009 to 2010 has clearly increased its *franching* network that from 437 went up to 550 with over 300 billion euro of revenue and over 150 MW of installed power, all on plants of power less than 1 MW (in particular 60% in residential and commercial plants, therefore lower than 220 KW, and 40% on plants from 200 KW to 1 MW). Moreover Enerray, an enterprise born as a *system integrator*, in the course of 2010 favored the installment of large size on ground-mounted plants (already by March 2010 it had built 5 photovoltaic plants in the Puglia region) and on large enterprise rooftops.

The *EPC Contractors* for their part, taking advantage of the *boom* of plants, have recorded an extremely significant growth in turnover and margins, with revenues in average in growth of 150% in respect to 2009 and peaks of 245% and 270% respectively for Enerray and Terni Energia. The latter has then enlarged its *business* further with a *joint venture* (Sol Tarent) that started in the course of 2010 and that involves the Ferrero group, since years engaged in the world of renewable energy.

Among the main ongoing dynamics it should be marked that a growing importance is that of the role of *Operation & Marketing* activities also as a way of loyalty of the client in respect to which, according to the interviewed operators, it is still a prize to have a "strong" presence on the territory. The majority of *EPC Contractors* have developed their own expertise, in some cases organized as real internal divisions, in this specific area. If we think of Enerqos, that has even opened in 2010 a centre dedicated to the monitoring of installations completed, located in Pisa. And of Terni Energia, that has created a team of internal resources and university researchers, with the aim of improving the performance of the monitoring *software,* of monitoring plants and carrying out the maintenance service. The latter is usually run by a contract *ad hoc* signed with the client, which varies greatly depending on the type of guarantees required (for example, related to production in the early years of the plant). In the course of 2010 also other "specialized" companies arose in charge exclusively of the O&M of the plants.

Another trend factor is represented by the issue of a "mixed" model, in which the *EPC Contractor* is also the owner of the plant. For the moment only Terni Energia has maintained a share ownership of about 60% of the plants created in the course of 2010, but operators are looking with a growing interest towards new forms of governance of the large plants that can enable them for example to limit variability in the results, ensuring certain revenue streams for a determined period of time.

In conclusion therefore a highly dynamic picture emerges. The industrial system shows significant growth rates and capacities for appropriation of the sector's margins increasing. It is clear that the phase we went through is very delicate as continuity in the development of the sector could lead to a consolidation of the national industrial system. Continuity in development is therefore subject and completely independent of a stable regulatory and legal framework and favorable. The Quarto Conto Energia (Fourth Conto Energia), recently published, should represent the substrate legislation for the next years: the following paragraph will briefly describe the essential elements and the estimated potential impacts.

1.4 Regulatory changes: the Fourth Conto Energia

The Fourth Conto Energia, signed last March 6, introduces some important innovations in respect to the previous criteria for incentive used in Italy to support the photovoltaic sector. First of all, and to be noted, are the terms of duration of the system that goes to 2016 for a medium range period plan and with 23 GW of installed power as an objective. Other innovations, that will be tackled in depth, are the changes in the classification of types of plants, the introduction of the *cap* cost mechanism (that will not be able to exceed a regime of 6 or maximum 7 billion euro), the introduction of the register of companies and obviously the determination of the new incentive tariff.

The Decree provides a distinction between small and large plants. In particular, differently from before when it was only the power of the plant to count, new "qualitative" criteria have been introduced. Small plants are those that, alternatively: (i) have a power not superior to 200 KW operating on a regime so called *scambio sul posto,* (ii) have been created on buildings that have a power not superior to 1 MW, (iii) are of any power but created on buildings of Public Administration. It is therefore clear (the definition is included in the introductive terms of the Decree) that the legislator intends to reward mainly installments "at low consumption" on the territory or anyway supported by public administration (and therefore, at least in theory, closer to the needs of the local communities).

Another aspect, this time totally new in respect to the past in Italy, but clearly inspired by the German model, is the mechanism of dynamic adaptation and the cost cap. The legislator has in fact issued a limit in installed power in the different periods based on an annual indicative cost of "booked" incentives in that period. Any overruns lead to a dynamic adjustment of remaining availabilities (and of fees) for the following period. The cost limit is applicable initially (in the period June 1, 2011 – December 31, 2012) to only large plants whilst "small" plants are admitted to incentives without any annual cost limits. Keeping in mind that the power limit provided by 2012 is of 2.69 GW and estimating installments of small plants for a power equal to about 1.4-1.5 GW, a photovoltaic market in Italy that in the next year and a half could exceed 4 GW of new installments (over 50% of which in "small" plants) can be assumed. For the 2013-2016 period instead, the excess over the cost limit is applied to all categories.

The Decree then regulates the access mechanisms to incentive tariffs and introduces for large plants the obligation to enroll in the ranking-list register of GSE. A "transitory" phase is foreseen in which plants that enter into operation within August 31, 2011 can access directly to the agreed tariffs for that period, whilst after this date, access will be regulated based on the ranking in the register (with priority given to plant that have already completed the phase of connection to the electric grid). The need to proceed to the enrollment into the ranking-list of large plants will cause a likely extension of time necessary to access to incentives and mostly to a higher uncertainty regarding the total of the relative tariff. Operators expect a lower bankability of the projects, with the possibility with the need in the first instance to finance in *full equity* mode the making of the plant and at a later time to enter the debt: it is clear how in this way the number of operators able to bear these types of operations is reduced.

The Decree fixes also new incentive tariffs. Compared to values foreseen by the Third Conto Energia (that should have been into force up until 2013 and that instead was overcome by the Fourth Conto Energia) it appears evident that, taking as reference the December 2011, tariffs are reduced in average by 24.5% for plants on buildings and by 25.5% for other plants, whilst similar values in December 2012 have marked a minus 34.2% for plants on buildings and a minus 35% for the other plants (see table 1.1). Also in this case, tariff variations affect mainly large plants reaching a decrease of about 30% at the end of 2011 and of about 42% at the end of 2012. Starting from the first semester 2013, tariffs take on a feed-in tariff and on the self-consumed energy share, as in the case for Germany, a specific tariff is given. For the following semesters planned reductions are of 9% in the second semester of 2013, and of 13% for all 2014, and of 15% in 2015 arriving to a reduction of 30% in the course of 2016.

	Fourth C.E. vs Third C.E. December 2011		Quarto C.E. vs Terzo C.E. December 2012	
	Su edificio	Altro	Su edificio	Altro
1<P<=3	- 21,6%	- 29,5%	- 29,5%	- 29,4%
3<P<=20	- 21,6%	- 29,4%	- 29,4%	- 29,3%
20<P<=200	- 21,7%	- 29,5%	- 29,5%	- 29,5%
200<P<=1000	- 21,7%	- 31,6%	- 31,6%	- 38,0%
1000<P<=5000	- 29,8%	- 42,2%	- 42,2%	- 42,0%
P>5000	- 30,7%	- 42,9%	- 42,9%	- 42,0%

Table 1.5 – Average decrease of tariffs

From table 1.5, and as mentioned in several points previously, it emerges how the mostly affected (both in cuts in tariffs and in bureaucratic "laces") are the larger plants. From December 2011, so that ground-mounted plants remain profitable, it is necessary that their cost falls under 1.800 billion euro per KW installed. For small and medium instead, profitability remains good and the fall in price necessary is definitely much smaller: the threshold of profitability is obtained at 4.600-4.800 billion euro for small plants and at 3.000-3.200 billion euro for medium size ones on coverage.

It is reasonable to expect that the Italian market, mainly starting from 2012, and therefore after having disposed of the "transitory" connected to the passage to the Fourth Conto Energia and to the turbulent affair of Salva Alcoa and the Third Conto Energia, changes significantly, with a redistribution of the market mix in favor of medium size plants (see diagram 1.6).

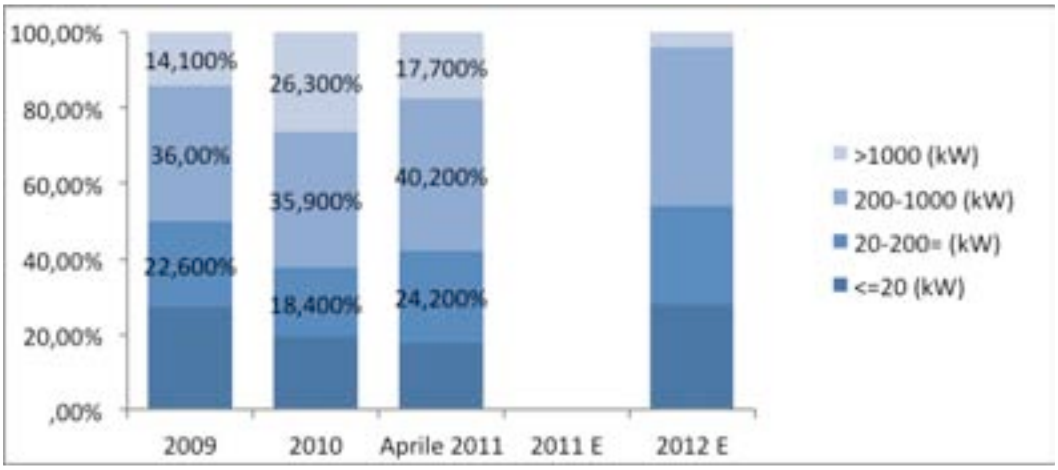

Diagram 1.6 – Market mix expected for photovoltaic plants

If, as it appears in more points, the intention of the legislator is that of favoring the "distributed generation" of energy and therefore a wider spread of smaller plants in our territory, it is possible to say that it will find a reasonable response in the market in the next years. It is not said though that our enterprises may be ready, mainly those producing cells and modules and that had enlarged their business model in the course of the last year towards active planning and installments of medium-large plants and that will be forced to modify again their focus and do "team work" with distribution and local installment. It may help them – but it's an issue to be monitored carefully – that the tariffs increase of 10% which has been foreseen for plants built with components produced in Europe.

The regulatory framework outlined by the Fourth Conto Energia is for sure challenging and obliges the sector to demonstrate it can strongly reduce, in the next years, the cost of energy production from photovoltaic sources. The central aspect to enable the attainment of this objective by industrial operators is maintaining the regulatory framework as such in the next years so to favor investments and developing plans in short and medium term periods.

2. BIOMASSES

2.1 Agroforestry biomasses

Plants powered by agroforestry biomasses are currently used to obtain two types of output: thermal energy and electric energy. Plants created for the production of electric energy are usually large-sized ones, superior to 5 MWe. Plants intended for the production of thermal energy can be divided into:

- systems for residential use, that are pellet-fired heater or boilers usually inferior to 1MWt size, that are used in substitution or integration of ordinary heating plants of one residential unit, of apartments of the same building or offices for small commercial or productive activities;
- district heating, systems that have an average power between 1 and 20 MWt and are used to supply heating to users connected to the grid (for example single residential unit, schools, offices, hospitals or companies that draw on thermal heat for their own productive processes).

This market segmentation is shown schematically below, highlighting the nature of the main investors according to the different plant typologies.

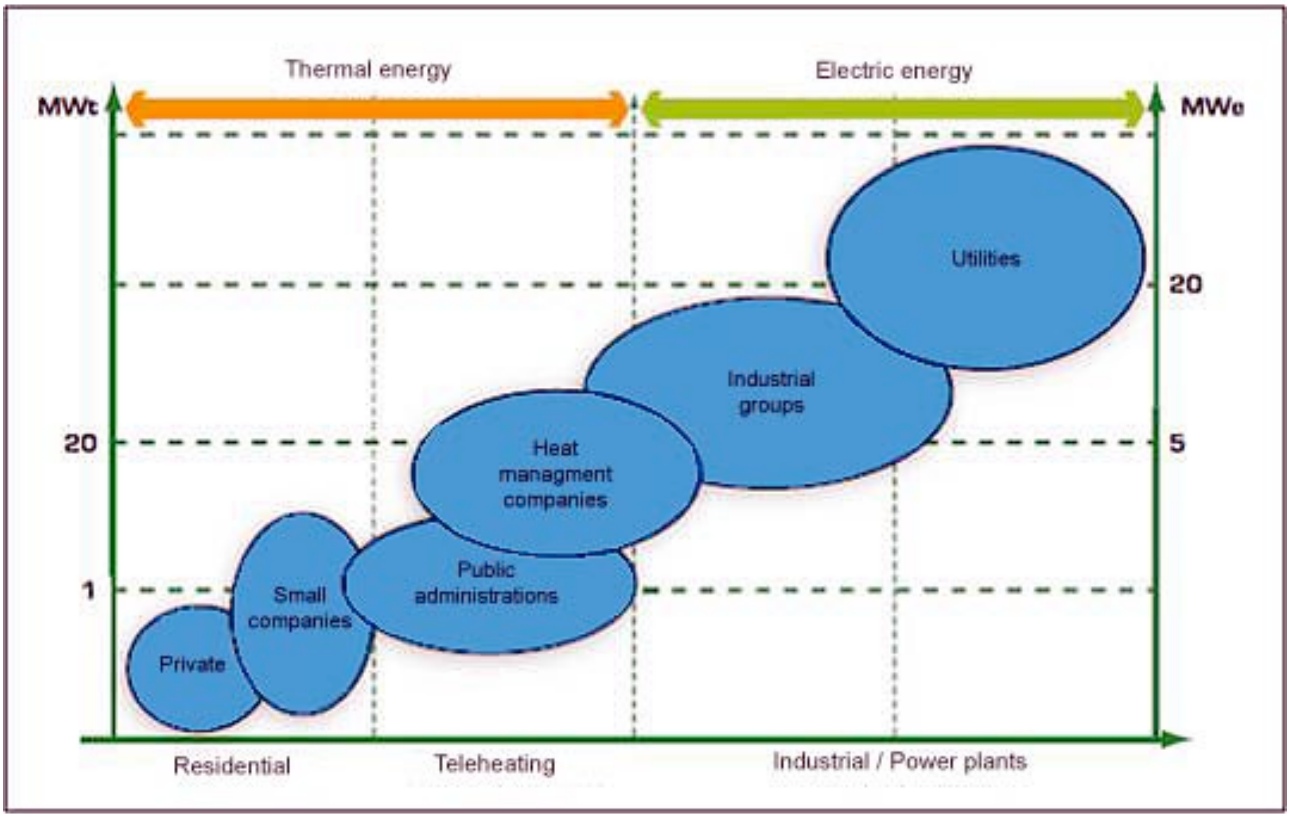

Figure 2.1 – Segmentation of the Italian market of agroforestry biomasses

Concerning small size plants for residential use, after the installation boom recorded in 2006 (as a consequence of the lower price of pellet in those months compared to traditional fuels) and the following drop of installations in 2007 (over 40% on an annual basis) for the rise in the fuel price, from 2008 the Italian market stabilized on a two figure growth trend, around 10% per year. During 2010 approximately 220.000 new residential plants were installed. The so long awaited fixation of a duty, starting from 2012, for the use of heating produced by renewable sources (up until 50% of the demand) in new buildings or in buildings under important renovation could represent a further strong drive to the development of this sector in the future years.

District-heating power plants, connected to a network in which an appropriate heat transfer fluid flows that supply energy to several buildings, at the end of 2010, are a little less than 250 in Italy, for a total thermal power close to 430 MWt. New installations achieved in 2010 don't change the biomass district-heating geography in Italy, with the North of the Country still being responsible for over 90% of the total installed power. In particular, Trentino Alto Adige, Lombardy, Piedmont and Valle d'Aosta play a pivot role in the Italian market for agroforestry biomass district-heating.

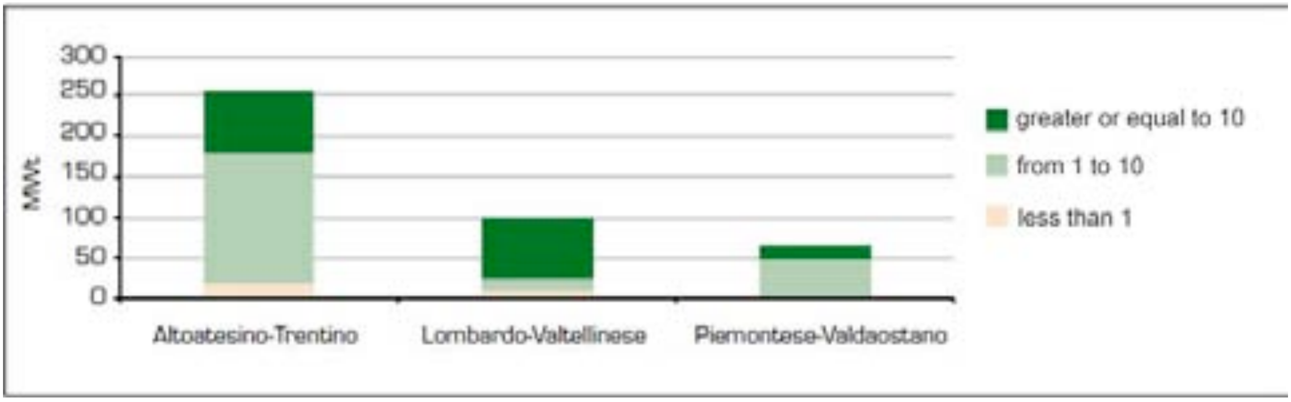

Figure 2.2 – Installed power in district-heating plants in the main Italian regions.

Concerning the evolution of new installations awaited in the short term, it is reasonable to believe that by the next 2 years, until the end of 2012, about 10-15 plants could be installed, reaching therefore a total power estimated of over 450 MWt. Moving to a medium-long term it becomes impossible to forecast the development that this sector of biomass energy production could have. In fact, the Renewable Decree(Decreto Rinnovabili) has fixed a key principle to be put into practice in the next few months that could significantly modify the prospects of the market growth.

This refers in particular to the introduction of a system to encourage the production of thermal energy, which is the main output of these plants, that could make investments more profitable, with enormous impact on the future development of the market. Both direction and entity of this impact will strongly depend on the specific levels of incentive that will be introduced, and by practical ways through which the incentive will be put into practice. Today it's impossible to anticipate and therefore to evaluate these aspects.

Large size agroforestry biomass plants are built aiming to electricity generation, to be allocated mainly to self-consumption (in the case of plants made by private companies and industrial groups that have available biomasses as waste of their productive processes) and for selling (in the case of power plants built by utilities and energy generation companies). During 2010 about 10 new plants of this type have been installed in our Country, to which corresponds a total power growth of over 40 MW. At the end of 2010, in Italy, there were, therefore, more than 100 biomass-fired thermoelectric power plants in use, with a cumulative power forthcoming to 550 MWe. These new plants determined a growth in the number of plants and in cumulative power respectively of about 14 and 8%, decisively lower values if compared to data reported in the last few years, that mark a slowdown given by an ever-growing uncertainty on the incentive system for large size plants which we have spoken about earlier. In 2010, the installed power has increased proportionally to a lesser extent compared to the number of plants, as an evidence that the average size of plants that came into operation in the last year is lower than the average recorded on the market.

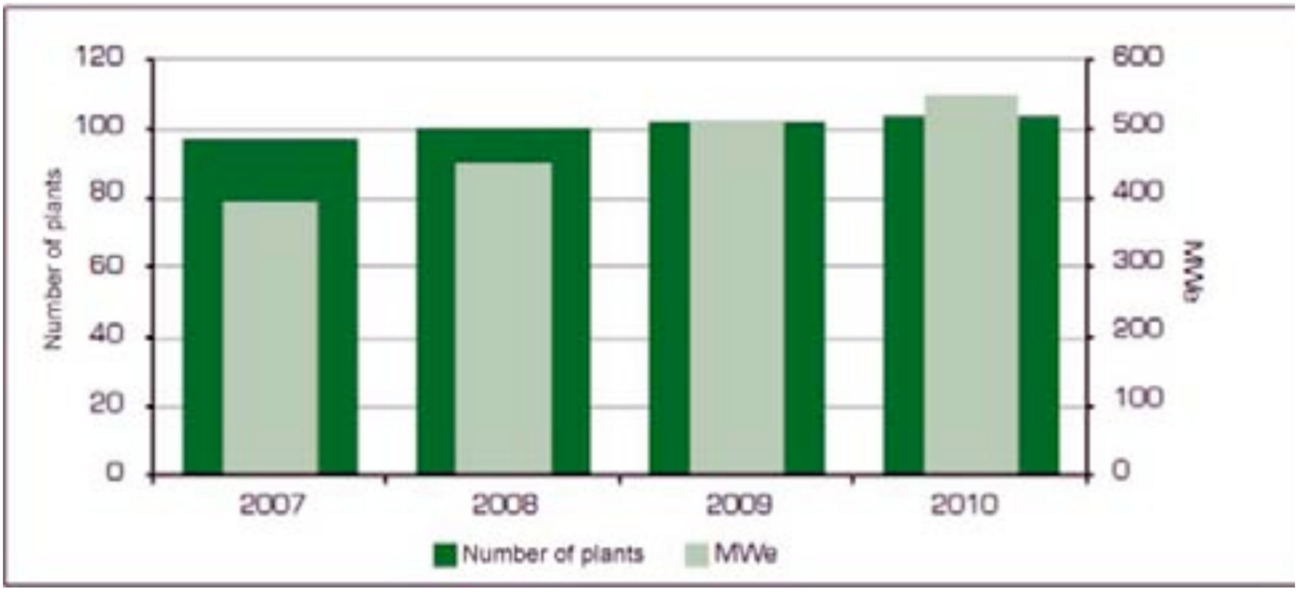

Figure 2.3 – Number of plants and installed power of theroelectric agroforestry biomass power plants

Concerning the future evolution of this market it has to be said that during 2011 it is likely to expect that some plants in operation will be objects of revamping because of the incentives' period expiration and the need of interventions of this type to be able to log back on the incentive system, also confirmed in the recent Ministerial Decree on March 3, 2011. If we assume that all the plants, that are next to the expiration period of the incentives, decide to carry out revamping investments on their own plants, it is then possible to make an overall estimation for the next 3-4 years of a power subject to this type of intervention, equal to 60-80 MWe that correspond to the need of investments for over 250 million euro.

The decrees that refer to the Renewable Decree of March 3, 2011, will be of great importance for the development of this market. The production of electricity through agroforestry biomass has been encouraged during 2010 through 2 mechanisms: for small size plants (inferior to 1 MWe, that represents less than 30% of the total installed power in Italy), through the feed-in-tariff, for plants size equal or larger than 1 MWe (over 70% of the total), through the Green Certifications mechanism. Both these mechanisms will be greatly modified as provided by the so called Renewable Decree (Ministerial Decree of March 3, 2011). The decree states, in fact, a difference in the way of delivering incentives in two categories: for small size power plants, not inferior to 5 MWe (eventually differentiable for the different categories of biomass and power classes), an incentive like a feed-in tariff will be available; for power plants larger than the minimum sizes, starting from 2015, an incentive will be assigned through bid auctions run by GSE.

For agroforestry biomass plants it is not yet known how these principles will be put into practice, but it is anyway highly likely that, considered the size of agroforestry biomass plants built in Italy, they will be part of the bid auction mechanism, potentially the most articulated and confused mechanism in its practical application. The approval of the Renewable Decree is the base for a deeper modification of the incentive system in this sector, as it introduces for the first time specific incentives (although still undetermined in the total and in the ways of delivery) for the production of heating plants powered by renewable sources including precisely the agroforestry biomasses ones.

The following illustration shows a representation of the Italian energy production chain by agroforestry biomasses updated to 2010, from which it is possible to understand the number of operators involved, the turnovers generated in the three market segments in which it is divided (that is pellet-fired heaters and boilers for residential use, district-heating plants and thermoelectric biomass power plants) and the presence of foreign and Italian companies.

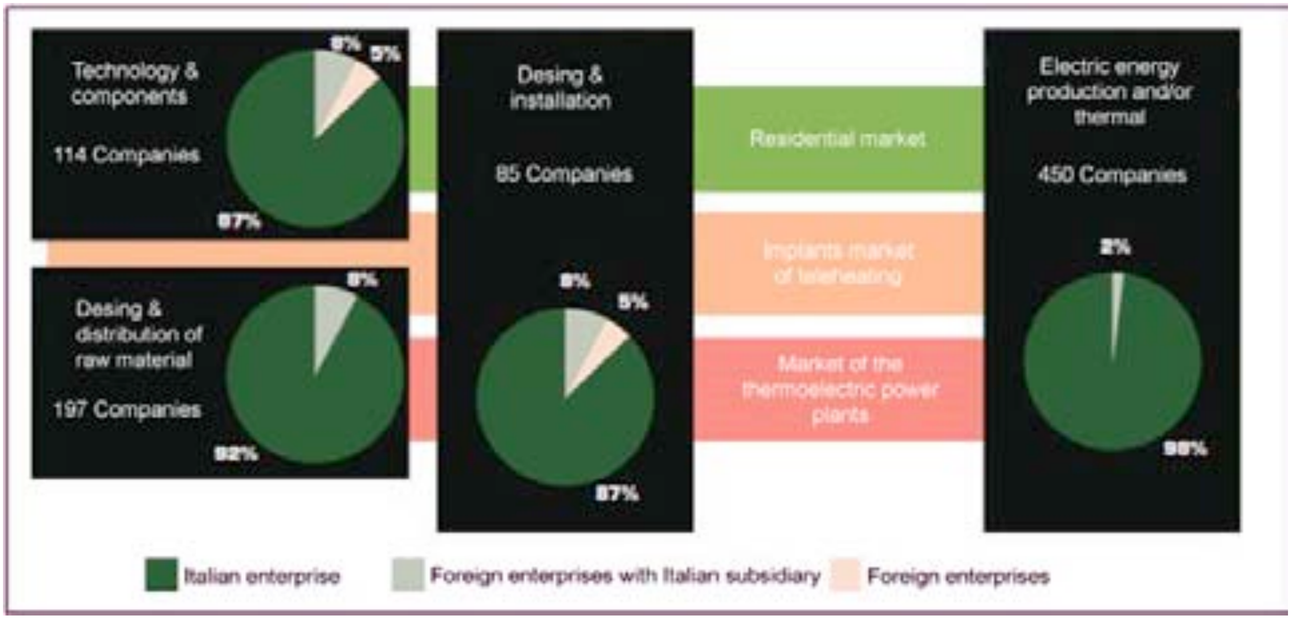

Diagram 2.4 – Division of the Italian chain of agroforestry biomasses

Concerning the number of operators, more than 380 active companies in the different stages of the chain have been identified, with the exception of the owners of district-heating plants and thermoelectric power plants, that exceed 200 units. Therefore, a significant increase in the number of active companies in this biomass sector compared to 2009 (of approximately 25%) and corresponding increase in competition can be observed. This implies that the Italian market, although characterized by not particularly high growth rate and uncertainty and ineffectiveness of the Green Certificates mechanism, has been judged as attractive by the different new operators that have decided to invest in it, as for example the specialized players in gasification or ORC technologies. It is interesting to notice how this increase in the number of operators didn't damage the Italian companies, who have kept unchanged their percentage weight (except for some cases such as the sector of technology and component production, where it has even increased). It is proved that, the sector of agroforestry biomasses presents a chain in which the presence of Italian operators, even in the business areas with a higher technological density is predominant, differently from what happened in other renewable sectors, above all the photovoltaic and the wind energy. Concerning total turnovers with an estimate that in 2010 reached and exceeded 2.1 billion euro, with a growth of over 15% compared to the value recorded in 2009. In this estimation revenues from the sale of raw materials, from the sale and installations of new plants, as well as the sale of not self-consumed electricity (and of the associated Green Certificates) are considered. The growth of the turnover compared to the previous year is largely due to a significant increase of the installations in the segments of thermoelectric biomass power plants, to which corresponds an increase in total revenues of over 27%. In a different way, the residential segment has marked only a slight increase in the total revenues (estimated at 6-7% on 2009), while the district-heating sector has recorded increases for only 1-2 percentage points.

2.2 Biogas

Concerning another important sector of biomasses, that of biogas, installed power in Italy in 2010 has grown 20% compared to the previous year, while the number of plants increased by 13% showing a continuous interest in this type of biomass exploitation. Expectations for the growth in the future appear optimistic, with operators opinions being rather in accordance in defining that the farm biomass market will continue to grow with consistent rate up until the end of 2012, when it could reach a total installed power of almost 800 MWe.

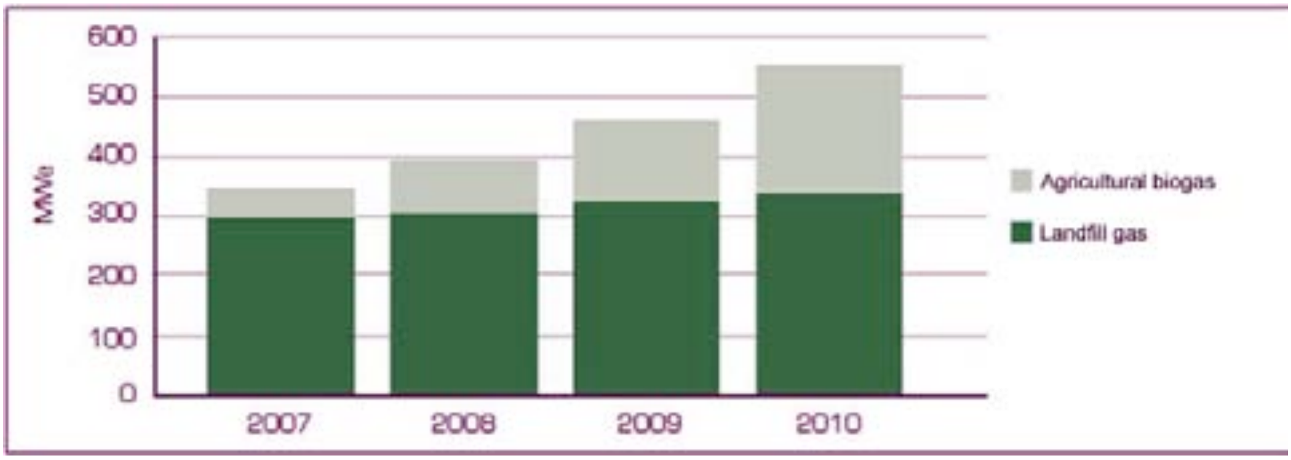

Diagram 2.5 – Installed power in Italy in biogas plants

During the last year the weight of farm and livestock enterprises, as promoters of the construction of biogas plants, has definitely strengthened and counted for 80% of the installations. Traditionally these have sized their plants according to their raw materials availability, to avoid any supply from outside, many times very costly and subject to price dynamics not always easy to handle. The trend, in spite of this, has changed, with many farming enterprises that have tried to enlarge the size of their plants up to a limit that allows to access the feed-in tariff (1MW), in the attempt to exploit scale economies that can be generated by an investment in biogas plants. The overall number of companies involved in the chain has increased (560 against the 500 of 2009). Also the number of employees overall committed in the Italian biogas chain has exceeded at the end of 2010 4.500 units, against the almost 3.000 workers of the previous year. This is also due to the fact that in this chain it is recorded a clear prevalence of Italian operators, that not even the 2010 growth (with a possible assault of foreign operators) has really brought into question.

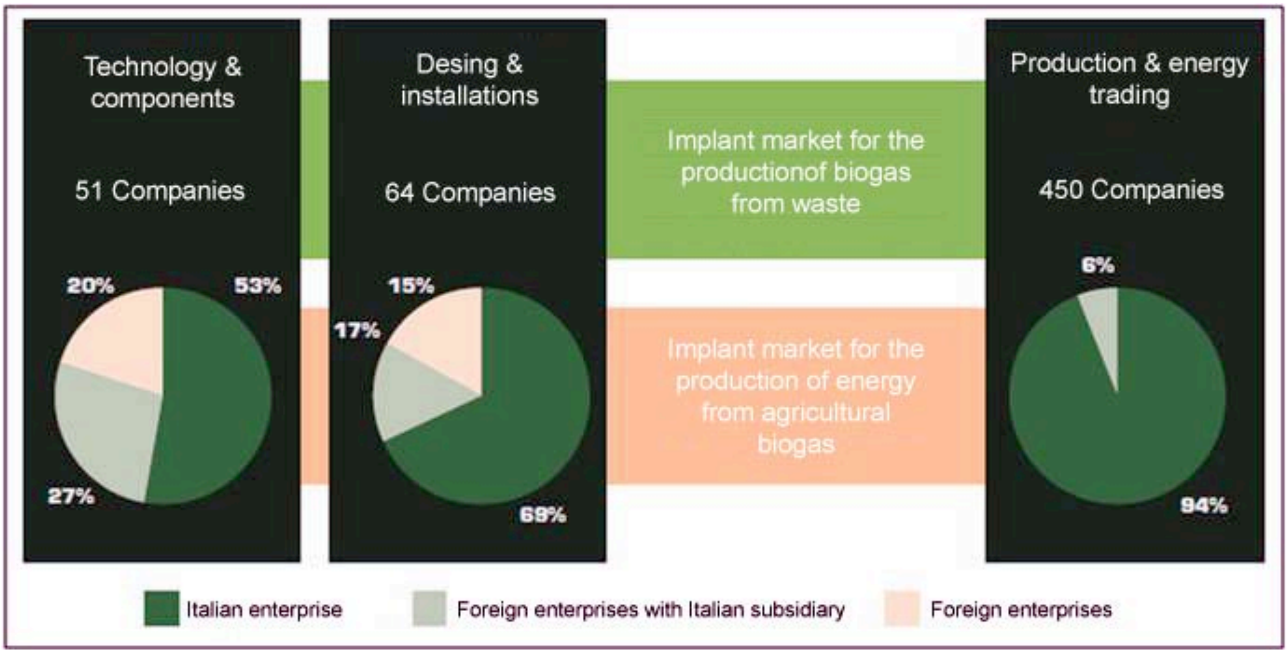

Diagram 2.6 – Division of the Italian biogas chain

The turnover is estimated at over 900 million euro, here also with a +60% compared to what was recorded in 2009. The growth is almost entirely to be attributed to farm and livestock biogas, with the installed power in landfill plants which remained steady (a clear sign of saturation by now reached in this market segment).

An interesting development concerning biogas is the exploitation of bio-methane. First with NAP (Renewable Energies Nation Action Plan), with a specific reference to the possibility of using bio-methane also in Italy, and then with the so called Renewable Decree of March 3, 2011, with the indication – still to be defined in its amounts and modality – as an incentive for the production and the emission into the grid of bio-methane, have laid the foundations for growth, at least in interest, towards this type of technology also in our Country. In Italy, today, no plant of bio-methane production exists. In Europe as well, despite important signs comes from both Germany and Switzerland, only in Sweden the development of a real market can be acknowledged. In this Scandinavian country, thanks to over 35 upgrading plants, 25% of biogas produced is "converted" into bio-methane (that can also be used to power the over 17.000 gas vehicles that contribute to the national car fleet). Bio-methane is a fuel mixture mainly consisting of carbon dioxide (CO2) and methane (CH4) obtained thanks to a consequent "purification" of biogas, or rather of the gaseous fuel obtained from solid or liquid biomasses of various nature. With a characterization similar to natural gas (and therefore of a fossil source), bio-methane can be placed in the national distribution networks, it can be used as fuel for vehicles, as raw material for the chemical industry as well as a source of energy of particular high tech processes. The transition from biogas to bio-methane is done through a process of purification which is commonly called "upgrading", whose primary aim is increasing the relative concentration of methane present in biogas up to a value exceeding 95%.

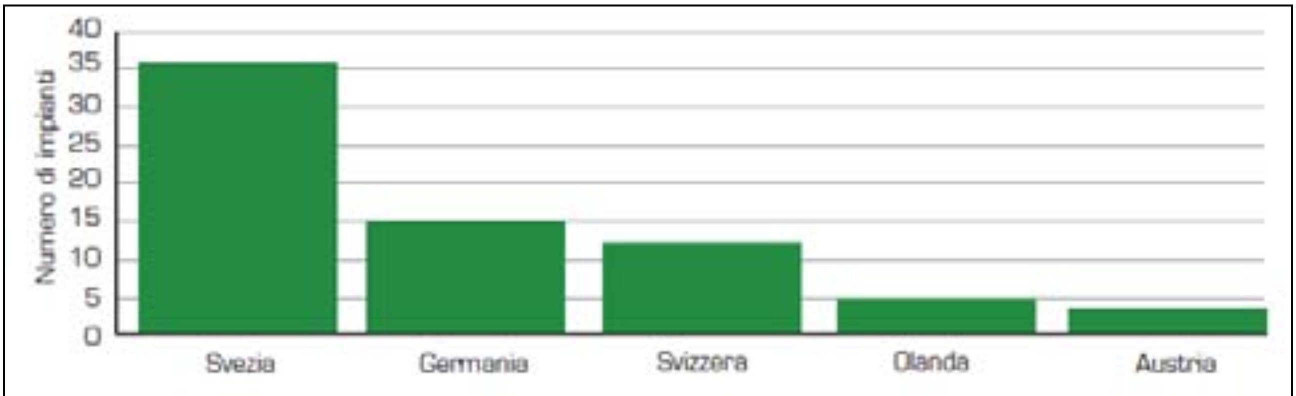

Diagram 2.7 – Number of upgrading bio-methane plants installed in Europe

In the Renewable Decree it is foreseen that the Electric Power and Gas Authority will issue regulations regarding the technical and economical conditions for the delivery of the service to connect bio-methane production plants to the natural gas grid. As said before, today in Italy plants for bio-methane production do not exist also due to the fact that the costs of the upgrading process are still extremely high. Our survey has highlighted, for example, that to allow a proper return on the investment necessary for the upgrading (mainly if we consider that the alternative is the use of biogas for the incentive electricity production) it would be necessary to buy bio-methane placed in the grid at a price between 0.8 and 1 euro/m^3.

This value is definitely high, if we think that in 2010 the price of methane gas for residential use was on average equal to 0.7 euro/m^3 (35% of which is linked to the real cost of that).

In conclusion, it can be asserted that the potential of energy production both from agroforestry biomasses and from biogas is for sure high and so the role of this source in the energy mix of the country could be fundamental. The development and spreading of these plants will depend on the efficiency of the incentive system to be published soon, not only with considering fees that will be approved, but also the possibility of improving complementary products such as bio-methane and thermal energy.

3. MINI-HYDROPOWER

by Giancarlo Giudici[1] (*), Fulvio Ghisla

(Politecnico di Milano – School of Management)

3.1 Introduction

Hydroelectric in Italy represents the main renewable source for the production of electric energy. According to Terna (2011) in the course of 2010 energy produced by hydroelectric plants in Italy has overrun 50 terawatt-hours (increasing of about 3% on the previous year), contributing for almost 15% to the energy balance of the national grid, whilst all the other renewable sources together stop at 7%. The gross power installed has reached by the end of 2010 the threshold of 17.8 GW.

Use of kinetic energy of a water flow for the production of work is probably one of the most ancient methods of efficient exploitation of a renewable source. Starting from the 19th century hydroelectric has been one of the most used methods for the production of electricity and for industrial activities in general by use of generators as alternators.

In hydroelectric power plants waters' potential energy is used relatively to the difference in height between the stream and the power plant, that is transformed by means of a turbine into mechanic energy to end with a production of electric energy.

Hydroelectric in Italy has experienced an enormous development in the first half of the last century; starting after the second World War but competition of fossil fuels for energy production caused a progressive disinterest. Only half way through the 70's, due to an increase in the price of crude oil, hydroelectric came back to be competitive in terms of production costs. Nevertheless nationalization of

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electricity in ENEL - has concentrated attention on large power plants with a progressive abandoning of smaller sized-plants.

Only at the end of the '90s, thanks to the liberalization of the energy market and the introduction of public incentives related to renewable sources (as a consequence of the efforts in reducing the use of fossil fuels), hydroelectric experienced a new development mainly in the so-called "mini" plants, that is plants of small dimension.

According to the official ranking of UNIDO (United Nations Industrial Development Organization), we can identify 4 main types of smaller-sized plants:

- "Small plants", characterized by an installed power inferior to 10 MW;
- "Mini" plants, with a power inferior to 1 MW;
- "Micro" plants, in case power is inferior to 100 KW;
- "Pico" plants, that is those with a power inferior to 5 KW.

In reality this distinction doesn't keep in account the specificities of each Country, related to geographical features and in force regulations. Concerning Italy, in fact, the most relevant threshold is that of 1 MW, below which it is regulated by the feed-in tariff and above which is by green certifications.

3.2 Technology

A hydroelectric plant, regardless of the installed power, is composed of a series of elements which allow an efficient transformation of the potential energy contained in water into electric energy. The two fundamental parameters from which to start to define a hydropower plant are:

- the head, defined as the difference in height between the water intake and where it is turbinated. The head in particular determines the number of revolutions of the operating turbine.

- the discharge, or rather the volume of inlet water in the turbine. Given the number of revolutions defined by the head, the discharge determines the section of the nozzle, therefore the dimension of the turbine and the nominal power. Whilst the head is defined and fixed (unless few variations due to abundance or not of water that could raise or lower the stream level) the discharge, in flowing water plants, is a variable parameter according to seasonality and rain conditions.

It is possible to distinguish hydroelectric plants according to their typology.

“Basin” plants (or “reservoir”) are those most common for the production of large power, superior to 10 MW. They present a strong environmental impact due to significant needed engineering works (barrages or dams) and to the dimensions of the reservoirs. This type of plant is released from single hydro-stream regulations, as it uses basin water allowing to regulate flow and therefore electric production. Depending on the needs it is possible to operate the facility or modify the flow in a few minutes; reason for which they are considered useful energy reservoirs to cover the load of the periods of greatest demand.

“Pumped - storage plants” are characterized by the presence of a higher and lower basin of accumulation. At night hours, by using lower energy costs, the water below is pumped into the higher basin and then used again for energy production, that will be sold at peak daytime hours, characterized by a higher demand and so at a higher energy price, which enables an arbitrary economic profit.

“Water flowing plant”, differently from the previous ones, don’t present any possibility to accumulate and regulate flows: as a consequence environmental impact is usually limited. Turbines in flowing water plants are usually powered by river water. Normally the difference of the head is minimal if compared to that of plants and reservoirs. Production of electricity depends on the exploitable flow of the river that there is in the course of the year, determining therefore a variation of production on a seasonal basis.

Lastly “water pipelines” are made inside artificial plants, as for example, aqueducts or lead channels or outgoing flows of industrial or purification complexes.

Figure 1 describes the typical structure of a mini-hydro power plant, in a mountainous area. Figure 2, instead, describes a typical structure in a flat area.

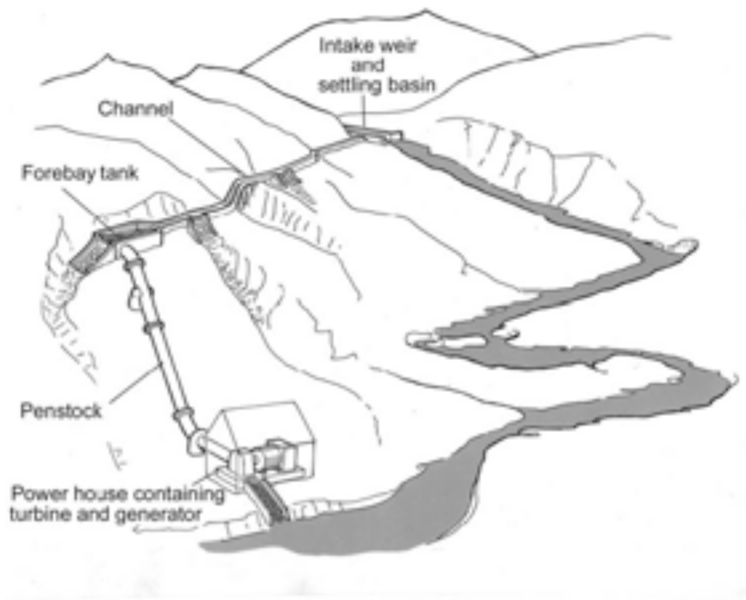


Figure 1. Schema of a mini-hydro power plant located in mountainous area.

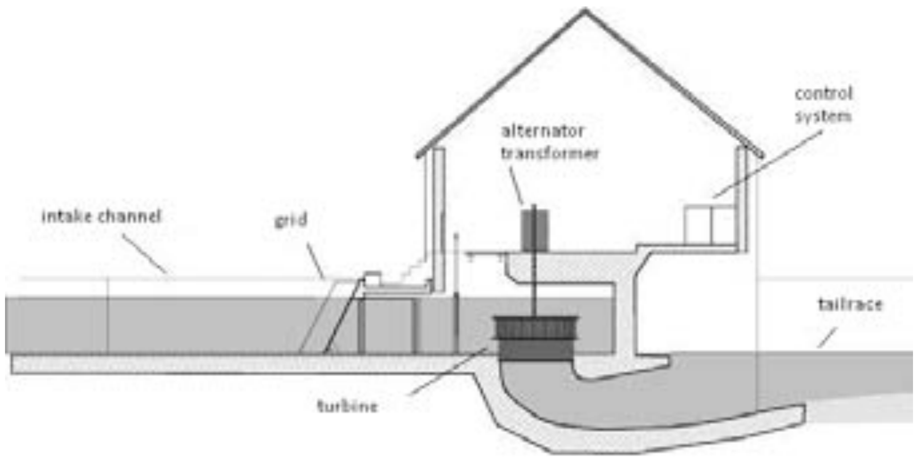


Figure 2 . Schema of a mini-hydro power plant located in flat areas

The design of a small-sized hydropower plant is divided in three activities: engineering civil construction work, design of the electro-mechanic components and the building of the lines for the connection to the grid..

In natural streams, to conduct the flow in an efficient way the latter is deviated laterally, intercepted through intake system works and conveyed through grids in order to prevent the entrance of material other than water, until reaching the turbine through penstocks. The energy of the flow is transmitted to the turbine blades causing the rotation of the impeller. The latter is connected to an electric generator that uses this rotation motion for the production of electricity. At times, specially for small plants, there can be a gearbox between the turbine and the generator. A transformer raises the output voltage from the generator at power line level, which connects to the grid through switchboards that handle the timing of the voltage. Control and tele-control systems allow the plant management also in remote, eliminating the need of the presence of personnel, that will ensure occasional cleaning and maintenance.

The turbine water through tailrace works is released in the river bed. Particular devices have to be respected to enable the passage of the fish (for instance secondary channels at intermediate heads) rather than keeping in the stream a minimum discharge volume necessary for the survival of flora and fauna (the so-called "minimum vital flow").

The theoretical electrical power obtainable by the turbine-generator group is expressed by the following relation:

$P = r \times 9.81 \times Q \times H$

where:

P = power expressed in KW

r = efficiency of the production turbine-generator group (usually for small plants it varies according to the typology of the machine and of the alternator, in the characteristics of the plant in respect to pressure drops and the variability of the flow curves, between 50% and 85%)

Q = water flow expressed in cubic meters per second

H = net head engine (prevalence) expressed in meters

An important difference between mini- hydro power and the other renewable energies is the specificity of each type of plant compared to the above characteristics. In fact, different typologies of turbines exist, suitable for different combinations of different discharges and prevalence. Pelton type turbines are characterized by spoon shaped blades and suitable mainly for plants with relevant water drops.

Turbo turbines are similar to Pelton ones, but cheaper to build. Cross-flow turbines (also called Banki-Michell) have radial arranged blades similar to those used by windmills.

Kaplan turbines are similar to propeller ones, with blades that can be adjusted in pitch relative to the flow to maintain a constant efficiency. Francis turbines are characterized by a centripetal blow that reaches the impeller through a spiral duct that wets it totally, then it is directed onto the impeller blades; also they, can be adjusted.

"Very low head" (VLH) turbines are propeller turbines made especially for smaller water drops, with small loads and easily movable.

Also screws (Archimedes's screw) found an application in mini-hydro power, that have the advantage of being very strong, they offer good performances also with small drops and give less problems to fish.

Lastly, also traditional rotors, typical of mills, have found their own application space, although the performance of these machines is not comparable to that of traditional turbines.

Various types of technology exist, especially developed for small-sized plants, up until "craft" type products thought for Pico plants, for example, in alpine huts or for self-consumption in rural areas.

Figure 3 shows a map that identifies, in respect to the different conditions of prevalence and discharge, the optimal conditions of use of the different types of plants mentioned. It is to be noted that a physiological limit exists to the possibility of exploiting in correspondence to discharges inferior to 0.1 cubic meters per second, and of heads inferior to about 2 meters. Under this threshold the economic profitability of exploiting hydro power is difficult to reach. The bet is therefore that of identifying solutions characterized by low cost, that can render exploitation in limited conditions interesting.

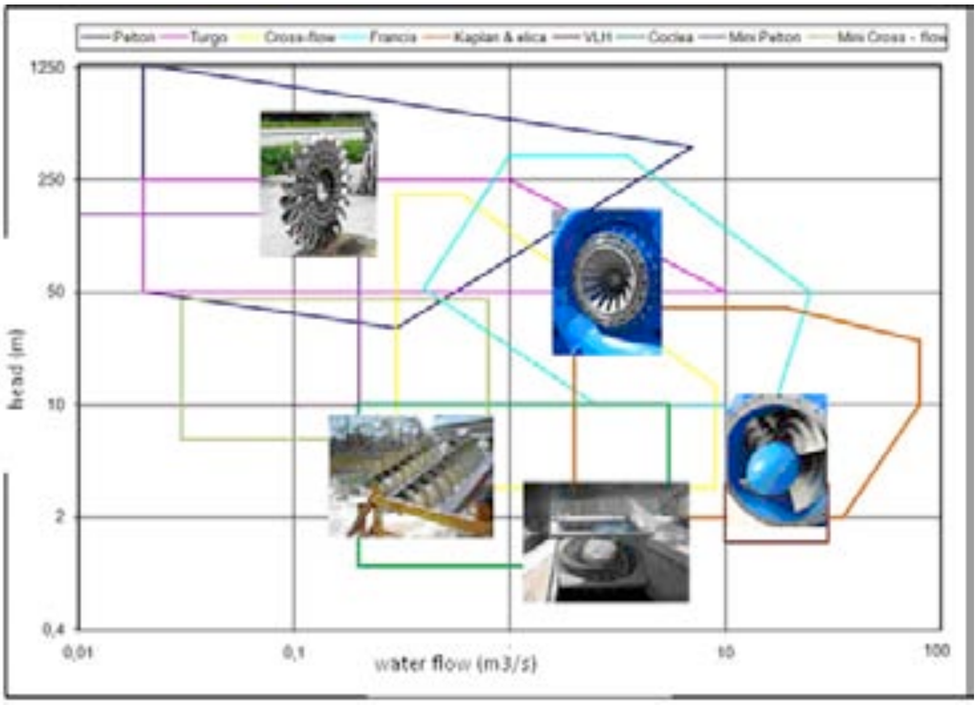


Figure 3. Optimal combinations of application of technologies for mini-hydro power, in function of prevalence and discharge.

3.3 Comparison with other renewable energies

The mini-hydro power, as well as exploiting a mature and tested technology, presents undisputable advantages both regarding large plants and other renewable sources.

First, investments for the construction are quite low: creating a small plant usually occurs on floating water that doesn't require the construction of costly works (such as large dams). This allows a quick economic return of the investment, that usually varies between three to seven years, according to the water flow conditions. Also *mini-hydro* plants are less invasive environmentally, and in some cases have no bad effects on the ecosystem (think of plants installed in aqueducts or waste water channels). Costs of management and maintenance are particularly low, thanks to the possibility of remote distance tele-control and automation.

Compared to the other renewable sources, that in these years enjoyed greater visibility (i.e. photovoltaic and wind energy) the mini-hydro power can claim a better sustainability, greater availability and therefore less costs for both installment and energy production, as described in the estimates made by the department of energy of the Milan Polytechnic and reported in table 1.

Type of Source	*EROEI index*	*Yearly availability (h/y)*	*Installation cost (€/kW)*	*Energy Production cost (€cent/kWh)*
Mini-hydro	*30-270*	*4,000-7,000*	*1,000-3,000*	*6-29*
Photovoltaic (silica)	*3-9*	*1,000-1,400*	*3,000-6,500*	*20-57*
Wind Energy	*5-80*	*1,500-1,800*	*1,200-4,500*	*7-29*
Biomasses (solid)	*3-5*	*6,000-8,000*	*2,800-7,500*	*11-27*
Geothermic	*2-13*	*6,000-8,000*	*1,600-6,300*	*3-9*

Table 1 – Comparison between mini-hydro and other renewable sources. Source: Politecnico di Milano School of Management (2011)

From a sustainable point of view, given the current technologies, the mini-hydro power is certainly "greener" compared to the other renewable sources. The index EROEI (*Energy Returned on Energy Invested)* is the ratio between energy needed to produce and dismantle a determined plant and energy produced by the latter throughout its profitable existence and therefore it shows the convenience of a system for energy production from an energy balance point of view. The higher the indicator is the better the contribution that its relative energy source gives to environmental sustainability.

For what concerns the annual availability, in reference to Italy, a mini-hydro plant works potentially most of the year (avoiding only periods of freezing in mountainous areas and in periods of particular draught, as well as in hours needed for maintenance and cleaning of the plant) whilst the photovoltaic and wind energy are constraint to the relative presence of light and wind.

Concerning installment costs, to current technologies, hydro power reveals itself to be competitive, mainly compared to photovoltaic and biomasses. Concerning operating costs only the geothermic is more competitive in respect to the mini-hydro power. It must be remembered that a mini-hydro plant, if well maintained, can last several decades, whilst other types of plants (mainly photovoltaic ones) are subject to a certain deterioration in performance and after some years have to be completely replaced with the burden of disposal costs.

3.4. Legislation in Italy

The Italian legal framework in which mini-hydro is placed is rather segmented and as such complex. It changes in fact from region to region concerning compatibility of works in respect to the environment, licenses for water use, connection to the grid and regulatory approvals for building a productive activity.

The legislative reference of water use in Italy is Directive 2000/60/CE (Direttiva Quadro sulle Acque – DQA) which outlines a picture for the protection of the inland surface waters, transitional waters, of coastal and underground waters by reducing at the source pollution and optimizing of uses. The directive mainly underlines the need to manage this resource through a planning at river basin level, according to an ecological perspective that considers water cycle and not the administrative borders of provinces, regions or states.

The license for obtaining public water deviation or hydro power use represent the most critical factor and sometimes limited in the start of a mini-hydro power plant. A fundamental turning point was the Article 12 of Legislative Decree 387, aimed to simplify and speed up procedures for obtaining grants, by permission only (aimed to reduce time required by a reduction of the fragmentation of procedure) and by creating the "conference of services" (with the aim of bringing together in a single counterparty administrations concerned). Nevertheless time required for obtaining it in reality are very long (in the order of 3-4 years with rare cases in which more were required) and it is not possible to establish which grant will be actually released. Water in fact represents a particular public good, as evidenced by the attention of public opinion also shown in the outcome of the 2011 referendum.

Grant has thirty years duration with the possibility of renewal at maturity. The legislation in this matter classifies leads based on their nominal power, distinguishing between: (i) small leads, with nominal power lower than 3 MW, whose license is released by the Province (ii) large leads, with nominal power higher than 3 MW, whose competence is instead given to the Regions-.

To obtain the grant it is necessary to present various documents which describe all the main characteristics of the basin and the project, including: hydraulic reports, drawings and technical reports of the project, financial and economic guarantees for the implementation of the project, a document of impact assessment (in case of projects in SIC or ZPS1 area subject to particular environmental constraints), request for the exclusion of the VIA process (only when holding the requirements). In fact, mini-hydro power plants have a rather limited impact on environment, and for this reason it is sufficient most of the time to obtain the Verification of Subjection, without having to use the Verification on Environmental Impact.

Particular attention should be paid to the legislation on the so-called "Minimum Vital Flow" (DMV): it concerns the quantity of water that cannot be exploited for energy production, being the minimum quantity to guarantee survival of the river, of animals whose life depends on the water course in question, and on other human activities that it will support (tourism, fishing, etc.) and which is determined on a case by case basis by evaluating the environmental conditions.

3.5. Incentives for mini-hydro power

In the context of the general legislation valid for all renewable energy sources and introduced by the resolution CIP6 of 1992, that introduces "guaranteed minimum prices" for the withdrawal of energy from the Italian national grid, since 2005 mini-hydro in Italy has the opportunity of accessing a single feed-in tariff for plants that have power inferior to 1 MW, equal to 0.22 €/kWh. Such a tariff has to be understood as including all forms of possible incentives. The foreseen incentive for plants that have a power superior to such a threshold is instead foreseen by “green certifications” introduced by law decree no.79 of 1999 (better known as “Decreto Bersani”) whose withdrawal is up until now guaranteed by the State.

The Finance Act of 2008 established the deadline for access to the all inclusive tariff to 15 years. It’s a significant advantage, that pushed in 2009 and in 2010 numerous subjects to request new grants (very often with bitter competition on the same sides between different candidates) and to grow the evaluation of existing plants on the market. A quick calculation can be efficient. An plant with a power slightly less than 1 MW and available for 80% of annual hours would generate gross profits from transfer of power to the grid for about 1.5 million € a year, ensuring a time to repay the initial investment on the order of very few years.

The Decree-Law no.28 of 2011 introduced some innovations on the incentive mechanism, advancing a rate review of the tariffs of small plants, and the progressive exceeding of the “green certification” mechanism, definitive from 2016. In fact, auction procedures will be introduced (for plants over 5 MW of power) for the allocation of incentives.

The publishing of new tariffs, which should concern plants that will become operative from 1/1/2013 is expected by May 2012. Expectations are related to the introduction of differentiated rates for power band, to take in account of average decreasing costs of management, to the increase of power delivered. It is likely that also the period of delivery of incentives could be modified, and the legislations related to partial and total plant renovations.

For plants with a power inferior to 1 MW that will enter into operation by 31.12.2012, the same tariff in force today should apply.

3.6. The state of the art in Italy

In Italy by 1/1/2010, 2.249 hydroelectric power plants were connected to the national grid, of which 13% with a power superior to 10 MW, 30% included between 1 and 10 MW and 57% under 1 MW. In reality if we look at the installed power, as much as 85% is related to 297 large plants, whilst mini-hydro plants contribute only for 3% of installed power.

The distribution on the territory is, without any surprise, not homogeneous. More than two thirds of the plants are located in five provinces: Bolzano, Trento, Sondrio, Verbano-Cusio-Ossola, Aosta.

The Legambiente report (2011) indicates that the Italian towns in which at least one hydroelectric power r plant is installed inferior to 3 MW are 946. In 155 of these, the mini-hydro power production can satisfy the energy need of more than half of its resident population.

The provisional data collected by the Milan Polytechnic indicated that today the threshold of 2.500 active plants has been overcome, of which almost 1.500 with a power inferior to 1 MW.

Type	*Number of installations*	*Total power installed (MW)*	*Average size(MW)*
Power > 10 MW	*297 (13%)*	*15.066,30 (85%)*	*50,73*
Power between 1 and 10 MW	*682 (30%)*	*2.189,60 (12%)*	*3,21*
Power <1 MW	*1.270 (57%)*	*465,60 (3%)*	*0,37*
Total	*2.249 (100%)*	*17.721,50 (100%)*	*7,88*

Table 2 – Authorized hydro power plants in Italy, by 1/1/2010. Source: GSE (2010).

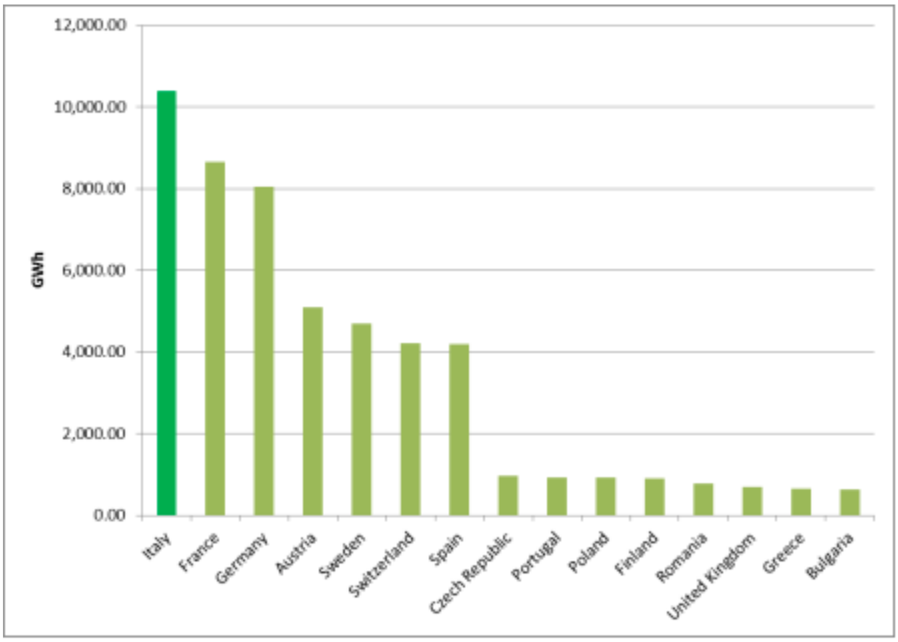
Table 3 gives us an idea of the time evolution of the plants entered into operation since 2004 up to today. Whilst opportunities for large plants are substantially sold out (the net increase in the last five considered years was only of 3 units, with an absolute increase of 1 per cent), you can see that "small hydro" plants (from 1 to 10 MW) have grown of 100 units (+17%) whilst "mini hydro" ones even of 125 units (+11%), with a significant increment starting from 2008, with the entry into force of the all inclusive tariff. Their contribution to total power available is therefore limited, but it is in this field that the highest potentials and opportunities of a further growth are recorded.

Power range	*Year*							*Annual increase %*
	2004	*2005*	*2006*	*2007*	*2008*	*2009*	*2009 vs. 2004 increase*	
> 10 MW	*294*	*293*	*294*	*293*	*296*	*297*	*3*	*+1,02%*
Between 1 - 10 MW ('small')	*582*	*598*	*613*	*641*	*665*	*682*	*100*	*+17,18%*
< 1 MW ('mini')	*1.145*	*1.164*	*1.186*	*1.194*	*1.223*	*1.270*	*125*	*+10,92%*
Total	*2.021*	*2.055*	*2.093*	*2.128*	*2.184*	*2.249*	*228*	*+11,28%*

Table 3 – Development of the number of plants in Italy from 2004 to 2009 per power band. Source: GSE (2010).

Italy is among the main hydroelectric energy producers in Europe, not only for large plants, but also for small plants. Figure 4.a highlights that our Country is the first in Europe for the production of energy from hydroelectric power plants with a power inferior to 10 MW, in front of France and Germany, whilst figure 4.b (that reports energy production in GWh only for plants under 1 MW) sees us in second place behind Germany. It is then perceivable that there is more space for development in this typology of plants.

(a)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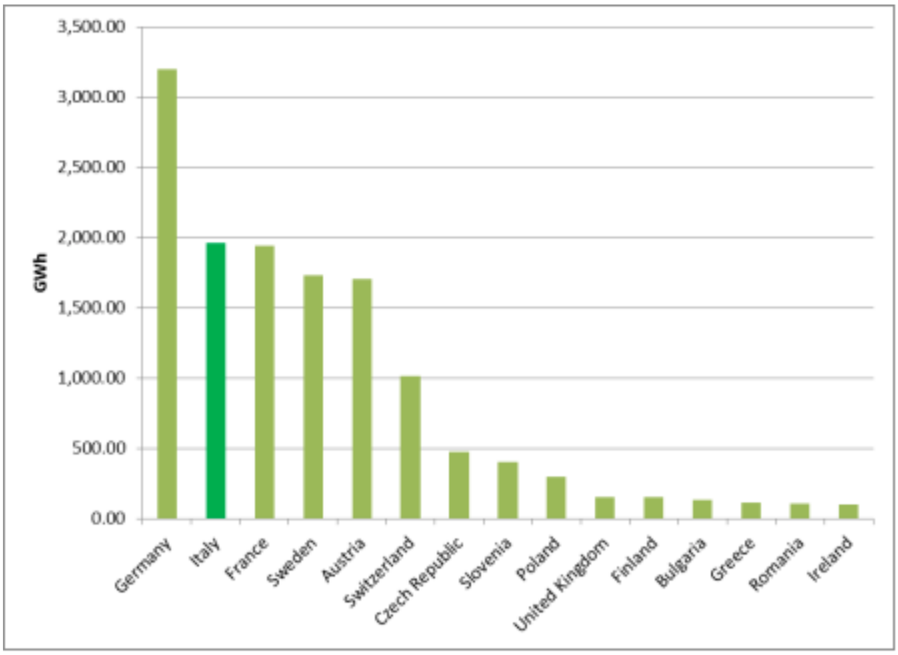
(b)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United Kingdom
Finland
Bulgaria
Greece
Romania
Ireland

Figure 4 – Hydroelectric energy produced in Europe in 2009 by plants with power inferior to 10 (a) and 1 MW (b). Data in GWh. Source: ESHA (2011).

Figure 5 compares the medium size of "small" plants (a) and that of "mini" plants (b) in the five most significant countries for hydroelectric power in Europe: Italy, Germany, France, Sweden and Austria. The interesting data is that four "small" plants Italy is very near to the average, whilst for "mini" plants we are significantly above average. Even in Germany the medium size is inferior to 100 KW. So, the presence of significant spaces for a further expansion of mini-hydro power in Italy appears, mainly for very small sizes. This would not give a significant contribution to the national energy balance but would certainly go in the direction of "distributed generation" by many desired.

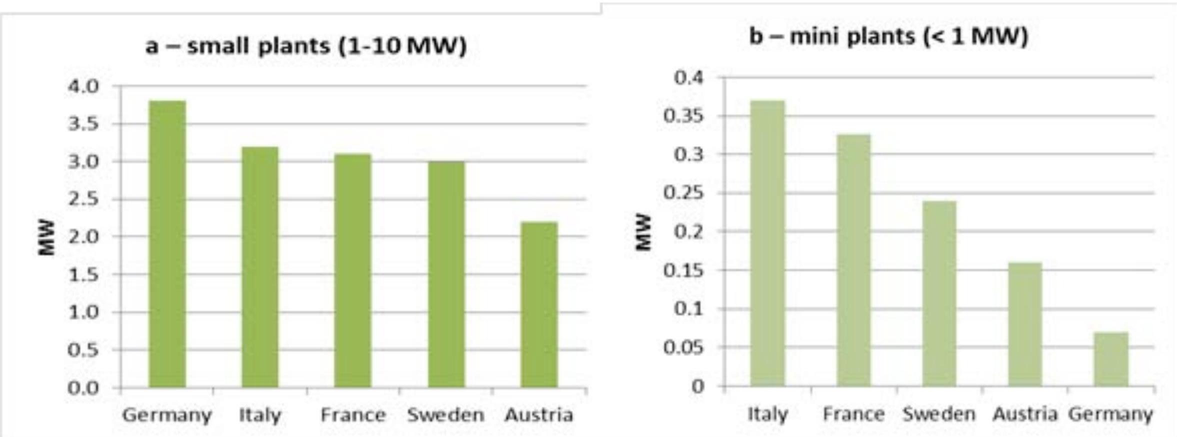


Figure 5 – Average power of "small" plants (a) and "mini" hydro plants (b) in Europe. Comparison between Italy, France, Sweden, Germany and Austria. Data in MW. Source: ESHA (2011).

3.7 The cost function

The cost items to consider for a project in a mini-hydro plant are substantially divided between initial investment costs and management costs.

Concerning initial investment, we have:

1) the design and the costs of authorization;
2) civil and hydraulic works;
3) electromechanical equipment;
4) connection to the grid.

The most important items are surely the purchase of electromechanical equipments and civil and hydraulic works. Each of these affects on average 40% of the investment value. Concerning management costs, the most relevant item is certainly maintenance (often outsourced to specialized firms), followed by periodic fees payable to public bodies (and any royalty in case of agreements with local administrations for environmental compensation).

The automation of the control is certainly a factor that contributes to management cost reductions.

Figure 6 reports an estimate of average management costs (in euro per megawatt-hours) in function of the annual production, made by the FEDERPERN association (for plants with high and low heads) put in comparison with those estimated by APER association, with an all inclusive tariff (220 euro megawatt-hours) and with a guaranteed minimum tariff established by the authority for electric energy and gas (AEEG). Costs also include plants depreciation ..

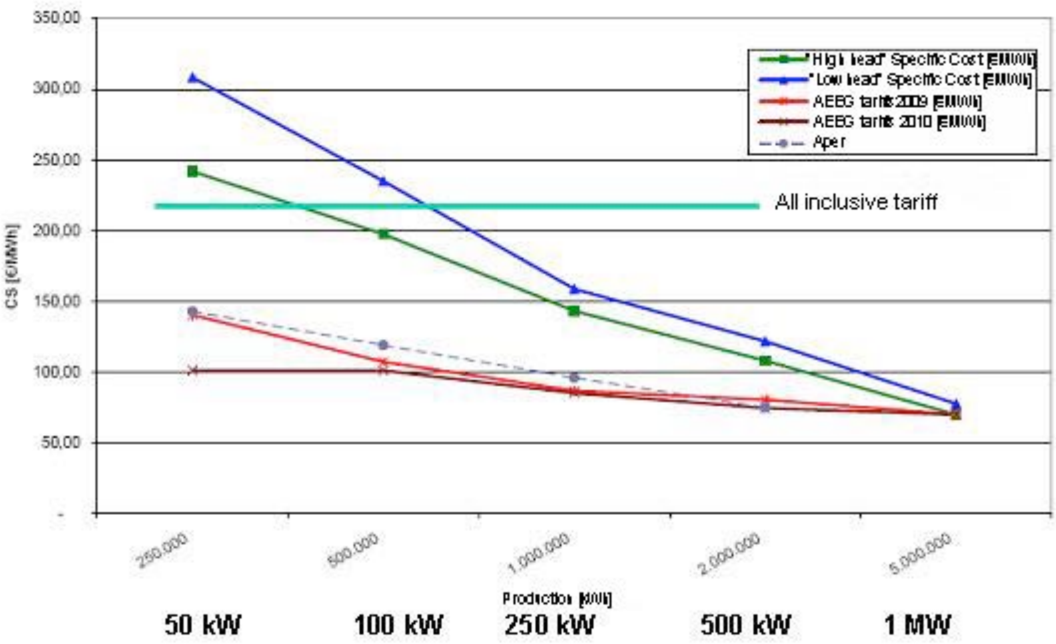


Figure 6 – Estimate of the function cost for mini-hydro power plants. Source: FEDERPERN (2011).

Plants at high head (that is with a prevalence higher than 80 meters) usually use Pelton turbines, that are less costly.

We can notice how the presence of economies of scale make the all inclusive tariff totally advantageous for larger-size plants, whilst average costs result higher for small-size plants.

3.8 The production chain

The industrial chain of the mini-hydro power can be described in two main sectors, and in a series of ancillary services, as reported in Figure 7.

Managers of plants in the world of hydroelectric power are very fragmented (at 1/1/2011, 982 accredited agents existed in Italy at GSE for the access to public incentives) and can be distinguished in four categories. The first is represented by utilities that carry out as a main activity production and injection of energy into the grid. They manage more than anything else plants of greater dimensions, and have diversified portfolios in alternative energy sources. We then have private investors, that tend to be specialized in mini-hydro power, and mainly seek a remuneration at low risk of invested capital. The third category is represented by local bodies and consortiums in the public sphere, that use control on territory and on water sources through aqueducts and irrigation canals to obtain an additional source of income, that, however, does not represent the main activity in reference. For this reason, often, they make use of a private specialized *partnership* or of utilities. Finally, we have subjects such as businesses, micro-businesses (huts, farms) or consortia of users that exploit hydro power essentially for self-consumption, with the objective of reducing energy costs.

The management and maintenance (*service*) support is generally carried out by the same business managers, or by multi-year contracts to specialized firms.

Concerning ancillary services, the design is in the hands of offices with specific technicians, that deal with both gross system design of the plant and economic and technical evaluation, but mainly of geological and of water studies which are needed to observe the reliability of the plant, the environmental impact, the theoretical annual production. We then have suppliers of the mechanical and electrical parts, that generally offer "*turn-key*" solutions using in turn a network of sub-suppliers for the single components (turbines, impellers, over-gear systems, alternators and transformers, switchboards, tele-control systems). It is about a very focused industry, both in Italy and abroad, because necessary skills for designing a plant of quality are very specific and a certain experience is needed especially in regards to the evaluation of the efficiency of the turbine, that is estimated based on historical data, or simulations of fluid dynamics, or in a laboratory with scale models.

A different matter goes for civil works and hydraulics, as they are usually contracted out to local companies.

The integration degree along the industrial chain is increasing, as different companies, since long active in one of these sectors, are conducting acquisitions to occupy spaces both at the start (managing their plants, even maybe abroad where there are higher development opportunities) and at the end (ensuring the supply of electro-mechanic components).

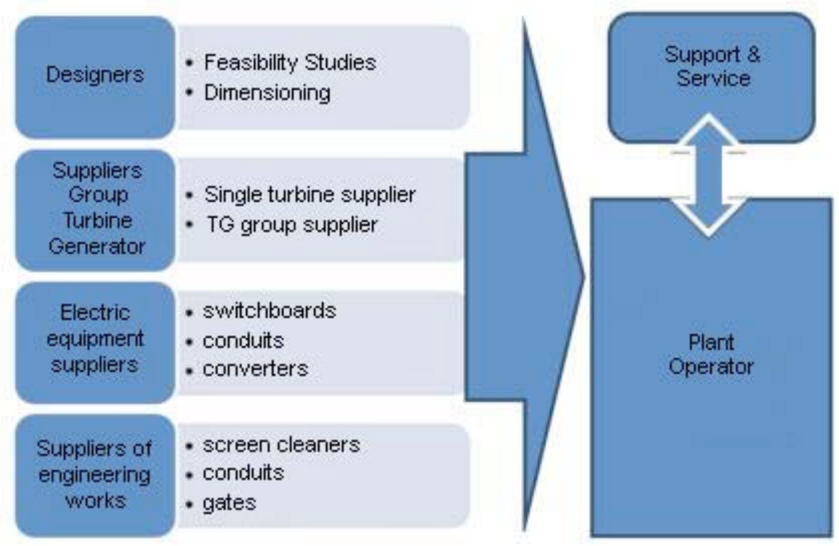


Figure 7 – The industrial chain of mini-hydro

The survey carried out by the Milan Polytechnic – Territorial Pole of Lecco under the aegis of the Silvio Tronchetti-Provera Foundation – has allowed to interview the most important *player* existing on the

Italian market in the business area of plant construction and to segment the market according to two dimensions: the market served (distinguishing between National, European and Worldwide markets) and the plant typology (of large, medium or small size). A not exciting framework came out in the Italian industry, and mainly for the Lombardy one, that in the past could boast excellence in the hydroelectric power sector now abandoned or absorbed by international groups, but that was able to partially recuperate thanks to the activism of entrepreneurs with distinctive skills in related fields(often plants, electricity, or civil construction sites) who have been able to take in time mini-hydro opportunities.

The three industrial giants at a global level, leaders in the market of large sized plants, are Andritz VA TECH, Voith-Siemens e Alstom.

The key companies of national importance, that have purchased also some spaces out of the borders, are: Franco Tosi (today purchased by the Indian group Gammon), the well-known De Pretto of Schio (today in the MAN-Sulzer group), STE Energy, Zeco, the Cover of Verbania (whose mini-hydro division has been acquired with a majority investment by the *private equity* fund Palladio Finanziaria). In Piedmont a good slice of market is the preserve of Scotta from Cuneo (that has invested directly in numerous plants managed, even abroad, and has concluded a strategic agreement with the research center Turbo Institute of Ljubljana) and of IREM for small plants, and also "portables". The Trentino Alto - Adige region can boast centers of importance like Troyer of Vipiteno and the Tamanini. in Lombardy, we have to put in evidence the Camuna installation of Pisogne, that quickly integrated from design to "turn-key" supplies , investing directly in Albany.

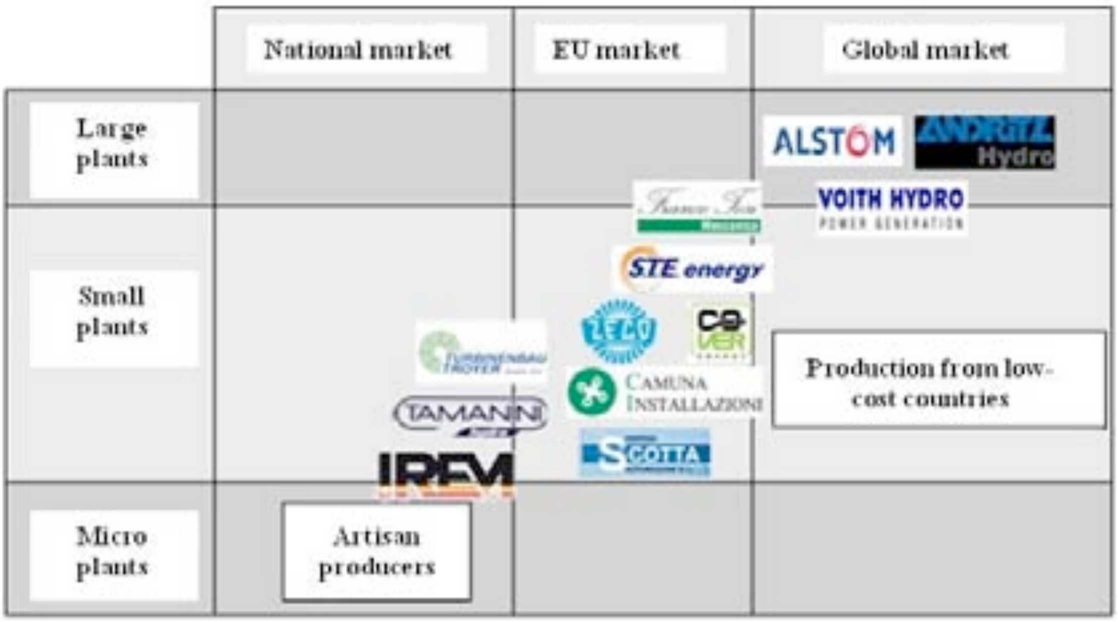


Figure 8 – Competitive matrix in the supply business of mini-hydro power plants

In recent times also the entrance on the Italian market of producers from low cost labor countries, like China, through representative and local importers, has been recorded. Results aren't always satisfying compared to the price advantage, in particular in respect to quality and reliability of the mechanic components.

Finally, on the national territory there is a multitude of micro-businesses specialized in supplying "standardized" small size plants, also of portable type.

3.9 Potentials for the future

Research has been made that has tried to estimate the potential of mini-hydro for the future in Italy. The National Plan for renewable energies of the Ministry of Economic Development published in 2010 shows the objective of new installations for about 581 MW in the next few years. The European Small Hydro Association (ESHA, 2010) estimates for Italy a much higher potential, 2500 MW. ARPER (Association of Producers Energy from Renewable Sources) indicates a potential between 1500 and 2000 MW whilst FEDERPERN (that groups almost exclusively operators of mini-hydropower plants) indicates a range between 1500 and 3300 MW. In reality are estimates that relate to the theoretical potential, but in reality everyone admits that is concerns not easily attainable goals, mainly for the complex authorization procedures and for the substantial moratorium that is in force for new installments in some territories. In the research carried out at the Territorial Pole of Lecco of the Milan Polytechnic and financed by the Silvio Tronchetti-Provera Foundation more than 1000 requests for new authorizations have been recorded in the Italian territory in date 1/7/2011. In the same way it is estimated that the "attainable" potential in 10 years' time is that of adding a further 1000MW to installed power. It is a negligible percentage in respect to the current availability (equivalent to 5% more in National production from hydroelectric energy, and to an increment of less than 1% in National production from renewable sources), but which is equivalent to the possibility of avoiding CO_2 emissions in the atmosphere for about 3700 tons a year. It also equal to a potential value of new investments for about a billion euro. There are in fact some difficulties that hinder a complete exploitation of existing potentials. Firstly, the hostility of the local population, in some mountain valleys, in respect to further exploiting of

natural streams, also on a small scale. In fact, it is about protecting tourism and the ecosystem and avoiding that stream water is subtracted from the environment. Secondly, completion for the award of concession is usually very high, and it is not rare that the development of new plants is hampered by claims and contentious that delay construction. Finally, it can happen that there are disputes in skills between private and local bodies, claiming a role in decision making.
On the other hand, there are some areas in which an easier development of new initiatives can be seen. This can refer to mountain aqueducts for instance, where it is possible to install plants with particular characteristics, that enable to recuperate energy where tank rolling is usually inserted used to reduce the strong pressure (that would damage households, but with an energy dissipation that could be recuperated). The research group of the Milan Polytechnic identified dozens of municipalities and local bodies that (directly or through multi-service companies or concessions to private use) have installed hydroelectric plants or have started an authorization process in this respect. A strong determinant in this case is the constraint imposed by the stability pact for local bodies, with progressive large cuts in state transfers to municipalities, that has led many mayors to seek alternative income opportunities. Also on flat land there are interesting potentials, and only partially used. The agricultural consortia reclamation and water management, federated in the National Association ANBI, are engaging with zeal to promote in their areas of competence the recovery of old mills and factories, as well the installment of small power units on intake channels, where favorable head conditions exist. To date many as 16 consortia ANBI result credited to the GSE for the withdrawal of energy produced, and the total power installed of the 116 plants managed is equal to about 50 MW. The consortia with the highest number of plants in operation is the Consorzio Est-Sesia based in Novara.

On occasion, educational and museum pathways are equipped, integrated with cultural and gastronomic ecologically sustainable itineraries. The Cremona Province , participated in a project funded by the European Union, SMART, to identify in the area suitable sites for hydroelectric plants. Another border area is the exploitation of water heads at the discharge of purification plants and those of water treatment. Crucial for the development of the new mini-hydro installations in Italy is the framework of government incentives that will be defined in Autumn of 2013. It should not then be forgotten that the necessary requalification of existing plants, both of small and of large dimension, must be made to maintain efficient the civil structures and the barriers (which in some cases are ultra-centenary and that pose problems also for the resident populations). This also will be an occasion for a strengthening and for an efficiency of the production, which may further contribute to the development of production of renewable energy. Separate attention is needed for   pumped storage power stations (which essentially serve as a basin for energy storage), which will require a strategic indication at National level, in function of macro-policies that the National system will undertake.

4. WIND ENERGY

By Francesco Strassoldo

Man has learnt to use kinetic wind energy since the beginning of history. It is sufficient to remember sailing navigation in ancient civilizations, that have favored trade exchanges and new territory discoveries. Wind energy has been, up until recent days, the main energy source used to power windmills destined for wheat and olive grinding and for pumping water from wells.

More than 8 million windmills were present at the end of the 19th century in the immense Midwest planes in rural American areas. At the beginning of the 20th century, many wind turbines that used mechanic energy to generate electric energy were installed in the US. In the '30s and '40s, networks able to distribute electric energy throughout the territory from production points were put into action and led to the progressive diminishing of wind turbines.

From the beginning of the '70s with the first oil crisis, interest in wind plants re-awakened and led to the development of wind farms in Denmark and in the US, with a continuous growth trend that spread also to other European Countries. This trend produced a significant development of the installed power in the last 10 years. The already consolidated technologies, together with generous supplies of such an energy source, led to claim that wind energy could satisfy a good part of the needs of electric energy in many Countries in the future.

Wind is the movement of masses of air on the Earth's surface mainly generated by different air pressure between two adjacent regions. Atmospheric pressure differences are caused by a diverse heating of the Earth's surface caused by thermal energy produced by incident solar radiation. Therefore, wind energy comes from solar energy. Approximately 2% of intercepted solar radiation by the Earth is converted into wind energy.

Air in the troposphere that extends from the ground to a height of about 10-15 km – respectively to the Poles and to the Equator – is warmer in the equatorial areas in respect to the polar ones. Air heating causes the diminishing of its density and generates rising currents that lead almost to the limit of the troposphere to a spreading towards terrestrial poles where due to the effect of cooling, goes back down to ground level. On the base of this principle, simple air circulation from the Equator to the Poles develops – and this happens in reverse at less elevated heights – terrestrial rotation operates in a way that the direction of the air, as it gets closer to warmer areas, is deviated – Coriolis Force – taking up prevalent directions in relation to the estimated latitude. These winds are generated by the movement of great air masses as a result of the phenomena described above.

Morphological characteristics of the territory and of the environment affect the direction and energy given by the wind. Local winds can be divided in two main categories: coastal winds on-shore and off-shore and winds from mountains and valleys. The former are generated along the coasts of seas and lakes and present a certain regularity during the course of the year that allows a constant supply of wind energy. The latter present a Summer prevalence, when solar radiation is more intense. Both are generated by a different heating of the terrestrial surface. An example of these specific local morphologic conditions, that influence considerably the intensity and the prevailing direction of the wind, is represented by the Apennine chain in central Italy. In this area, by the effect of different atmospheric temperatures connected to the Tyrrhenian and Adriatic basins, a particularly accentuated windiness is produced in respect to the national territory's average.

Figure 1 represents the annual average windiness conditions on the Italian territory. The most interesting areas for the installation of wind plants result to be the islands, the southern Italian coasts and the northern Tyrrhenian. The average annual speed of the wind is instead moderate in the Po valley. For example, in the Emilia region, we can find a speed in the order of only 4 m/s in the valley, but that can reach values of 7-8 m/s in the Tuscan-Emilian ridge area where in fact we have a concentration of wind plants installed.

When the wind blows in ground vicinities or on the sea surface, it causes a friction phenomena to arise due to the presence of a boundary layer whose height depends on the irregularity of the surface. This is an effect that can be detected up until a height of 500 meters from the ground, but whose importance, for the purposes of setting a wind turbine, is detectable within the height of 20 meters. For this reason, the machines are generally installed on towers of the height of 20 to 50 meters and in woodlands at even higher altitudes. Forests and mountains, in fact, reduce the wind's kinetic energy, in the same way as buildings do in big cities. It is therefore considered that a correct collocation of the wind generator is particularly important, as one has to find sites free of turbulences generated by obstacles – trees, buildings, etc. – and by frictions generated from the ground.

In brief, there is a higher disposition of wind energy at elevated positions and where no obstacles are present in the ground: in the planes, on-shore and off-shore.

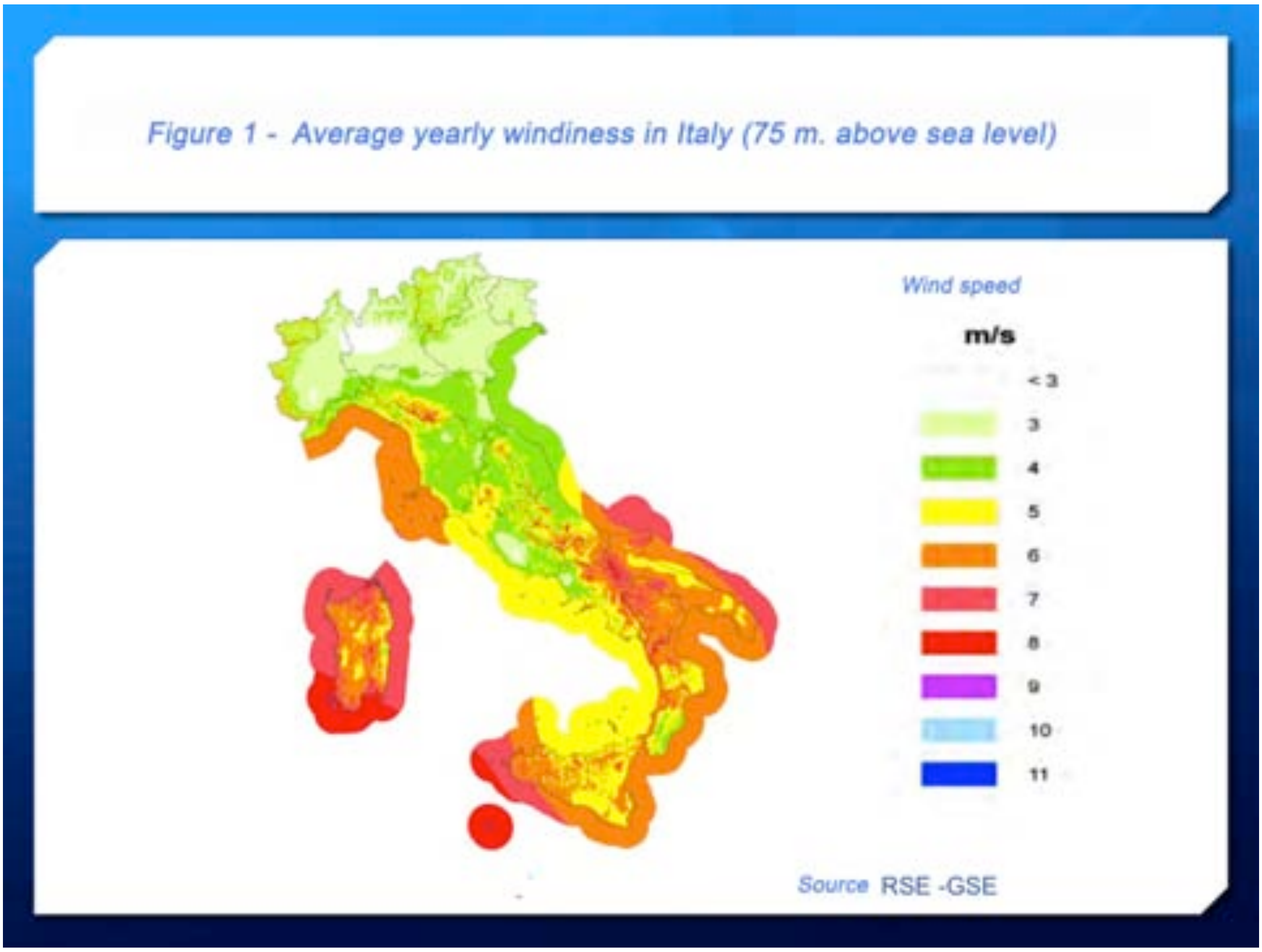


FIGURE 1 - ANNUAL AVERAGE WINDINESS (75m. on sea level)

1) Wind speed (pag72) Source RSE-GSE

4.1. OPERATING PRINCIPLES AND PLANT CLASSIFICATION

Wind turbines use the kinetic energy (Ec) of air masses. This energy is intercepted by rotor blades. The wind passes along both sides of each blade and generates a difference in pressure between the two surfaces, creating an aerodynamic lift. This lift, that on the wing of an airplane enables its lifting from the ground, in the "aero generator", thanks to constraints, generates a couple that produce a rotation around the hub. The rotor, therefore, converts the kinetic energy into mechanical energy rendering it available on a rotating hub that then rotates at the same angular speed.

This slow rotating main hub can be connected through a gearbox to a fast countershaft that sets the rotor of the alternator to rotate to then convert mechanical energy into electrical energy. Generally alternating current is produced with characteristics - intensity and effective voltage – that are then corrected by electronic components (inverters) to allow the connection to the grid.

The available kinetic energy is given by:

$$Ec = \frac{1}{2} m \cdot v^2 wind$$

The air mass m that reacts with the rotor can be calculated as:

$m = A\ v\ \rho$

Where A is the area drawn by the rotor, v the speed of the wind and ρ the air density. It can be assumed that air density, in the lower layers of the atmosphere, varies with the height of about 1% every 100 meters. It varies slightly also due to temperature and humidity but such variations result irrelevant for energy purposes.

Developing the formula we can obtain that the energy available varies with the cube of wind speed and with the square of the rotor's diameter. The power produced has therefore a cubic proportionality to intercepted wind speed and is linearly proportioned to the area swept by the rotor's blades. In designing a wind energy implant, it results to be quite critical the correct identification of a site with high windiness and the evaluation of the actual electric energy demands of the users, rather than a use of wind energy generators with efficiency peaks.

It has then been demonstrated (A.Betz) that only one part, and precisely 59.3%, of kinetic energy held by air can be theoretically caught by the rotor of a wind energy turbine and therefore converted into mechanic and electric energy. If it were to deliver all its energy, wind would reduce to zero its speed immediately downstream the rotor. In reality, air, passing through the rotor, undergoes a slowdown and delivers therefore only a part of its kinetic energy.

The limit fixed by the coefficient of Albert Betz

C_{Betz} = Extracted energy / Available energy = 0.593

is experimentally confirmed by the fact no wind turbine designed up until now has been able to overcome such a limit. Downstream of this reduction due to physical principles, the global efficiency of the wind energy generator has to be considered. In practice, the efficiency in collecting energy by a rotor is between 35% and 45%. The electric generator as a whole (rotor, transmission, generator, etc.) makes available from 10 to 30% the wind energy. Therefore the mechanic relation provides a correlation between energy available and wind speed with a cubic proportionality, the actual increment of power in an wind energy turbine proves to be little more than linear.

The following table gives a draft indication on different sizes of wind energy turbines and on the application fields:

POWER OUTPUT	ROTOR DIAMETER[m]	TOWER HEIGHT[m]	APPLICATIONS
100-500 W	1<d<2	2<h<6	Small and isolated users
From 1 to 6 kW	2 <d<5	6<h<8	Isolated users Or connected to the electric network
From 6 to 60 kW	5 <d<18	8<h<30	Users connected to the electric network (civil, farms and industries)
From 61 to 200 kW	18 <d <30	30<h<60	Users connected to the electric network (civil, farms and industries)
From 201 kW to 5 MW	30 <d<80	Over 60	On-shore and off-shore large plants to generate electric energy

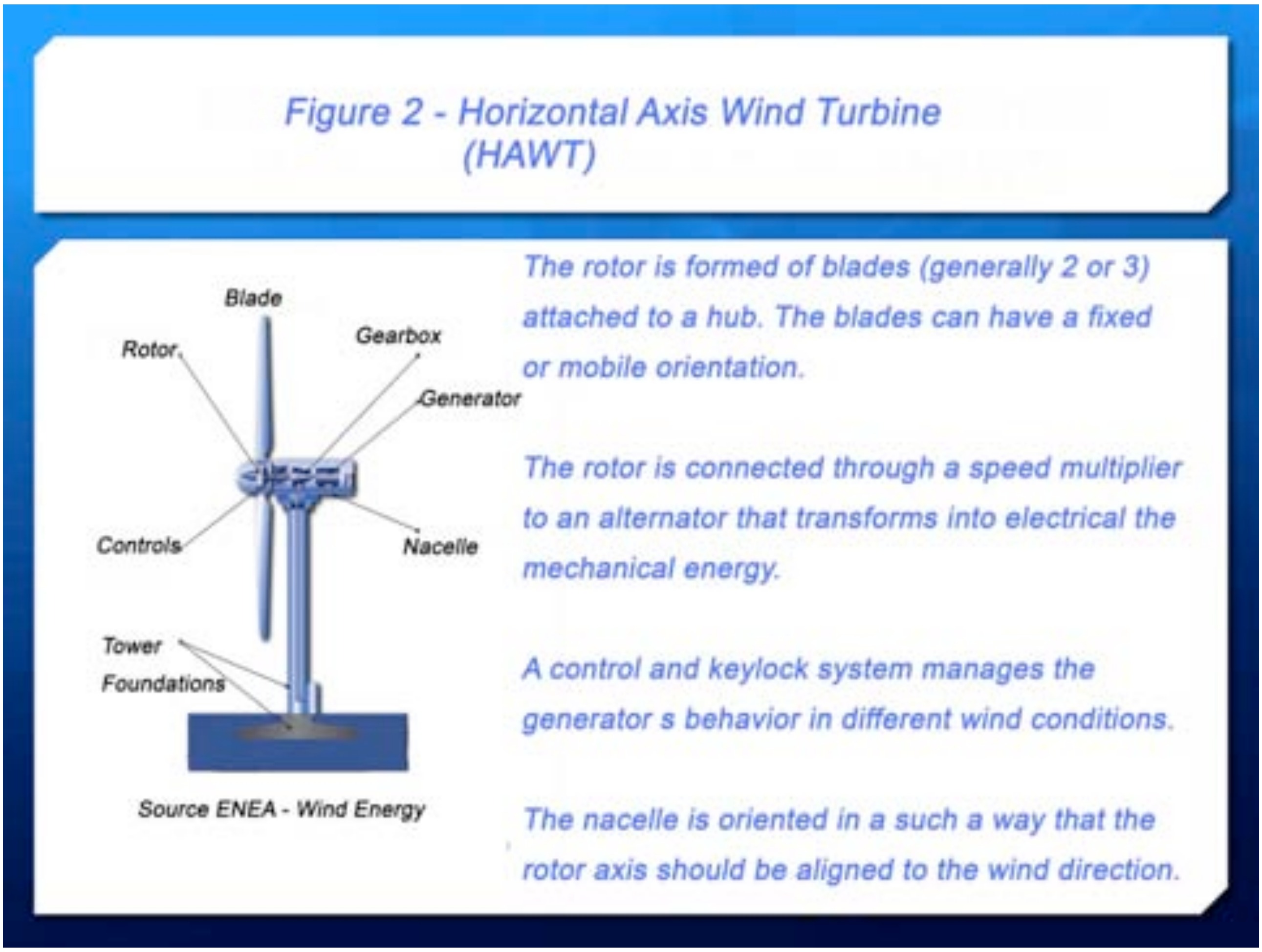
Table 1 – Plants classification on the basis of installed power

Wind energy plants can be classified also in reference to the rotor's disposition, horizontal or vertical. Horizontal axes plants HAWT (Horizontal Axis Wind Turbine) are more common and come from technologies of large wind energy plants. The rotor (usually 2 or 3 blades) is perpendicular to the ground and orientates the axis with the wind's direction. Vertical axis plants VAWT (Vertical Axis Wind Turbine) instead, present the rotor in various shapes and geometries according to the technical solution found by the designer. The blades of a vertical axis turbine are connected to the central axis, in turn connected to an alternator. They have interesting characteristics in terms of sturdiness and noise but are generally more expensive and less efficient than the previous ones. On paper they present the advantage of a less critical positioning and a running independent from the wind's direction, but in actual installments they have proved to be less efficient and less reliable.

4.2 Wind Turbines

The rotor is the component which interacts with air (Figure 2) . It usually consists of two or three blades that rotate around an axis at a speed determined by the wind and by the shape of the blades themselves. Blades are made with synthetic plastics (for example plastic reinforced by carbon fibers or glass fibers) particularly resistant and relatively cheap. As anticipated, blades are designed according to the same principle as the wings of an airplane. When the air flow interacts with the blades, due to the wind a difference in pressure is generated between the inferior and superior part. As the blades are fixed to the central axis, the lift generates a torque that sets the rotor in rotation. The blades of the machine, are fixed to a hub. The hub is connected to a shaft that rotates at the same angular speed of the rotor. This slow shaft is connected by means of a gearbox to a fast shaft, downstream of which the electric generator is connected.

Blades have a life of more than twenty years and don't interfere with electromagnetic signals. The diameter of the rotor, as already mentioned, is an important measure to evaluate productive potential of electric energy by the machine. The rotor's blades can rotate at peripheral speed that touch 200 km/h. By increasing the number of blades, the speed of rotation decreases, while performance, the uniformity of the torque and together with it the price, all increase. Last generation wind turbines install a motor of 3 blades, that represents the optimal solution to a good compromise, but products of 1-2 blades are available on the market. Two blade turbines are lighter and less expensive, they operate with at a higher speed of rotation the energy produced being equal, but appear to be noisier.



Turbines are usually designed to express a maximum power and a determined speed, chosen in function of the site's anemology features and it corresponds to about 1.5 times the average speed registered.

All the components are positioned in a container called nacelle, adjustable in function of the direction of the wind. The whole nacelle is placed on a bearing set on the tower, in a position able to be adjusted according to wind direction.

The tower is usually composed of a steel pylon of a height variable between a minimum of 2 meters (small systems of a few hundred W) and a maximum of over 60-70 meters (wind generators with installed power superior to 200 kW). The height of the tower is conditioned by surrounding obstacles and also by law restrictions enforceable to the site. From a functional point of view, the higher is the height of the tower the more the intensity of intercepted winds increases and therefore arises the need of confronting the incrementing of energy produced with that of realization costs. The height of the tower allows to intercept wind flows where they suffer less the presence of the ground or of other obstacles. The tower is fixed to the ground by iron-concrete foundations that sustain it during oscillations.

The generator converts the movement of the blades in electric energy. It is able, according to design characteristics, to produce alternating or direct power.

The control system of the generator and of the inverter, are electronic devices which manage the operating of the rotor-generator system in all wind conditions and allow the adjustment of electric energy produced to the characteristics of the electrical grid. The control system of the nacelle enables to keep the rotor's axis geared in the direction of the wind. Power control enables to vary the inclination of the blades increasing and decreasing the torque generated. The start and stop of the machine determine the operative range according to wind speed. Control systems are prepared also to prevent overheating and damage to the generator in conditions of high windiness, reducing the rotor's speed. Usually two solutions are applied: a different adjustment of the rotor in respect to the wind's direction and a change in the angle of the blades. Naturally even a block system exists in case of high speed winds during violent atmospheric events. In the phases of reduced windiness, when the machine could produce an irrelevant quantity of energy, also a function that prevents the starting of the rotor under a determined wind speed exists. The minimum threshold, called cut-in, is generally set at a wind speed of 3m/s and depends on characteristics of the wind turbine, on its dimensions and on the technology used. The maximum threshold, called cut-out, defines the stoppage conditions of the rotor to avoid damage to the turbine.

We report by way of example characteristics and maximum dimensions of some "sizes" of wind energy systems.

Commercial wind generators with power around 1 kW are composed of a turbine, a metallic support pole anchored by tensions roads, inverter, electric components and battery. The diameter of the rotors is of about 2-2.5 m. They are horizontal axis generators, the blades usually in plastic or fiberglass and tubular tower with heights variable between 10 and 30 m. The wind's minimum speed needed to operate the blades' movement is 3m/s.

Turbines with power from 10 to 20 kW can feed batteries or be connected directly to the grid. Horizontal axis wind generators, with three blades, present a rotor diameter between 5 and 8 m, a support tower of a height between 20 and 40 m and a wind activation speed of 3 m/s.

Turbines with power from 50 to 100 kW are connected directly to the grid, without accumulation systems, mainly due to costs and dimensions. They are vertical axis wind generators, three blades and support tower between 30 and 40 m. The diameter of the rotor can vary between 15 and 25 m. The operating conditions are put into action by a wind speed of 4 m/s.

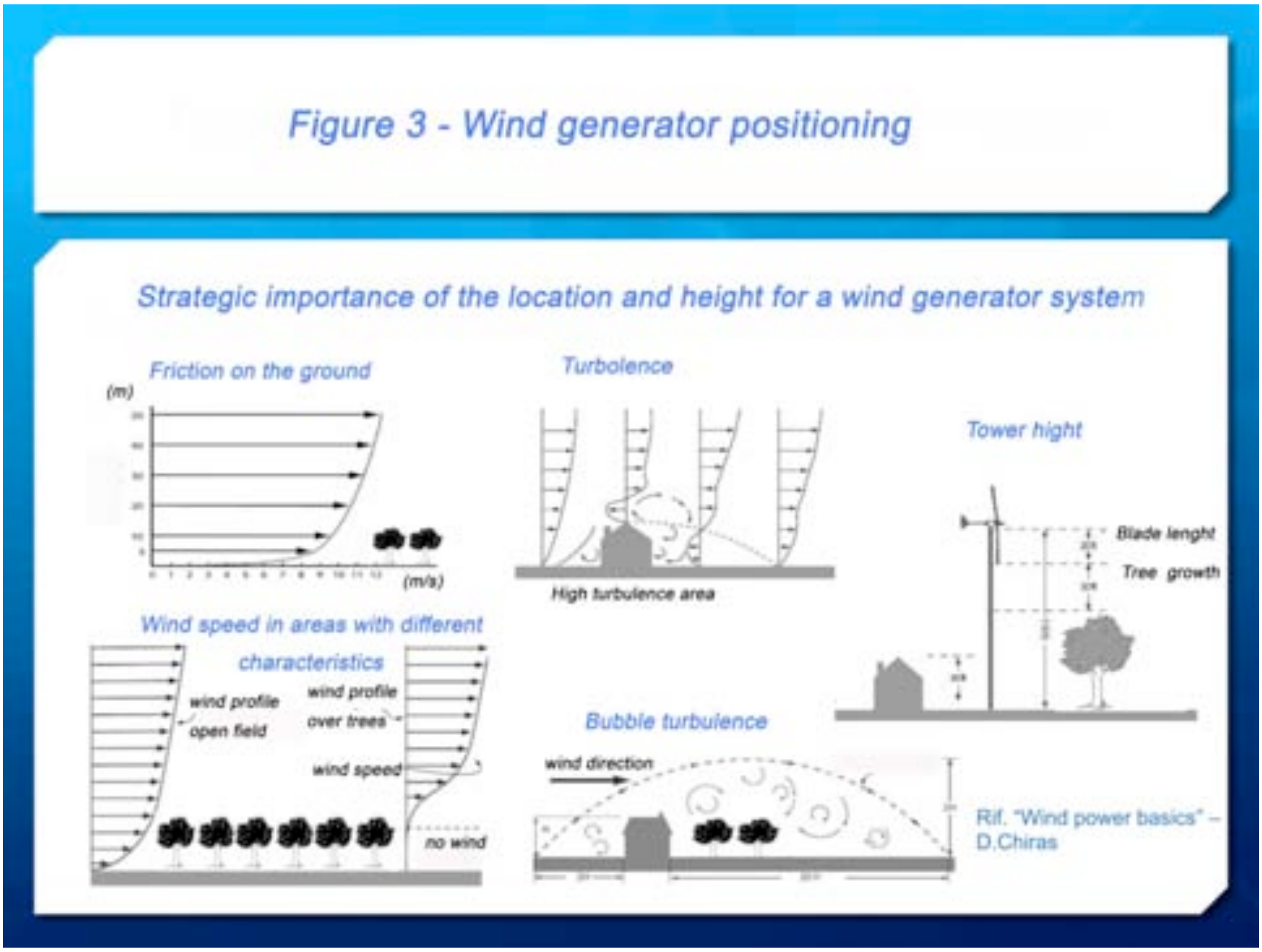
To avoid damage to the turbines a maximum speed for the rotor to stop is set, which varies based on the construction features of the rotor but roughly it is set over 25-30 m/s.

4.3 Evaluation of site windiness

Sites have to be selected with attention based on climatic data available, relying also on biological indicators (on the possible inclination of trees and plants), geomorphologic (natural obstacles and artificial ones such as terrain, presence of long-stemmed vegetation, buildings) and on the possible historical memory of residents. Also an exam on possible existing constraints has to be developed (environmental, archeological, public federal property).The definitive identification of the site could also require a survey campaign of speed and wind direction. Accessibility, vicinity to electric lines and users' positioning (especially in the case of mini-wind energy) are other important factors for a correct project estimation. In general, sites considered interesting are those which guarantee at least 80-100 days of wind a year (1900-2400 h/year).

Wind site evaluation is the estimate on a yearly basis of average wind speed. An important analysis instrument in this extent for installations on National territory is represented by the wind energy interactive Atlas made by ERSE (ENEA Research on the Energy System http://atlanteeolico.erse-web.it/viewer.htm) that provides applications able to quantify, with a good approximation, the number of equivalent hours yearly in the geographical area under consideration.

Considering a bounded area of territory it is possible to find that wind doesn't flow in a homogeneous way on the surface but encounters some resistances that generate friction. This causes wind speed reductions in a different way according to the ground roughness. The more the surface is irregular, the greater the friction (figure 3). It is always to be remembered that an increment in wind speed is able to offer an important increase in the quantity of energy generated by the turbine.



As previously mentioned another important aspect is the turbulence, produced when the air flow encounters objects like trees and buildings with an effect that can be compared to the water flow of a creek against a rock. A correct positioning of the machine avoids in this case potential damages. The turbulence can be minimized by positioning the turbine on a lift-up-tower. In this way we access at a height where wind speed results more intense and it is possible to avoid the "Turbulence bubble" generated by obstacles present on the ground. As an indicative reference, the rotor has to be positioned at a height superior to at least 10 meters in respect to the nearest obstacle within 150 meters above the trees' line.

4.4 Advantages of wind energy

A wind plant enables to transform kinetic wind energy into mechanic energy and from this, by means of an electrical generator, into electric energy, through installations of moderate dimensions for mini-wind energy plants. There are multiple advantages offered by these plants:

-wind is a strong renewable energy source that doesn't produce unhealthy emissions or climate altering

-a consolidated technology is used, that is also reliable and economically competitive, with further potential improvements.

-it enables distributed generation of electric energy with all the benefits in respect to vicinity of the energy production site with that of use

-it doesn't occupy very vast areas and it has a limited impact both in terms of height and encumbrance. The areas can be used for agriculture and breeding, as usual, and recuperated at the service life end. Also acoustic emissions are, in general, limited

-wind turbines don't consume water (contrary to conventional and nuclear plants) and can therefore be used also in dry and desert areas

-wind turbines don't produce unhealthy emissions and contribute in reducing acid rains, global warming and don't cause health damage

-wind turbines are safe and accident free for the population

-wind plants have a long service life (20-25 years) and maintenance costs are limited

-global efficiencies are usually high

-the wind energy sector can create new employment and enables to develop a new productive National chain with important export opportunities

-wind energy can enable to achieve targets enforced by European regulations for the Italian production share of energy from renewable sources.

The main advantage is given by the fact that wind energy primarily is free and production costs for electric energy are already now competitive with conventional plants, enabling a reduction of dependence on energy supplies from other Countries.

4.5 Obstacles to the development of wind energy

As all renewable energy sources, wind is an intermittent low density source and therefore it has to be integrated by other energy sources. Besides this aspect, the visual impact is usual one of the main obstacles to the development of wind energy. In sites relevant from an environment and landscape

point of view it would be appropriate to avoid installing wind energy systems. If we consider, instead, a "normal" context, we would verify that wind energy systems do not bring further damages to urban and rural areas usually already affected by industrial buildings and civil works of low aesthetic quality and environment compatibility. If we further consider that the production of electric wind energy doesn't release any unhealthy emissions or climate-altering and it in fact reduces emissions in the atmosphere of conventional thermal electric plants and long term damages for people's health. The aesthetic problem linked also to the visual impact on structures, not yet ordinary, could be reduced by off-shore wind farms and the use of components which present neutral colors and regular geometries in a way that such wind energy structures integrate in the territory. This problem is obviously of a lesser extent for mini-wind energy that for its dimensions is less "visible".

Another aspect is given by the noise generated during service by electro-mechanic components and by the blades' rotation. In reality, often, background noise caused by wind, covers the noise of the same generators and in high potential plants disturbance perceivable at a relatively short distance can be compared to normal conditions of urban noise.

Electromagnetic interferences can be caused by blades in motion when designed with metallic materials. A correct implant location, far from telecommunication repeaters, together with the use of non-metal components in designing turbines, is in case sufficient to avoid these problems.

One problem is the impact of wind energy plants on bird fauna. Birds can be killed in the collision with blades in motion. Various studies on this subject have highlighted that this phenomena, not at all irrelevant, is less important than others as a bird mortality cause. As a first cause of mortality there are ordinary buildings and windows, pet cats, power lines, vehicles, pesticides, and last but not least, hunters.

A recent study has quoted the cause of mortality by wind energy plants as being 0.3% (P. Erickson). A Spanish study, carried out around an important wind energy site, has observed that birds have an ability of adaptation to new obstacles given that in time an important reduction in mortality on the site has been recorded.

4.6 Wind energy systems and connection to the grid

Wind energy plants can be subdivided in three categories according to their connection to the National electric grid: plants connected to the grid, plants connected to the grid with storage batteries and not connected plants.

Systems connected directly to the electric grid deliver surplus energy in respect to the users' demand. When the system isn't on service, the grid delivers to the user the necessary electric energy. The dimensioning of the generator for a determined installations depends obviously on the necessary energy and on windiness conditions on the site. In general a wind energy system is dimensioned to supply between 25% and 75% of the users' needs.

In some of these systems, the wind energy generator produces electric energy in alternate power with a frequency and voltage which vary with wind speed (wild AC). The more the speed of the blades increases, the more the voltage and frequency increase. In a connection with the grid these quantities have to be converted into standard values with a controller and an inverter. Also wind energy generators at induction exist, which produce AC power already compatible with the grid and therefore that do not need further "adjustments".

Systems connected to the grid without batteries represent a more used solution also because they are simpler, with less need of maintenance and reduced costs. Furthermore they can virtually store on the grid all exceeded energy produced, without suffering from leakages and wastes due to energy conversions (from electric to chemical and vice-versa) typical of batteries. Moreover batteries contain potentially toxic components that if not well-disposed of, once finished working, can damage and pollute the environment. However, systems without batteries can resent of eventual situations of the grid's malfunctioning.

In areas in which the grid presents frequent interruption, a system with a battery backup can guarantee a continuous supply of electric energy. In this case the bank of batteries has to make up for critical phases and therefore be of moderate dimensions .Obviously part of the produced energy by the wind energy generator (around 10%) will be destined to keep the bank of batteries in charge. Also a charge controller will be necessary for the system.

The negative aspects of this solution in respect to the direct connection to the grid are of greater cost, lower system efficiency, lower environmental compatibility due to battery components - to be disposed of once exhausted - and greater need of maintenance.

All these critical issues are amplified in the course of an off-grid completely autonomous system, justifiable only in the case of an isolated installation far from the grid.

4.7 Italian legislations and facilitations in the use of wind energy

The 18/12/2008 Decree of the Ministry of Economic Development, published in date 2/01/2009 on the Official Gazette, has introduced important incentives on the use of electric energy plants from renewable sources.

In particular it defines that for wind energy plants entered in operation after December 3, 2007, with a nominal power up until 200 kW, energy injected on the grid can be incentivized, in alternative to green certifications and to the so-called scambio sul posto with a feed-in tariff of 0,30 €/ kWh for the duration of 15 years.

The feed-in tariff will be varied every three years with a Decree of the Ministry of Economic Development, ensuring the congruity of remuneration to the ends for incentives of renewable energy sources.

At the end of the 15 year period energy produced can be sold to GSE according to the procedure of the so-called "ritiro dedicato" (article 13 Legislative Decree 387 of December 29, 2003) or benefit of the so-called "scambio sul posto". This last mechanism determines costs and economic benefits for the injection and withdrawal of electric energy on the grid and is regulated by the "integrative text of technical-economic procedures and terms for the so-called scambio sul posto" (TIPS), resolution of the electric and gas Authority (AEEG) nr. 74/2008. Energy produced by the implant and not used directly is recorded and injected into the grid. With a quarterly cadence the GSE, in case of positive energy balance injected into the grid in respect to that withdrawn, pays to the user the equivalent sale price.

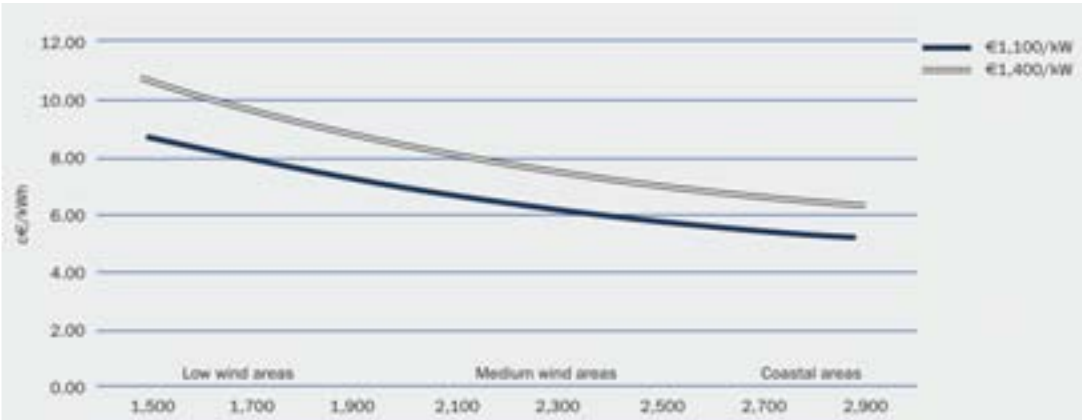
Also the approval process is simplified, with the Ministerial Decree of 10/09/2010 of the Ministry of Economic Development, published in the Official Gazette of 18/09/2010, containing the "Guide-lines for the Authorization of feed-up plants from renewable sources". The installation of wind energy plants up to 16 kW, in absence of territorial constraints, can be authorized against a Business Registration Start-up (D.I.A.) presented to the town of residence.

4.8 Electric energy production cost from a wind-energy source

Electric energy production from a wind-energy source has achieved in these last years, together with a technology maturity, first among renewable sources, an economic and competitive force against fossil fuel sources. Naturally this result is achievable in function of different factors like windiness and site location, dimension and use of the plants, typology of the user and all the environmental compatibilities characterized destined to favor the choice in respect to climate altering sources that can't be overlooked.

The cost of electric energy production is correlated to, in addition to the already quoted elements, the realization and management costs of the implant not to mention the service life of the same, that in various analyzed studies is estimated around 20 years, but in reality could reveal itself much longer. The graph in figure 4 taken from a recent EWEA (The economics of wind energy 2009) document, presents the cost of electric energy from a wind energy source in relation to the installation sites (equivalent hours of full power running during the year). It can be seen the due to abscissas intermediate values between areas of reduced windiness and medium windiness (approximately 2000 hours, corresponding to an average yearly windiness of 5-6 m/s), the cost of kWh produced sets between 6 and 8 c €/ kWh, values comparable to current costs of production of a thermal electric conventional power station. The two curves present installation costs of the plants per kW installed, values of inverse proportion to the dimension of the facility.

Figure 4 – Cost of electric energy (c€/kWh) from wind power source on the basis of location and investment cost



Hour/year at full power

Source: The economics of wind energy – EWEA 2009

For an evaluation of economic feasibility it is initially appropriate to estimate the average speed of wind per year on the interested site and its distribution around such a value. For the Italian territory we can refer to statistic data available (Wind energy Italian atlas – http://atlanteeolico.erse-web.it) rather than basing it on experimental measures of the site, that require long periods of surveys and measuring instruments economically not within any users' reach. Referring to figure 1 that presents windiness on the national territory, we can already distinguish at a glance, the areas in which realization isn't economically understandable, with an average annual wind speed inferior to 5 m/s. As already mentioned, the ones to be mostly considered are the islands, the coastal areas in the south of Italy, the north coast of the Tyrrhenian and particular areas on the Apennines favored by particular windiness.

Valuating criteria to verify the feasibility of a mini-wind energy plant in Italy, that consider also economic incentives previously described, are available on the "Mini-wind energy guide" arranged by ENEL GREEN POWER, an important national operator in the sector of renewable sources (figure 5). Let's consider the installations of a mini-wind power facility on a site with an average annual speed between 5 and 6 m/s with an expectation of electric energy between 1000 and 1800 kWh per year for every kW of installed power. In this case, the wind generator will have an annual functioning equivalent to the service at full capacity (to nominal power) of the duration of 1000-1800 hours. Let's consider a service life of the plant estimated to approximately 20 years, three different values of windiness of the site, a precautionary installment cost for an implant of 20 kW, the incentive at a fixed feed-in tariff of he first 15 years and the so-called "scambio sul posto" for the following years. We obtain investment return time around 7-9 years. If then we consider a more favorable windiness condition on the site, cost of installation and life service of the implant, we can easily reach economic estimates even now very favorable for the use of a mini-wind energy implant.

4.9 Global wind energy power installed at the end of 2010

The realization of wind energy plants at a worldwide level has had in the last decade a development that we could define explosive. Figure 6 taken from the "Global wind report 2010" of the Global Wind Energy Council (GWEC) highlights this evolution, with a temporary slow-down in 2010 due to the economic crisis. In the list of the ten countries that have installed the highest number of wind energy plants (figure 6), we notice that China had in 2010 a leading role with the installation in the course of the year of about half the total world-wide power.

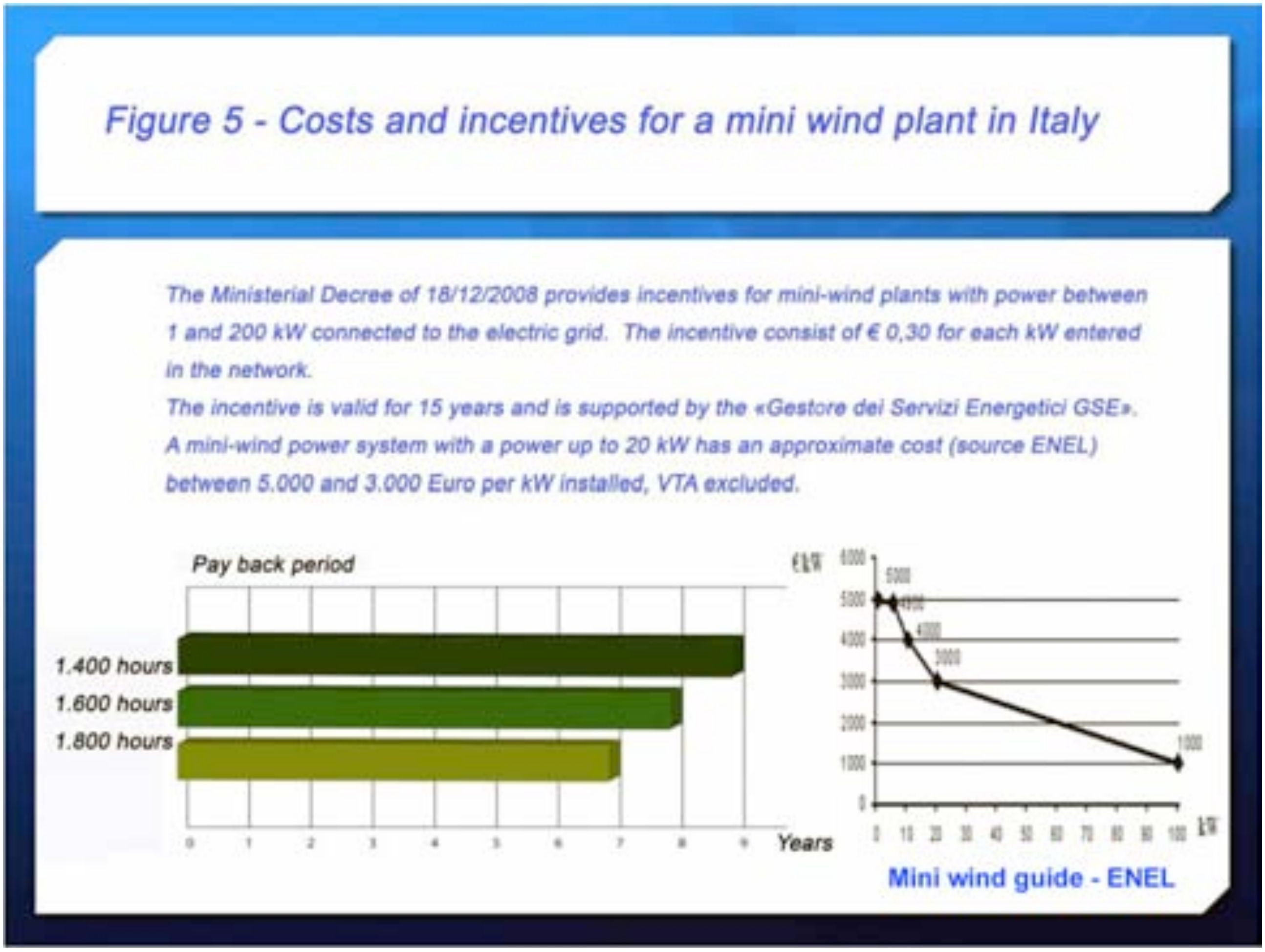
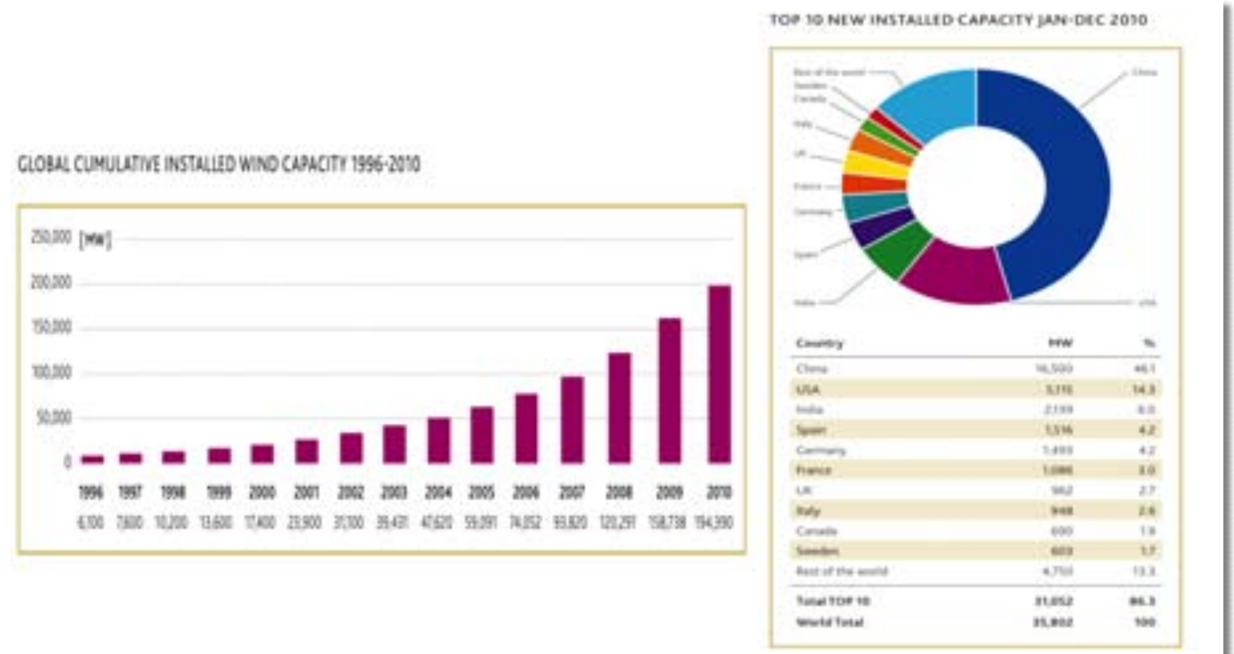


Figure 5 - Costs and incentives for a mini wind plant in Italy
The Ministerial Decree of 18/12/2008 provides incentives for mini-wind plants with power between 1 and 200 kW connected to the electric grid. The incentive consist of € 0,30 for each kW entered in the network.
The incentive is valid for 15 years and is supported by the «Gestore dei Servizi Energetici GSE».
A mini-wind power system with a power up to 20 kW has an approximate cost (source ENEL) between 5.000 and 3.000 Euro per kW installed, VTA excluded.
Pay back period
1.400 hours
1.600 hours
1.800 hours
Years
Mini wind guide - ENEL

Figure 6 – Global wind power installed (MW) by the end of 2010



Source :Global Wind report 2010 GWEC

Bibliography

Sources : ANEV, AWEA, IEA, CESI, ENEA, ENEL, EWEA, GWEC, Greenpeace, Iowa Energy Center, Parma University (A. Gambarotta), US Department of Energy.

5. Solar Thermal

By Francesco Strassoldo

The sun can be compared, in a conceptual signification, to a nuclear fusion reactor that converts hydrogen into helium.

The sun is seen by a terrestrial observer with an angle of 32’, and has a surface temperature equivalent to a black body, according to Stephan-Boltzmann’s law, of about 5760°K.

By positioning a black body of unitary surface oriented perpendicularly to the incident radiation outside the atmosphere, in reference to Stephan-Boltzmann’s law, an equilibrium temperature equal to about 120°C is obtained. This value has to be considered a theoretical limit reference, outside the atmosphere. At ground level, in addition to the atmospheric absorption which significantly reduces the solar radiation available (from about 1.4 kW/m^2 to a value inferior to 1 kW/m^2), conductive and convective losses become important for the air’s presence. Therefore temperature values so limited as to render difficult any practical use can be reached. For low temperature uses (flat collectors) special devices able to reduce the energy re-emitted from the absorber are necessary. For thermodynamic applications, which requires higher temperature, it is essential to increase the solid angle of the incident energy by adopting technological solutions that can concentrate the solar radiation on the absorber.

The different systems that convert solar radiation into electric energy through a thermodynamic process make up the technology of the “solar thermal”.

Direct solar radiation, properly concentrated on a receiver element, enables to heat a work fluid at high temperatures from which mechanical energy through a thermodynamic cycle can be produced and subsequently converted into electric energy.

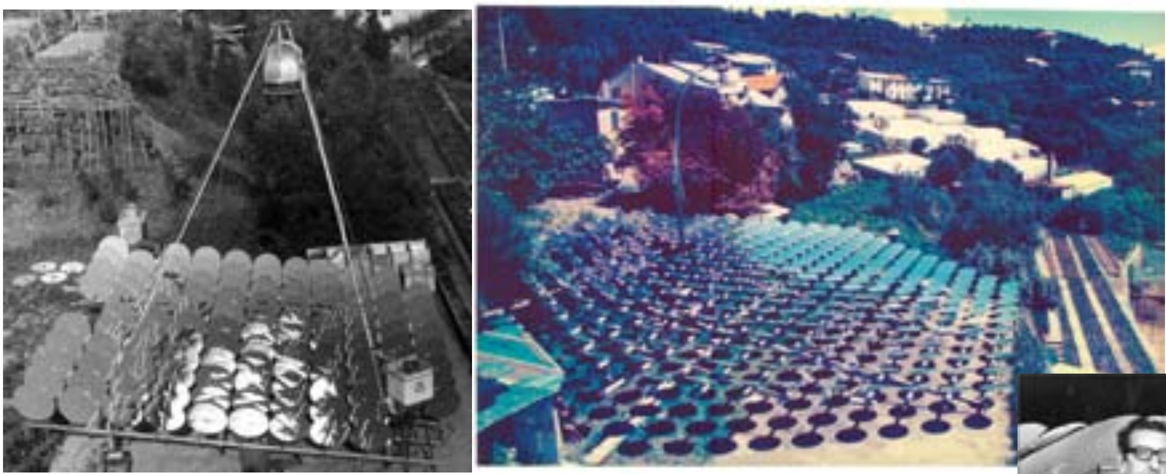
A system of solar thermal power technology has a section that concentrates solar radiation through reflecting surfaces. These “mirrors” pursue the apparent motion of the sun while maintaining steered to the focal area the incident radiance. A second section transforms thermal energy into mechanic and electric and it is usually based on technologies similar to those normally adopted in conventional thermoelectric power plants.

Some differences in meaning of the adopted definitions in English and Italian texts exist. In English references the solar thermodynamic is defined as “solar thermal” whilst in the Italian definition “solare termico” indicates the uses of solar energy at low temperature (in English defined as “solar heating”).

A more appropriate definition is “Concentrated Solar Power” or CSP and it refers to the technologies which transform solar energy into electric through reflective concentrating systems, including in this sector also photovoltaic plants equipped with concentrator systems.

If we overlook the pioneering experiences that date back to the early decades of the last century, the achievements which we refer to see the first experiments in the ‘70s in Europe and in the United States. Among these are of particular relevance the experiences of Giovanni Francia, who achieved in S.Ilario di Nervi (Genoa) the first mirror solar-power system and has developed different technologies at that time advanced and still to this day of reference for new projects (the control and operating system of the kinematic mechanism of the solar mirrors, the anti-irradiation honeycomb cells, the concentrator with black body characteristics) (Figure 1).

Figure 1 – The first experiences of a solar concentrator in Italy



St. Ilario solar plant in 1965 and 1972
Giovanni Francia

Photos given by the Francia heirs to the Group for the solar energy history (www.gses.it) for the national Archive on the history of solar energy at the Museo dell'Industria e del Lavoro of Brescia.

In the ‘80s the experiments developed following 3 project chains: parabolic trough, solar tower power and dish-Stirling to which in the last years was added a fourth, resumed from early experiences of the ‘70s, compact linear Fresnel reflector. The typology of linear parabolic was the first to overcome the prototype phase in the industrial realizations for commercial uses, with the installation and operation in California, in the course of the ‘80s, of 9 plants currently operating of the total nominal power of 354 MW electric.

The solar tower systems have brought to the development of molten salt storage solutions, with a storage at high temperature that allows to put into the grid electric energy from solar also in low irradiation periods and during night hours. The dish-Stirling have shown subsequently the possibility of attaining the highest global performances within CSP plants also for systems of limited capacity inferior to 30kW electric.

After an initial phase of rapid development, mainly derived from the energy crisis of 1973, we have passed by with the collapse of oil prices in 1986, to a stagnation period which lasted about 15 years. The lack of adequate regulation and economic support, the high investment costs required for research and creation of demonstration plants, in addition to economic non-competitiveness with conventional sources of energy, seemed to have set a definite decline to the solar solution.

The gradual recovery in oil prices, the new demands for energy independence along with environmental issues sensitive to the containment of greenhouse gases, have reawakened interest in these applications.

The recent Spanish policy of strong incentives of solar has created new possibilities for the realization of thermodynamic plants since 2004, with the introduction of an economic contribution per kW produced from a renewable source. In the same way, thanks to similar types of incentives that favor the use of renewable sources, the Member States of the southwestern U.S. have seen a restart of solar thermal concentration plant realizations. The use of solar thermal plants has proven particularly effective in these areas because the maximum production of electric energy from solar energy occurs in periods with load peaks generated by Summer air-conditioning demand.

The most suitable areas for the creation of these CSP plants are, furthermore, those that have a statistically high direct solar ground radiation throughout the year. The southwestern United States, the deserts of north Africa and the southern Mediterranean Countries, the Australian desert, all have the ideal characteristics for such achievements (high direct solar irradiation, flat lands available, low humidity).

The last three years have literally seen an explosion of solar power initiatives and achievements. Thus a crucial phase has arrived which will set on the basis of the different variables (cost of energy from fossil, reliability of new plants created, possibility of reproducing on industrial scale the solutions adopted making them economically interesting, competition with other renewable sources such as wind-energy and the same solar photovoltaic and many others) the real potential of development on a large scale of the use of solar energy for the production of electric energy.

The possibility of producing electric energy with CSP plants well-distributed and with limited size, sees the dish-Stirling systems particularly promising for development potentials (high performances, reduced occupation of the territory, environment compatibility). However, important objectives remain to be achieved such as the optimization of maintenance activities and the periodic replacement of the Stirling engine sealing components. When the solar dish presents characteristics of high reliability in time and autonomous performance, the passage to mass production will be easy. Incentives to overcome the first phase of market startup and enable production on an industrial large scale will be necessary.

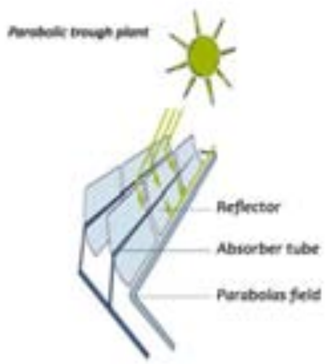
In the last decade, considerable interest towards thermodynamic applications of solar energy has been seen, with a recent important development of realization plants. The current scenario sees a rapid evolution of the working plants, of realizations in progress and of projects to be defined. We will, therefore, try to present an overview of the current situation as far as possible, describing the various types of plants with the most interesting technological solutions.

The attention will then concentrate on solar Dish-Stirling plants, the current candidates for production of electric energy on a small scale and properly definable “mini” solar thermodynamic.

5.1 – Parabolic trough plants

Among the CSP technologies the most experimented and reliable one for an on field running is that of parabolic trough (figure 2), that has seen in the last years, the achievement of several plants, mainly in Spain and in the United States. This type of plant currently has the largest number of commercial embodiments that provide electric power to the grid to which they are connected. In these systems solar radiation incident is concentrated by means of parabolic trough on a receiver tube positioned in the parabola’s focus.

Figure 2 – Types of solar power concentrating systems: parabolic trough systems



Concentrating ratio 70-100

Operating temperature 350-550°C

Average efficiency 11-15%

Tracking with rotation on an axis

1-80 MWe (operating plants)

Established technology – developments on heat transfer fluids and on component cost

The linear collectors are formed by a reflective surface with a curvature which approximates a parabola. A black metal tube contained in a transparent coaxial tube which reduces the heat loss is located on the parabola's focal line. The working fluid (heat transfer oils, molten salts) transfer the heat energy to the turbine.

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SES –Tessera Overwiew & strategy 09,
Solar Thermal Electricity 2025 Estela, others

Linear parabolic concentrators are placed in parallel rows with the axis usually oriented north-south. In this way the mirrors can follow the apparent motion of the sun from sunrise to sunset. Another possible orientation is the east-west one, but normally it isn't used for the following reason: although collecting, in fact, the same energy in respect to another configuration, it has more uneven temporal distribution with a very significant peak in the central hours of the day. Furthermore, the shadowing losses require a higher occupation for the disposition of the parabolic troughs.

The collectors consist of a concentrator shaped like a parabolic trough that reflects the solar radiation in the focus; of a receiver that consists of a tubular component in which heat exchange fluid flows; of a support framework and of a sun tracking engine, with its sensors and control systems.

The reflectors are usually made of glass of the thickness of a few millimeters (4-5) of low iron content and high transmittance, silver mirrored on the rear and covered by a protective film. The glass is curved in the shape required by the high temperature furnaces.

The receiver tubes are the most sophisticated technological elements of the system as they have to enable the circulation of fluid (synthetic heat transfer oils, molten salts) to a temperature higher than 350°C and have to maintain their absorption characteristics unchanged. They consist of a metal tube (usually out of steel) in which thermal fluid circulates, on which is deposited a layer of selective material that has a high ratio of absorption of solar radiation in the visible spectrum and a low emissivity in the infrared range at operating temperature (respectively higher than 94% and lower than 15%).

In these systems, the concentration factor is of about 70-100 on the absorption tubes, that can operate at temperatures between 350 and 550°C, and are isolated by a vacuum air chamber created by a coaxial tube usually out of borosilicate glass, transparent to visible solar radiation but absorbent in infrared. The vacuum air chamber has the function of inhibiting the thermal convective losses and of protecting from deterioration the selective layer applied onto the metal tube.

It is critical to keep the vacuum in the cavity: operating conditions and the different thermal expansions between glass and metal require fittings able to withstand these stresses adapting to the continuous changes generated by the different operating conditions.

The heat carrier fluid (usually thermal oil) transfers collected thermal energy to an exchanger that produces high pressure overheated steam. The steam powers a turbine connected to a generator that produces electric energy. The thermal oil, to avoid thermal cracking phenomena, works at temperatures not exceeding 400°C and this condition limits the thermodynamic efficiency. Solutions with transfer fluids which permit the exercise at higher temperatures are being studied. Prototypes of plants that use molten salts and others in their circuit that provide the elimination of the exchange circuit and a direct production of steam in the linear absorbers have been made.

Sun tracking by parabolic troughs is driven by sensors which detect the sun’s position and orient it for an alignment with the focal line. The movement can also be managed by an appropriate software which evaluates according to time, day and location, the exact position of the sun, regardless of the visibility of the same.

The array of the solar parabolas is set in parallel rows with collectors oriented along north-south, and the parabolas that follow the sun from east to west from sunrise to sunset concentrate the solar radiation on the receiver in which the thermal fluid flows.

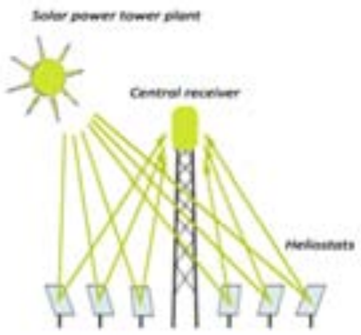
The exchange fluid passes through the heat exchangers and generates high pressure overheated steam. The steam powers a Rankine cycle where a turbine connected to a generator produces electric energy. The steam from the turbine is condensed and sent back again to the circuit of solar receivers.

Usually integration systems with fossil fuels for steam production and possibly thermal fluid preheating are provided, in order to prevent interruption of operation due to a reduction of direct solar radiation available. The plant thus described employs solar energy as the main source for the production of electric energy. Another solution consists of combining the solar section to a conventional thermoelectric plant, integrating the production of steam of a system having a larger turbine and higher efficiencies.

5.2 – Solar Tower Power plants

Solar tower power plants consist of a field of slightly concave mirrors which direct solar radiation onto a receiver placed at the top of a tower (figure 3). The mirrors, defined as heliostats, track the apparent movement of the sun with a rotation on two axes so that the reflected radiation always impinges on the receiver. The working fluid, flowing inside the receiver, heats up to high temperatures (over 500°C in new realizations) and subsequently gives the thermal energy to the steam generator that powers a Rankine cycle plant. Concentration ratios exceeding 400 suns, are usually achieved.

Figure 3 – Types of concentrating solar systems: solar tower power plants with heliostats



Concentrating ratio 400-600

Operating temperature 300-550 °C (in future 800°C)

Average conversion efficiency 12-22%

Tracking with rotation on two axes

1-20 MWe (operating plants)

Mature technology with future trends

The solar power plant uses a field of mirrors (heliostats) that track the sun and reflect solar energy onto a receiver placed on top of the tower. Solar energy, converted into heat energy, is transferred to a working fluid which generates steam for a conventional turbine.

The plant is made up of: heliostats and relative tracking system, circuit with working fluid (molten salts, steam, air), thermal storage and control system.

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The first experiments were carried out with the pilot plant Solar One achieved in the Mojave Desert in California in the ‘80s. The power plant, in operation from 1982 to 1986, had a field consisting of more than 1800 heliostats, each of the surface of 40m^2, a tower 75 meters high and the steam production was made directly by the receiver. The plant operation highlighted the direct production of steam by a non-steady heat source which generated continuous thermal stresses, discontinuity of operation and a rapid deterioration of the materials used. These difficulties have brought to an extensive overhaul of the plant in the early ‘90s. The power plant, renamed Solar Two, was restored with some important changes and additions: a further array of hundreds of larger size heliostats was added, a primary circuit with a mixture of molten salts was used (a combination of sodium nitrate at 60% and potassium nitrate at 40%) and a solar plant was integrated by a cumulating system. The accumulation system composed of two tanks, a charge and a discharge one, has allowed to exceed the critical nature of thermal transients and also to continue electric energy production for some hours without sun.

With the adjustments described above, the plant was able to achieve the peak power of 10MWe and allowed to consolidate, with long hours of exercise, the experience in the field of tower concentrators.

The molten salts allow higher operating temperatures to 500°C but must operate within well defined limits of temperature: over 570°C the mixture becomes highly corrosive to steels, whilst below 220°C it solidifies. For this reason new receivers of ceramic material capable of heating the air to 700°C are in study, thus to generate overheated steam at 550°C for a standard Rankine cycle.

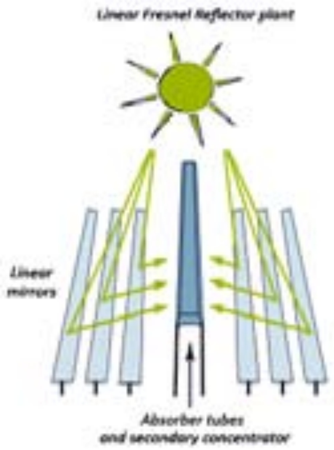
5.3 – Compact Linear Fresnel Reflector

Compact Linear Fresnel Systems represent a simplified solution, with potentially lower costs, which summarizes some of the technology of parabolic troughs and solar tower power systems (figure 4).

Compact Linear Fresnel Systems work like flat segments of parabolic troughs. They are positioned at the height of the land, with low installation costs, and address solar radiation onto a fixed linear receiver in an elevated position.

The receiver is equipped with a second concentration system that converges with reflectors the solar radiation onto pipelines in which thermal fluid flows.

Figure 4 – Types of solar concentrating systems: Linear Fresnel reflector systems



Concentrating ratio 25-100

Operating temperature 250-320°C

Average efficiency 9-11%

Tracking with rotation on an axis

1-5 MWe (Operating plants)

Pilot plants, “new” technology

The system is composed of linear reflectors which focus solar radiation onto an overhead stationary receiver, provided with a secondary concentrator. The optical performances are reduced compared to parabolic trough systems.

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In the concentrator, the exchanger pipelines are thermally isolated from the external environment, through the insulation of the receiver and a glass panel, transparent to incident radiation, which separates from the outside the hollow volume.

The steam produced is conveyed to a turbine for the transformation into mechanical energy and then into electric energy.

With this configuration the cost of production of flat surface mirrors and of the tracking system is reduced. In addition, a primary circuit of exchange is avoided, because steam generation takes place directly in the receiver.

In view of these advantages a reduced efficiency of the system is obtained, with a steam production at relatively low temperature.

The realization costs are limited and the current experimentation phase with “made-to-measure” components for specific plants, encourage to hope in an industrial scale economy which makes this application competitive, already tested in the ‘60s by the pioneer of solar energy Giovanni Francia.

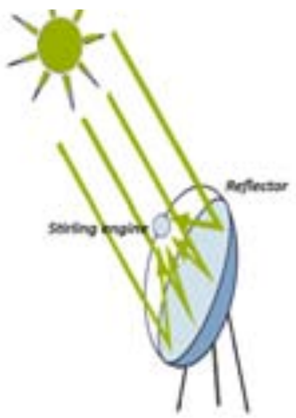
5.4 – Dish-Stirling solar concentrators

Dish-Stirling systems convert thermal energy, obtained from solar energy, first in mechanic energy and then in electric energy. These systems use a set of mirrors to reflect the direct solar radiation and address it, concentrating it, onto a receiver in order to obtain the temperatures necessary for an efficient conversion from thermal energy into mechanical work.

Such systems are made of a solar concave concentrator with a parabolic structure (dish), a hollow shaped receiver, a Stirling engine and an electric generator (figure 5).

To constantly direct the incident solar radiation onto the receiver, the reflecting dish has to track the sun's motion, moving on two axes of rotation. For this purpose a tracking system that maintains the optical axis of the concentrator pointed directly at the sun is adopted. The concentrator, with its curvature, converges the solar radiation on the receiver, positioned at the focus of the concentrator itself.

Figure 5 – Types of solar concentrating systems: parabolic dish-Stirling engine systems (mini solar thermo-dynamic)



- Concentrating ratio 600-2500
- Operating temperature 500-900 °C
- Average efficiency 20-27% (max achieved 31%)
- Tracking on two axes
- First commercial products
- 1-25 kWe (operating and experimental plants)
- Good potentials for cost reduction on large scale

The parabolic dish reflector follows the sun, moving on two axes and concentrates radiation on its focal point. A Stirling-engine is placed in the receiver which combined to a generator, transforms thermal energy in mechanic energy and subsequently into electric energy.

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The receiver, designed to operate as an ideal black body, absorbs the incident solar energy and transfers it as heats to the working fluid of the Stirling engine.

The Stirling engine operates with a working fluid (usually hydrogen and helium) contained in a sealed circuit, alternately heated and cooled. The engine compresses the working gas when it's cold and it expands it when hot. The mechanic energy produced with the gas expansion at a high temperature is superior to that requested for the compression of cold gas. The piston movement therefore produces mechanic energy that is converted into electric energy through an alternator or a separate electric generator.

The Dish-Stirling systems are characterized by high efficiency, they are modular, automated and able to operate combined to a conventional plant which guarantees the necessary energy integration. Compared to the various technologies of the solar thermodynamic, they have the most interesting characteristics for a distributed use and enable to foresee a scale economy when the technology is well developed. Among all the technologies used, Dish-Stirling systems have allowed to obtain the highest efficiency of conversion of solar radiation into electric energy (maximum experimental value obtained 31%) and have the potential to become one of the best solutions for using solar energy. Systems with rated power of 3 and 25 kW are already commercially available, whilst new prototypes are used for experiments on critical components of the system. The achievement of new Stirling engines designed specifically for solar thermodynamic use, together with the adoption of components with high resistance to thermal stresses will enable the transition to a phase of expansion of the use of Dish-Stirling.

5.5 - The concentrator

Concentration systems generally used in Dish-Stirling systems are parabolic dish concentrators that reflect incident direct solar radiance in an area corresponding to the focus. The ideal shape of the surface of the dish is that generated by the rotation of a parabola around its own axis. The dish can be made of a one-piece structure or of a group of mirrors that approximate the design of the ideal structure. The shape of the rotating parabolic is particularly effective because it is able to concentrate solar radiation in a well-defined area in proximity to the focus.

In the design of the dish the ratio of concentration is of particular importance, defined as the ratio between solar energy that passes through the receiver's entrance and the incident solar energy onto a surface equivalent to the receiver's entrance. This project value is particularly sensitive to the achievement accuracy of the concentrator and in operating plants it is around a concentration of 1500-2000 suns.

The dish dimensions is related to the power of the solar energy project in the location, or rather to the reference value of the highest level of incident solar radiation on the concentrator. With reference to an indicative value of 1000 W/m^2, we can approximately consider for a Stirling engine from 3-5 kW/e a dish of the diameter of 5-6 m and for an engine of 25 kWe a dish of 10-12 m.

Sun tracking along its apparent path is essential for maintaining the incident solar radiation concentrated in the focal space of the concentrator. To allow such tracking, the dish has to move rotating on two axes.

5.6 – The receiver

The receiver has the function of collecting and transforming the energy of solar radiation into thermal energy, and transferring it to the working fluid of the engine. The solar radiation is not concentrated in one point only but the focus is distributed in a limited three-dimensional volume not only for the constructional inaccuracies of the parabola, but also for the fact that the sun is not a punctual source. The cavity of the receiver presents a reduced opening and the absorbing and exchanging element is located at the bottom of the internal volume, in order to reduce the convective and radiated heat losses and distribute over a larger surface the intensity of trapped solar radiation.

To transfer the energy collected to the engine's gas exchange, two different ways are used. The first one, more conventional, consists in making the radiation impact directly on the hot heat exchanger of the Stirling engine, placed appropriately on the bottom of the cavity. The receiver, with the exchange surface directly enlightened by the concentrated solar radiation, very quickly transfers the thermal helium or hydrogen flowing in the high pressure circuit , thus making the handling of the temperatures on the cylinders of the Stirling engine particularly critical. For this reason, a second solution has been experimented, but still in a developing phase, which provides the use of an intermediate fluid for the transfer of heat between the surface of absorption and the Stirling exchanger. A metal is used in liquid phase (for example sodium) which is vaporized on the receiver's surface of absorption and condensed on the pipes of the Stirling exchanger. The exchange takes place in the heat pipe with a continuous movement of the sodium which vaporizes in contact with the absorber and condenses on the heat exchanger, after which it returns by gravity to the heat absorber. In this way a more uniform supply of energy to the heat exchanger is ensured, with a higher operating of the engine and a higher return.

5.7 – The engine

The Stirling engine, patented in 1816 by Reverend Robert Stirling, saw its first application in the field of solar energy in 1872 by the inventor John Ericsson. From its origins to now, several prototypes have been developed, tested on vehicles and boats. Recent experiments have verified the possibility of using this engine for the propulsion of submarines or as an electrical generator in extra-atmospheric satellites. The Stirling is presented on paper as the most efficient engine in converting thermal energy into mechanical energy, when used in particularly high operating temperatures.

The source of thermal energy external to the engine and the demand for high temperatures make the Stirling engine a good match to a concentration solar system.

The Stirling engine operates with efficiencies progressively higher with increasing operating temperature. From the moment that such temperatures are easily obtainable with a concentration solar dish, the optimal operating conditions are limited only by characteristics of the materials used for its construction.

The engine of a dish-engine system converts thermal energy into mechanic according to ways similar to other conventional engines, compressing a working fluid when cold, by heating and expanding the compressed fluid through a turbine or with a piston to produce work. The mechanical work is then converted into electric energy by a generator or an alternator.

For the dish-engine systems different thermodynamic cycles and working fluids were also taken into consideration, such as the Rankine cycle which uses water or organic working fluid and the Brayton cycle which uses gas in open and closed cycles. Conventional Otto and Diesel cycle engines are difficult to be used because the thermal energy source is external, and thus in real applications it is not possible to adapt them to the concentrated solar source. The Stirling engine is amongst all ideal for this use, as the cycles are at high temperature and the heat source is external to the engine.

The optimal temperature range, supported by the materials used, varies from 600 to 800°C, and the pressure between 40 and 200 bar. The high pressure enables to maximize the engine’s power but makes the sealing of the working gas circuit critical in respect to the parts of the engine that operate at atmospheric pressure.

The engine presents a conversion efficiency between 30 and 40%. For these operating temperatures, hydrogen results being the optimal working gas. Nevertheless, often, helium is preferred because of its characteristics of higher compatibility to materials and higher safety conditions during operating.

The engine incorporates an effective heat exchange system that receives the heat when the fluid is cooled at constant volume and restores it when the gas is heated at a constant volume.

The need for economic competitiveness compared to the traditional sources makes it necessary to design engines able to operate for long periods with reduced maintenance. A life time can best be seen around 50.000 hours of operation, approximately 10 times the normal duration of an internal combustion engine for motor vehicles.

There can be various mechanical frameworks which enable this thermodynamic cycle. The majority of these involve the use of pistons and cylinders and some particular ones using a floating piston, which move the working gas between hot and cold regions while maintaining the process at constant volume.

The majority of Stirling engines achieved use a crankshaft. There also exists a free-piston configuration, in which the piston is not connected to drive shafts or other mechanisms but it is reciprocated by springs and by the pressure of gas. Energy is extracted from a power piston through a linear alternator.

The thermodynamic efficiency of the engine consists, as is well known, by the ratio between the thermal energy converted into mechanical work and the heat supplied to the engine.

The efficiency is limited by the value that is obtained in a Carnot cycle which represents the maximum efficiency of an ideal cycle that operates between two fixed levels of temperature. The efficiency grows with the increasing of the maximum temperature of the cycle and with the lowering of the minimum temperature.

Therefore, the design of the Dish-Stirling has to keep into consideration the need to achieve the highest possible temperature (compatible with the materials used) by the solar concentrator and the lowest temperature release with a suitable cooling system. The latter should be as close as possible to room temperature.

The conversion efficiency of solar energy to electric energy is determined by the chain of performance of the system:

$\eta_{conv} = \eta_{conc} \ \eta_{ric} \ \eta_{eng} \ \eta_{alt}$

where

η_{conc} is the concentration system performance

η_{ric} is the thermal energy transformation

η_{eng} is the thermodynamic efficiency of the Stirling engine

η_{alt} is the conversion efficiency of the generator

Of course also electric energy consumption to keep in operating conditions the system dish-Stirling must be considered (engines and cooling pumps, control systems, tracking systems) and then subtracting such consumptions from the numerator of the gross return, an effective ηconv yield will be obtained.

5.8 – Concentrator-receiver system

The concentrator, as already mentioned, intercepts the solar radiation from the sun on a wide area with a disc-shaped opening and concentrates it into a restricted area. The receiver absorbs this energy and transfers it to the Stirling engine. The quantity of heat effectively transferred can be defined "useful heat Q_u"

In order to maximize the useful energy Q_u it is important to obtain a high concentration value: at a high solar radiation "collection" area, A_{ap} must match an area of concentration A_{rec} as small as possible.

The ratio between these two quantities is defined as a geometric ratio of concentration and is expressed by the following equation:

$CRs = A_{ap} / A_{rec}$

The increase of the concentration ratio collides with the cost of realization of the collector that must be more and more accurate for this purpose.

The concentration ratio refers to an ideal situation, in which the solar flow is distributed evenly on the opening of the receiver. In reality, this distribution is not uniform but usually has a peak towards the center of the area and decreases towards the edges in a more or less uneven way.

Peak concentrations from 3 to 5 times higher than the geometric concentration defined above can be found.

The parabolic is formed by a surface generated by a parabola which rotates around its axis. The surface is designed in a way that all the rays parallel to the axis are reflected to a single focal point.

The concentrators in approximating the actual parabolic shape have different optical defects that lead to dispersing the solar radiation compared to the point of concentration. Even small variations in respect to the design curve may cause significant losses of concentrated radiation. Optical errors can also be generated by the reflecting surface itself that can spread the direct incident radiation, with no mirrored reflections.

Two types of failures linked to optical alignment can shift the focus from the position where it should be. The first consists in a potential mechanical failure of the alignment of the receiver in respect to the concentrator. The second, defined as tracking error, occurs when the axis of the concentrator isn't pointed directly towards the sun.

A further cause of radiation dispersion in respect to the focus is generated from a situation that, contrary to the previous, cannot be improved by a more accurate quality construction. The sun isn't a punctual source that emits parallel rays, but presents an apparent diameter whose reflected image is dispersed over a cone of approximately 9.3 milliradiants (angle of 0.533°). This dispersion is furthermore incremented by the presence of particulate in the atmosphere.

Another aspect to consider attentively is the reflective "quality" of the concentrator's surface which conditions the ability to reflect solar radiation on a limited area.

The surfaces are usually covered by a thin glossy aluminum or silver layer placed on the back of a glass or on the front of a support surface. The quality of the reflecting surface is determined through reflectance and mirroring features. Reflectance is the percentage of light reflected from the surface in respect to incident light whilst mirroring indicates the ability of the surface to reflect light without dispersions in respect to the incident angle, but on an angle corresponding to this one.

The silver layered surface presents a greater reflectance compared to aluminum and other metal surfaces over the entire solar spectrum. To this, a paint and a protective surface on the back is applied, just like for traditional mirrors.

The currently used glass panels have a limited thickness and a very low iron content leading to values of reflectance of 95%.

Concentrators demand a rigid support structure that can maintain the curvature of the project and that can resist to harmful actions of the wind. The optical elements can be integrated and incorporated into support structures or physically separated from them.

The receiver absorbs the concentrated solar flux and converts it into thermal energy that transfers it to the Stirling engine's working gas. The internal surfaces of the cavity between the opening and the surface of absorption are reflective. The absorbing surface is usually placed in a rear position in respect to the focal point of the concentrator, so that the density of the incident flux on the surface is reduced.

Two types of receivers exist in the parabolic disc concentration systems: hollow and external receivers. The most commonly used is the hollow shaped one already described, which allows the absorption of most of the incident radiation within the hollow structure. External receivers have absorbent surfaces directly visible from the concentrator and usually present a spherical shape, so that the apparent size results the same independently from the direction from which the reflected radiation comes from. However, these receivers have more heat loss and lower operating temperatures.

Hallow receivers have on the other hand the advantage that the absorption surface is greater than the opening of the absorber and therefore the removal of heat can take place with less thermal stress for the materials used. The cavity also reduces heat losses by natural convection thanks to the design and the angle of the component, protecting furthermore the absorbent surface from wind cooling.

The operating temperatures favor particularly the transformation efficiency of thermal energy into mechanical and electrical but increase the heat losses of the absorber.

Convective losses of the cavity can be eliminated by closing the opening with a transparent glass, but this solution reduces the incident energy because it inserts a transmittance coefficient in the system's balance equation. A Francia honeycomb system can instead be inserted in the cavity, able to limit convective movements in small portions of the same cavity.

To increase the absorbance of the exchange surface layers of materials with a high coefficient of absorption of light radiation in the solar spectrum may be applied. Such coatings should have an absorbance higher than 90% and should maintain their own characteristics at temperatures around 600°C.

In order to reduce radiated heat loss it is important that the absorbent surface presents a low emissivity. For this purpose the coating that increases the absorbance should operate in a selective way by presenting a reduced emittance in the wavelengths typical of thermal radiation. These coatings generally have a rather fast deterioration of the characteristics in time.

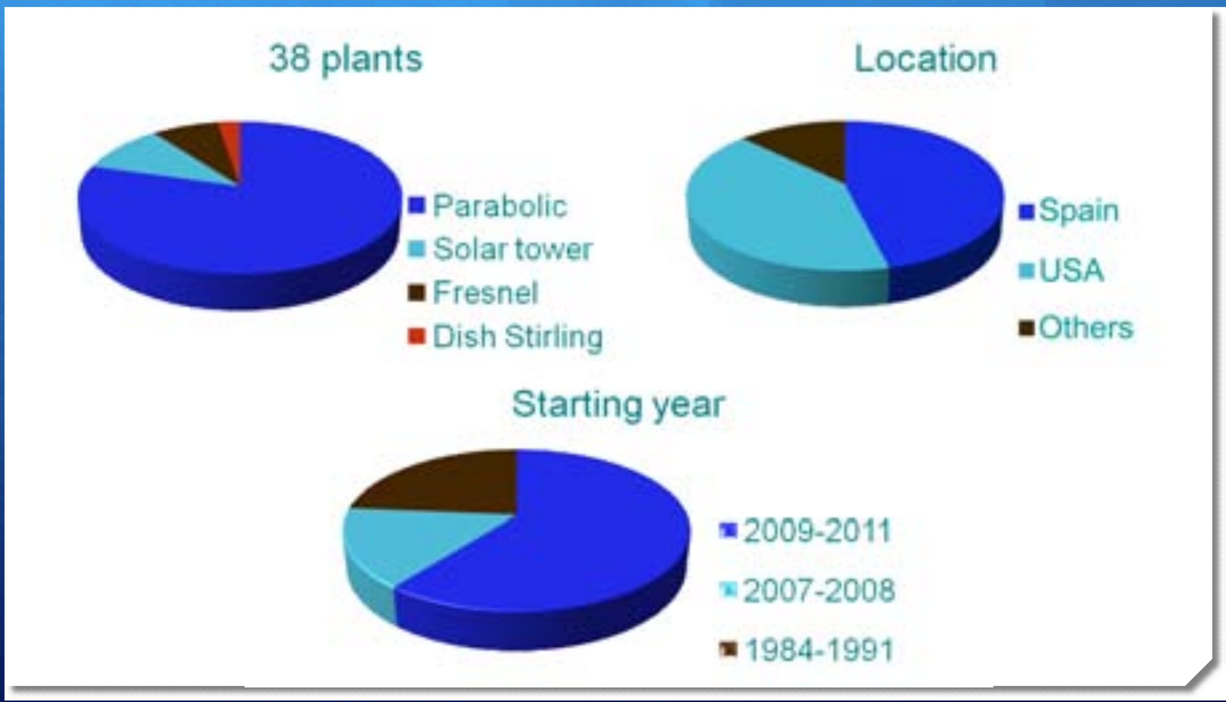
5.9 – CSP plants in operation

The CSP operating commercial plants up to April 2011 (with power output higher than 1 MW) were 38, for a nominal installed power of 1320 MWe. If the plants are divided by type (figure 6) it can be observed that most of these were made in accordance with the design philosophy of solar troughs. They are located mainly in the southwestern United States and in southern Spain and almost all have been brought into operation since 2007.

Solar troughs concentration systems present an installed peak power between 1 and 80 MWe with a total power of more than 1250 MWe.

As previously reported, the two leading Countries in the implementation of these systems are the United States and Spain, in virtue of the availability of land areas with low population density and high sunshine.

Figure 6 - Commercial solar thermal plants in operation
(April 2011, power superior to 1 MW)



In the Mojave Desert, in southern California, in an area which has the most sunshine of the United States, a system of nine solar trough collector plants has been operating since the ‘80s. The SEGS system (Solar Energy Generating Systems) has a total power of over 350 MWe of peak, with about 900.000 mirrors that concentrate incident solar radiation and a surface equal to 2 million m^2. The system is distributed on an area superior to 6 km^2.

The plants work with a synthetic thermal oil which enables operating temperatures around 390°C, and produce steam that is transferred to a turbine-generator system which produces electric energy, injected into the grid.

On cloudy days the plant has a natural gas conventional integrated boiler that provides an average of 25% of thermal needs.

The plants have been designed to provide energy in energy load peak phases, mainly in Summer afternoons, when the generator is able to work at a maximum power. The now long-term plant operation has allowed to optimize operations and reduce maintenance costs by at least a third compared to the first years of operation. Major improvements were brought to the absorbers and to the logic of interaction with the conventional integrative system. In more than 20 years of operation the average performances fell only of 3% and the plant is operative for 99% of the period of annual profit.

The Martin Next Generation Solar Energy Center is for size the second Worldwide concentration parabolic trough plant and is linked to a pre-existing cogeneration plant, the Martin County Power Plant, which is currently the biggest thermoelectric Plant in the United States, powered by fossil fuels (3.705 MW). The solar plant, with a power of 75 MW, has an array of parabolic troughs with 1.800mirrors on an area of 200 hectares and became operational in 2010.

The Nevada Solar One realized by Acciona Solar Power, near Boulder City in Nevada, is the first thermodynamic solar power plant build in the USA after the SEGS and was connected to the grid in 2007. With a nominal power of 74 MWe it has 760 parabolic troughs made of more than 180.000 mirrors with a total area of 357.000 m^2.The parabolas concentrate solar radiation onto the absorber tube, in which thermal oil circulates heated up until 390°C that produces steam onto the exchanger at a temperature higher than 370°C. The plant doesn’t have an integrative conventional source nor a thermal storage because it has been designed to satisfy Summer peak loads linked to greater demands of air-conditioning implants in that period.

The number of plants under construction or planned in the U.S. is really important and susceptible to constant changes and updates. An always updated list is available on the website nrel.gov/csp/solarpaces/.

The other Country that sees many initiatives in the thermodynamic solar field with operating plants and many others under construction or planning is Spain.

Three out of five twin concentration plants foreseen (Solnova 1.3 and 4) with parabolic troughs that have a total reflecting surface, per single plant, of 300.000 m^2, were made by Abengoa Solar in the vicinity of Seville during 2010. Each plant has a power of 50 MW and occupies an area of 115 hectares. The absorption system is made of two concentric tubes arranged along the focal point of the linear concentrator. The external tube out of glass is separated from the internal metal tube from a zone of vacuum. The heat transfer fluid is made of synthetic thermal oil which at the exchanger generates high pressure steam and powers the turbine as previously described. Plants are also equipped with a conventional gas-powered system.

In Andalusia near Granada three plants (Andasol 1,2 and 3) each of the power of 50 MW, were made and became operative between 2009 and 2011. Andasol 1 is the first linear parabola plant that became operative in Europe and presents, the same as its “homonyms” a fundamental characteristic which distinguishes it from previously built plants. It in fact has a molten salt thermal energy storage, made of a mixture of sodium nitrate for 60% and potassium nitrate for 40%. The storage system has a total capacity of 28.500 tons and is distributed on two tanks of 14 meters high and 36 of diameter. The thermal storage enables a running self-sufficiency of over 7 hours without sun. Also a thermal energy production with integration from a conventional source has been provided.

In Spain 9 other plants of the peak power of 50 MWe and with design features similar to Andasol described above came into operation in the two year period 2009-2011.

In 2010 the Archimedes’ plant by ENEA in Sicily was completed. Archimedes is the first concentration plant with linear parabolas that uses directly as heat transfer fluid molten salts and the first plant to be integrated in a thermoelectric power plant of combined cycle. The linear parabola field occupies an area of about 80.000 m^2 with a total reflecting surface superior to 30.500 m^2. The molten salts, used in a circuit for transferring thermal energy to the turbine and in the thermal storage, are a mixture of sodium nitrate ($NaNO_3$) at 60% and potassium nitrate (KNO_3) at 40%. They become liquid at a temperature of about 240°C and remain steady until the planned operating temperature around 550°C, much greater than achievable temperatures with heat transfer oils. These salts, used in common fertilizers, are not inflammable nor are they toxic and have a low cost. The storage system is made of two tanks where the working fluid is stored at two different thermal levels thus allowing to run the plant in standard operating conditions for about 8 hours. The nominal power output is equal to 5 MW, and the Global average annual return planned is around 15%. In the circuit that connects the linear concentrators to the storages, the molten salts are moved by circulation pumps. The two storage tanks differentiate themselves for the average temperature of contained salts. The higher temperature tank is kept into operation at about 550°C and the other at a temperature lower than 290°C. When the solar radiation exceeds a threshold value the mixture of salts is moved by the tank at “low” temperature to the solar collector field where it is heated until 550°C and is transferred to the warmer tank. The salt at high temperature goes through the heat exchanger of the steam generator producing overheated steam and goes back to the “cold” tank. This solution enables to use energy from a solar source providing process thermal energy at a very high temperature as integration to the industrial plants which use fossil fuels.

The integration of the ENEA solar plant to a conventional combined cycle plant that produces electric energy is an optimal technological solution. The steam provided by the solar plant has the same pressure and temperature characteristics of the steam coming from the heat recovery generator of exhaust fumes of the gas turbine.

Moving on to the description of tower plant types, the Solar Power Tower PS10 (Planta Solar 10) plant realized in Andalusia near Seville, was the first commercial European heliostat tower plant. It became operative in 2007 and has a power of 11 MW and a field of 624 heliostats, each of which with a surface of 120 m^2. The solar radiation is concentrated on a tower of the height of 115 meters where the solar receiver and the turbine are positioned. The plant was initially expected to use air as heat transfer fluid with a solar receiver able to collect room temperature air and heat it until 700°C. The hot air should have generated steam at 550°C passing through an air-water/steam exchanger. The difficulties encountered in the realization of a solar receiver with these characteristics brought to adapt the system for steam production, with a project conceptually similar to that of Solar One.

Compared to the Californian realizations of the 80's a heliostat field numerically inferior was made, increasing the surface of each of these. Furthermore, the plant operates at temperature conditions (around 300°C) less severe (there is no overheating of steam) from which less stress follows for the receiver and consequently a longer life for the system. Also the storage made up of 4 tanks is more simple to use, as there aren't any fluid for intermediate thermal exchange. On the other hand it results in a lower energy efficiency.

PS 20 (Planta 20) with a central tower receiver steam came into operation in 2009 in Spain, supported logistically by PS 10. It is currently the largest of this type. The tower is 165 meters high; the heliostats, with a surface of 120 m^2 each, are 1255 and occupy an area of 80 hectares. Incident radiation is reflected onto the receiver, positioned at the top of the tower, that produces steam converted into mechanical energy and electric energy for a peak power of 20 MWe.

The system isn't supported by a conventional plant powered by fossil sources; it offers only a modest water-steam heat storage equivalent to about 30 minutes at full power.

In California as well, in the Mojave Desert, a new power tower started operating: the Sierra Sun Tower with a power of 5 MWe. This plant at the moment is the only CPS tower one in operation in the United States. In this case as well, the technology is based on a direct production of steam into the receiver located on the tower. The solar field made of 24.000 heliostats occupies 8 hectares and is divided in 4 subsystems that concentrate radiation onto two towers. From here begins the overheated steam that powers the turbines.

Among the different projects of solar towers in progress Solar Tres should be noted, whose project is based on the experiences of Solar Two, a molten salt plant, that will have a higher nominal power (17 MWe instead of 10 MWe). It will have a solar field of 2500 heliostats of 120 m^2, of a storage made of two big molten salt tanks, able to guarantee a self-sufficiency of 15 hours.

For Fresnel type plants it is important to point out that in 2008, Kimberlina Solar Thermal Power Plant, the first commercial plant with this technology became operative. The plant located in California has a power of 5mw and the manufacturing company has plans to build in the same area, a Fresnel plant of 177 MW.

For Dish-Stirling since January 2010 a commercial plant of 1.5 MW made of 60 units Sun Catcher Stirling Energy Systems in the County of Maricopa in Arizona has been operative.

5.10 – Commercial dish-Stirling systems

The different prototypes realized (mainly by U.S. companies) currently operating are being optimized and tested on site.

Some of these have achieved technological maturity and reliability and are therefore available for commercial distribution.

The Sun Catcher generator built by SES (Stirling Energy Systems) has been produced in a significant number of samples, and as previously reported, 60 units are coupled together in the Maricopa Solar Plant, a commercial plant of 1.5 MW located in Arizona and operating from January 2010.

The Sun Catcher has a disc of the diameter of about 12 m, it is equipped with an automatic system for tracking the sun and collects incident solar radiation directing it onto the receiver positioned in the focus. It's equipped with a Stirling engine of 25 kW four cylinder that operates in a closed cycle. The receiver irradiated by solar energy forms the heat exchanger of the sealed circuit, in which hydrogen circulates. The overheated gas powers the Stirling engine to which a generator that produces electric energy compatible with the grid is connected. The "cold" exchanger returns thermal energy to the ambience with radiators similar to those used in vehicles. The cooled gas is sent again to the heat exchanger. In this way the system does not consume water if not when the cleaning of the mirrors is required.

Another interesting model, smaller by size, is the Infinia 3.0 ISS of the Infinia Corporation. Equipped with a disc of a diameter of about 5 m, it has a Stirling engine of 3 kW with particularly interesting characteristics: it is the first commercial model of mono cylinder free piston Stirling engine.

In Italy, INNOVA produces a dish-Stirling co-generative system of the power of 1 kW and 3 kW thermal. The concentrator presents a diameter of 3.75 m and installs a Microgen engine.

The Euro-dish system of European production is a in late-stage testing and will be described in the next chapter.

5.11 – The Euro-Dish generator

The solar generator Euro-Dish is a system of Dish-Stirling of European design that converts solar energy into electric energy by thermodynamic.

The system is produced by a consortium of German companies coordinated by SBP (Schlaich Bergermann and Partner) of Stuttgart. European research on Dish-Stirling started in the '80s by constructors with the support of the Solar Energy Department of DLR (Deutsche Zentrum fur Luft und Raumfahrt) and the system has been tested for a long period in Almeria in Spain, at the PSA (Plataforma Solar de Almeria).

A prototype of the generator was installed in 2002 in Milan at the experimental area currently RSE where for some years monitoring and optimizing activities of the system took place (period 2002-2008), bringing the prototype to reliable and high efficiency operating conditions.

The concentrator, constituted of a parabolic equipped with a reflecting surface of 56 m^2 and a diameter of 8.5, directs onto a receiver direct incident solar radiation (figure 7).

Figure 7 - Euro-Dish prototype generator

The generator, with a parabola of the diameter of 8,5 m., is incorporated in a structure that enables rotation on two axes. The Stirling SOLO 161 engine, nominal power of 10 kW, is installed at the top, with heat exchanger on the focal plane of the concentrator.
It is located in Milan at the RSE laboratories (Ricerca sul Sistema Energetico) of the GSE group (Gestore Servizi Energetici).

Photo RSE

Solar energy is therefore transformed into thermal energy at a high temperature and from the receiver it is transferred to a Stirling engine of the nominal power of 10 kWe, which drives a asynchronous generator with a subsequent production of electric energy.

A tracking system drives the parabola keeping it oriented towards the sun. The control system elaborates the sun's position and operates the auxiliary engines which move the parabola.

The Stirling generator is a piston engine with a sealed circuit that contains gas that carries out a thermodynamic cycle which transforms thermal energy into mechanic energy. The engine rotates a three-phase alternator connected to the grid at low voltage.

The support system of the sun tracking parabola is constituted of two circular structures. The first is a rotating platform with two support systems and it allows to follow the movements of the sun's azimuth. The second is constituted of an annular support structure to the concentrator and it is able to vary the parabola's inclination in respect to the ground. A rack structure regulates the dish inclination.

The structure also supports the fixing cage of the Stirling engine, with the solar heat exchanger positioned in the vicinity of the focal plane of the parabolic.

The reflecting concentrator consists of 12 sectors in glass fiber suitably shaped covered by glass slabs glued in a way to make a homogenous surface.

The system is able to operate individually assisted by a software that manages not only normal operating conditions but enables to take on stand-by and safety positions needed to avoid situations of thermal stress of the components.

The management and control software is set-up with a series of data that refer to the installations' geographical location (Coordinates) and general parameters (switching on/off time, solar radiation threshold for morning ignition and for operation in stand-by, limit values for operating temperatures and for wind and other safety conditions).

The receiver has to be positioned correctly in respect to the focal plane of the parabola in order to optimize the efficiency and at the same time prevent damage from exposure to an excessive temperature. The temperature of the receiver increases with the diminishing of the distance in respect to the focal plane. To avoid the melting of the receiver it is necessary to increase the removal of thermal energy from helium which circulates in the exchanger, increasing the density and consequently the cylinders' pressure. If the receiver is put closer to the focal plane, the result is an increase of the pressure of helium, which translates into an increase of the mechanical power output and in a better performance of the system.

The distribution of solar radiation onto the surface of the radiator is not even but presents a Gaussian distribution more intense at the center of the focal plane which is progressively reduced towards the outside, with temperature gradients also irregular, depending on possible inaccuracies in construction of the parabola. During the experimental tests carried out on prototypes installed in Almeria, concentration factors on small areas of the receiver up to 5000 suns instead of the design value of 2000 suns were found. These values can bring to a melting of the absorber and consequently its position on the focal plane must be carried out correctly to avoid severe thermal stresses.

The efficiency of the thermodynamic cycle obviously results higher with a more uniform distribution of the temperatures.

The energy efficiency is the ratio between the net power produced by the generator and the solar energy collected by the concentrator. The net power is calculated by subtracting from the gross power generated the auxiliary consumption (fan pump and cooling circuit, dish tracking motors, electronics of the Stirling engine).

The generator in fact is equipped with a series of auxiliary services which keep on working not only in the mode of power generation but also in the other intermediate modes. Consumptions generated by these are not in function of energy produced, but remain almost steady if dish movements which have the highest absorption of electric energy aren't considered.

The gross power depends on the sequence of fundamental parameters, which: the position of the solar receiver in respect to the focal plane, the maximum set temperature for the receiver and the maximum pressure of the engine, the adjustment of helium pressure in the engine in function of the incident radiation, the temperature of cooling water, the mirror cleaning, the system's stability and obviously, above all, the intensity of direct solar incident radiation on the disc.

If we consider the solar radiation constant , the efficiency of Stirling generator is a function of ambient temperature and with the growth of the latter, the efficiency goes down a few percentage points.

5.12 – Development of CSP technologies

The development trends of CSP plants are linked, besides evolution of costs of fossil sources and of "Competitors" in the renewable sector (mainly photovoltaic), to the improvement of technologies and to the increase in reliability and efficiency.

The main objectives are:

- An increase in the overall efficiency of the system in the production of electric energy, achievable with higher operating temperatures, improved yields (37) of the turbines and engines, increased efficiency of the concentrator and the receiver;
- An optimizing of the different components with the adoption of new design solutions and new materials;
- A greater reliability of the systems with a parallel reduction of production costs, assembly and frequency of planned maintenance;
- A reduction of energy and water consumption needed for plant management.

For parabolic trough plants new support structures of the parabolas are being studied, with higher resistance to atmospheric elements, greater precision in the radiance concentration and of course reduced costs. Also new materials for mirrors, with reflecting surfaces in thin glass and polymeric surfaces with aluminum reflectors are being studied. Moreover, new solutions for receivers, with more resistant selective surfaces, better vacuum seal between coaxial tubes, greater resistance of flexible connectors and greater reliability of all components are being studied.

An increase in operating temperature could lead to higher conversion efficiencies of the thermodynamic cycle: for this purpose the possibility of using new heat transfer fluids is being evaluated. Synthetic oil, in various formulations, is the mostly used current fluid, but it implies safety problems, of deterioration and thermo-chemical decay with the need of a partial periodic substitution and of a slow but progressive reduction of the empty cavity of the tube due to hydrogen permeation. For these reasons the use of synthetic oil requires not to exceed the working temperature limit of 400°C.

The direct steam generation (DSG) without intermediate exchange fluids would allow the raising of the operating temperature to 500°C avoiding also the thermal differential due to the heat exchanger. However, critical issues related to higher stress in the thermal and dynamic operating conditions with high internal pressures, to corrosion and material degradation of coatings of the selective receiver tubes, should be solved.

Also the possible use, as an exchange fluid, of a mixture of molten salts up to now used only in some solar tower power plants is being studied. ENEA, first, adopted this solution in the Archimedes plant, with parabolic troughs, in operation from mid 2010.

Another activity in research consists of the realization of resistant coatings to operating temperatures higher than 400°C, avoiding the demolition of features of low emissivity, for these higher temperatures.

For thermal accumulation the most used current solution is that of molten salt tanks. Other solutions with high thermal capacity materials such as synthetic oils, oil-sand-rock mixed combination systems, concrete blocks with exchange buried in serpentines are being studied. Other systems under study are based on latent heat of change state, transition of stages and thermo-chemical reactions.

For tower power plants studies are going towards the improvement of heliostat features, with optimized sizes of the single elements and new geometrics. Particular attention is given to tracking devices and to a more efficient positioning of heliostats with the option to create less extensive fields with more than one solar tower. Moreover studies are in progress to optimize solutions for working fluids (molten salts, overheated steam, air) and for thermal accumulation.

In linear Fresnel systems the attaining of an improvement of the structures and components is needed, with the start of a full scale production. Also higher operating temperatures have to be obtained to increase the efficiency of the thermodynamic process.

For dish-Stirling plants, studies are aimed at creating new support structures of the mobile element, with a reduction of costs achievable thanks to reduced used of materials and to an industrial production process. The precision of mirrors has to be improved and its assembly simplified. Intelligent systems have to be developed in order to manage the system and control and correct any mistakes during operation, in order to make the generator autonomous and self-sufficient. The Stirling engines have to be designed, as in the U.S. experiences, for a specific solar source use, increasing therefore reliability and performances. Lastly, it is important to reach an industrial production series which could enable to cut costs and make this type of plant that has such promising features competitive.

5.13 – Electric energy production trends with the mini solar thermodynamic

As highlighted during the presentation of the developments in solar thermodynamic, the real opportunity of bringing this application to the production of electric energy distributed on small scale lies in the solar dish.

The development trend of this type of CSP plant is strictly correlated to the opportunities of improvements previously described and to the effective passage from an experimental dimension to an industrial one.

In favorable sunlight areas, with a reduction of costs, the solar dishes could be competitive also in respect to photovoltaic, allowing a more limited space occupancy for the installation.

An assessment of the costs of generating electric energy and the achievement of economic competitiveness compared to production from conventional sources is particularly critical and cannot exclude the premises and the set boundary conditions. The different studies examined differ in absolute values but show a comforting homogeneity in the evaluations of trends and in comparison to the different sources and production technologies.

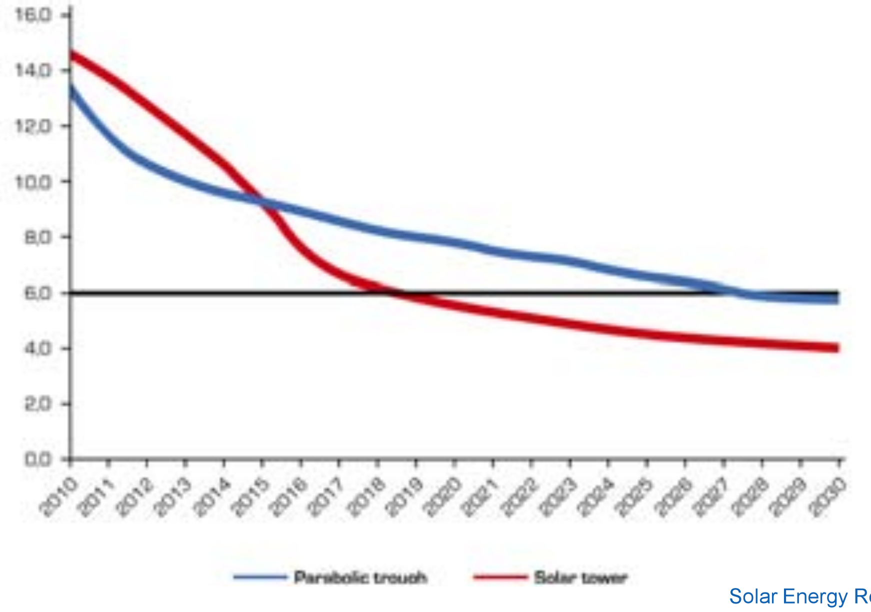
In this respect the recent elaboration presented in the “Solar Energy Report 2011” arranged by the Department of Management Engineering of the Politecnico di Milano (figure 8) is of particular importance. The achievement of grid parity, indicated in the study at 6 c€/kWh, is obtained towards the end of the decade by solar tower power plants, that implement a pass on the economic competitiveness against parabolic troughs. The solar dish trend isn’t reported in the graph as the objective of developing the industrial series production remains under observation. If this condition were to take place, the solar dish would follow a trend comparable to that of solar tower power plants.

Another aspect that could favor the solar thermodynamic development is linked to the regulations containing economic incentives.

In Italy the Ministerial Decree 11/04/2008 of the Minister for Economic Development shows “Criteria and procedures for increasing the production of electric energy from solar energy through thermodynamic cycles”. Below are the most qualifying aspects:

- Incentives are recognized between 0.22 and 0.28 € per kWh in relation to the percentage of solar components of the plant

Figure 8 - Evolution of electric energy production costs (c€/kWh) for solar thermodynamic



Solar Energy Report 2011

- The hybridization of the plant is admitted with unlimited minimum percentages of solar contribution
- The plant has to be connected to the grid
- Thermal oil plants are allowed only in industrial areas
- The incentive is limited up to a maximum total of 2 million square meters installed
- A thermal storage is required for each type of concentration plant to the extent of 1.5 kWh thermal /m^2
- The minimum size of reflectors per plant is equal to 2500 square meters.

The two last given references in fact make this incentive non usable for dish-Stirling plants. Probably such lack is given by the fact that at the drawing up date of the Ministerial Decree in question, it wasn't possible to foresee these new potentials and Italian companies working in the solar dish sector still didn't exist. An adjustment would therefore be desirable which could include this type of application and create new market opportunities in the Italian industry of

CSP that is growing rapidly (V. web site ANEST), but that will find itself facing Spanish and American competitors with already acquired know-how during at least a decade of experiences.

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6. THE STRATEGIC ROLE OF ENERGY EFFICIENCY WITHIN THE ITALIAN GREEN ECONOMY

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6.1 Preface

The European Union has definitely started an irreversible path taking on the global leadership in the struggle of climate change. With the last measures of the better known "Energy-Climate Package", and in particular the 406/2009/EC Decision, The European Union has undersigned a unilateral objective to reduce greenhouse gas emissions by 20% in respect to the values of 1990 (-14% in respect to 2005). Recently, the same European Parliament had evaluated the hypothesis of expanding from 20% to 30% the reduction of emissions by 2020[3], but the decision was rejected.

Europe, moreover, engaged in reaching a 30% reduction of emissions in case of a ratification of a new international agreement for the period post 2012, provided that also the other industrialized Countries undertake objectives equivalent to those of the European Union and that developing Countries give a appropriate contribution to the reduction of emissions. The means to reach such objectives are detectable in the promotion of renewable sources and energy efficiency. In reference to energy efficiency we need to consider that although the European Council of March 2007 had considered in the sustainable environmental strategy also a reduction objective of 20% of the end uses of 2020 energy, nevertheless this target hasn't declined in a binding directive. With the lack of a long term European political strategy on energy efficiency, the objectives of energy saving, of average term, remain effective, fixed by the 2006/22/CE Directive of the European Parliament and the Council of April 5, 2006 regarding efficiency of end use of energy and energy service bearing abrogation of the 93/7/CEE Directive of the Council, that establishes for each State member an approximate National objective of energy saving to 2016 equivalent to 9% of the average consumption of 2000-2005, to be obtained by

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[2] This paper was presented to the Convention organized by the Silvio Tronchetti Provera Foundation of July 20, 2011 "Renewable Energies and energy Efficiency: Scenarios and Opportunities". The tribute updates a previous paper of the of the Author published on the "L'Industria" n. 2/ 2011. The data reported are taken from the research project coordinated by the Author on behalf of Confindustria titled "Confindustria's Suggestions for the Energy Efficiency National Plan to 2020". We thank for the support on data mining, Dott.ssa Sara Rosati and Dott. Massimo Rodà.
Cfr report Eichhout rejected by the European Parliament July 5, 2011.

[3] Cfr report Eichhout rejected by the European Parliament July 5, 2011.

energy services and other measures of energy saving improvements. This Directive was put into force in Italy with the National Action Plan for Energy Efficiency of 2007 that established an objective to 2016 of a 9.6% of saving in respect to 2005 (10.8 Mtep).

On the front of National initiatives the Government intervened to strengthen action on energy efficiency with the May 30, 2008 Decree nr. 115 that puts into force the Directive 2006/32/CE identifying article 5 with which it is stated that the Ministry of Economic Development issues by June 30, 2011, the second PAEE and afterwards, by June 30, 2014 a third PAEE. Straight after with the Law 99/2009 article 27 comma 10, it is fixed that by 2009 the Ministry of Economic Development has to issue the New Plan for Energy Efficiency updating data in respect to the objectives of 2016. On the European front it is important to remember two recent interventions. On March 8, 2011 two important documents were presented, regarding the European strategy on Climate-Energy: The 2011 Plan on Energy Efficiency and the Low Carbon Economy Roadmap 2050.

The 2011 Plan on Energy Efficiency doesn't define binding targets of energy saving but establishes a strengthening of the current measures through a more compelling monitoring of The 2011 Plan of Energy Efficiency and their revision for 2012. Only if the National Plans' result insufficient, the Commission will consider the option of binding National targets, measured on the basis of starting conditions, population, economic performance.

According to the Roadmap if the target of 20% of energy efficiency by 2020 is reached, this will enable the EU to reduce emission costs of 5% more in respect to 20% by 2020 and therefore to establish a new upstanding target of 25% on climate changes.

The Commissions' document of March 2011 has assumed very high programmatic reductions of CO2 emissions to reach a cut of almost 80% in respect to the 1990 levels.

Greenhouse gases reduction per sectors following 2050 Roadmap (%)			
GHG reduction vs 1990	**2005**	**2030**	**2050**
Total	-7	-40 a -44	-79 a -82
Sectors			
Energy (CO_2)	-7	-54 a -68	-93 a -99

Industry (CO_2)	-20	-34 a -40	-83 a-87
Transport(CO_2 per aviation included maritime excluded)	+30	+20 a -9	-54 a -67
Residential and services (CO_2)	-12	.37 a -53	-88 a -91
Agriculture (non CO_2)	-20	-36 a -37	-42 a -49
Others(non CO_2)	-30	-72 a -73	-70 a -78
Source: Roadmap for moving to a competitive low carbon economy in 2050 – Comunicazione Commissione Europea			

The European Commission is certain that to fulfill this program, in the next 40 years, the Union will have to make further investments but a good portion of these will be counterbalanced by a less onerous energy bill for gas and oil and by a social-economic impact that will take European industries to reach a technological leadership in sectors linked to sustainability.

The investments will also reduce Europe's dependence on energy imports and hence our vulnerability versus possible oil price fluctuations, will stimulate new sources of growth and will create new employment. The data of reduction per sector are however worrisome: if we look at the term "power", in the table reported above, it can be noted how the percentages of reduction are extremely high both for 2030 (up until -68%), and for 2050 (up until -99%).

This paper aims to evaluate the green growth potentials of sustainability linked to energy efficiency by means of costs and benefits analysis in the attempt to assess the effectiveness of incentive policies not only with respect to environment but also in terms of industrial growth and employment. .

6.2 The relationship between energy efficiency and sustainability goals

To understand the leading role of energy efficiency it is necessary to consider the strong complementary connection towards reaching binding targets for renewable sources granted to Italy by the European directives. The relationship between the two instruments has to be considered with reference to the assumptions on the evolutionary scenarios on the energy's final consumption. Table 1, below, allows us to analyze how, from 2007 to 2010, the weight and the strategic role have so deeply modified in respect to the Community commitments undertaken by our Country on the subject of sustainability: in the table along the lines is reported the time evolution of the "energy scenario" foreseen for Italy; along the columns are reported respectively the final consumptions for 2020 (column 1), the evolution of the objective of 17% on final consumption of renewable sources (column 2) and finally the size of the objective of energy efficiency to fulfill binding targets.

In the first row of the table the foreseen scenario for our Country at the beginning of 2007 is reported, in which, on the basis of the data collected among the State Members, the European Commission estimated for our Country a consumption trend to 2020 equal to about 166.5 million tons of oil equivalent[4] to that (following Mtep, first row). In the same year the European Commission anticipated the agreements of burden sharing, that would be ratified with the 28/2009/CE Directive, which assigned to Italy a target of 17% of produced energy by renewable sources in final energy consumptions, to be reached in the electric, thermal and transport sectors. Observing the data along the second column, that report in Mtep the target of 17% of renewable sources assigned to Italy, it emerges that if the final trend evolution consumptions were of 166 Mtep, the target of 17% would correspond to 28 Mtep of energy from renewable sources: it was a target impossible to attain, as also stated by the same Italian Government that had estimated in 2007 the potential theoretical maximum of renewable for our Country in 20.97 Mtep[5].

In 2009 the National trend scenario to 2020 was revised (second row in table 1) at 145.6 Mtep. The revision was necessary by effect of the severe economic crisis that hit the main European Countries determining a strong shock in energy consumption. The economic crisis determined a reduction in consumption trend of 10.1 Mtep. To this reduction in 2009, a further amendment was added, as in the meantime the plan for energy efficiency through PAEE[6] (Action Plan for Energy Efficiency) had been presented, in implementation of obligations introduced by Community regulations in the 2007-2009[7] period. The objective expected by the Plan envisaged to reach by 2016 a decrease in a consumption trend of 10.8 Mtep (second row, third column). The conjunction of these two effects determined a reduction of final gross consumption equal to 20.9 Mtep in respect to the anticipation of the scenario of 2 years before. Nevertheless, despite this strong reduction of consumption by 2020, the binding target

[4] The estimate has been carried out by the Directorate General Energy and Transport and reported in "European Energy and Transport-trends to 2030" of 2008.
[5] Position Paper of the Italian Government of September 10, 2007.
[6] Ministry of Economic Development "Action Plan for Energy Efficiency 2007" July 2007.
[7] 2006/32/CE Directive concerning the efficiency of the final energy uses and of energy service repealing the 93/76/CEE Directive of the Council.

for renewable sources would be equal to 24.8 Mtep even higher to the potential maximum value for our Country.

Table 1 – Trend consumptions, efficiency objectives and renewable by 2020

Mtep	Forecast of final energy consumption by 2020	Forecast objectives Renewable/Efficiency	
		Objective RES 17%	Energy efficiency objective
2007 Estimeed trend	166,5	28,3	0
2009 post crisis and PAEE trend	145,6	24,8	10,8
2010 in accordance with PAN trend	133	22,6	12,6
	Total efficiency objective		23,4

The third scenario update is the one that the Italian Government presented in 2010 contextually to the disposition of the Action Plan for Renewable[8] Energy (third row, table 1).

In such a scenario a new energy consumption trend level is established of 133 Mtep to 2020 and, simultaneously, it is expected that the 17% target of renewable on final consumption will be reached with 22.6 Mtep. By what emerged from the evolution of scenarios and on the basis of the binding target defined by our Government for renewable sources, it is possible to define the implicit objective of energy efficiency equal to 23.4 MTEP on the trend. We are dealing with an ambitious objective, essential to achieve to be able to attain the Italian objectives of sustainability.

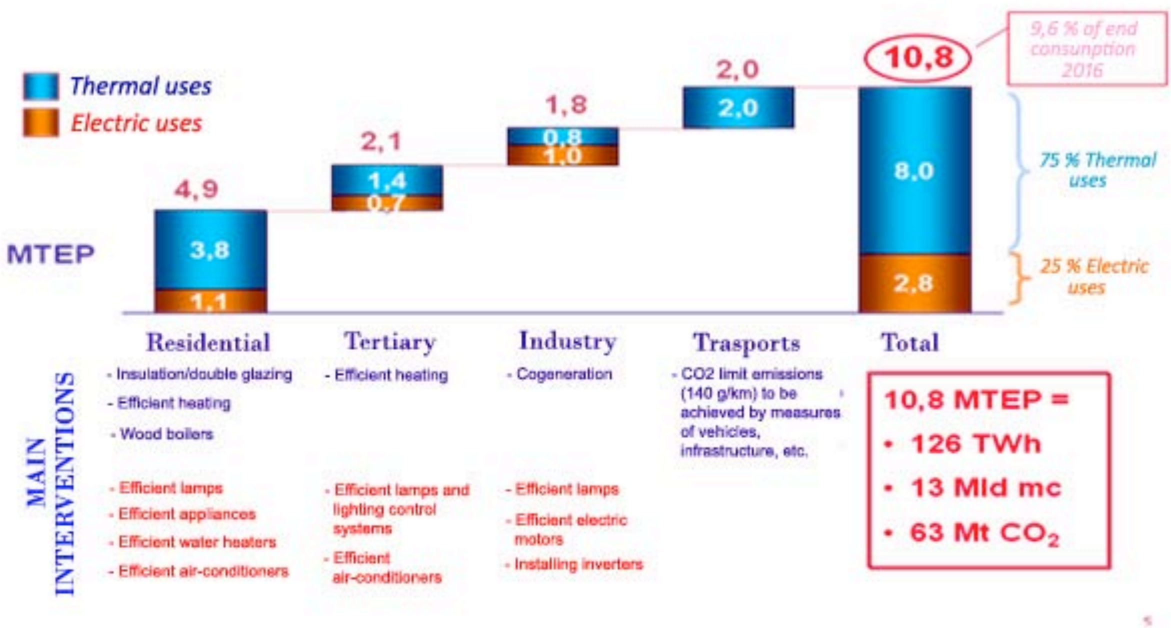
[8] The Action Plan for Renewable Energy to 2020 has to be presented and updated in via biennial according to the dispositions of the 28/2009/CE Directive.

6.3 Energy efficiency and developing opportunities for the Italian industry

Once identified the objectives of sustainability on the programmatic plan, the ability of transforming the challenge of National green economy in an opportunity of technological development and economic growth becomes of strategic relevance. For this reason it is very important to coordinate measures on environmental policy with objectives of industrial development that is identifying policy measures starting from an analysis of the strategic positioning of the Italian industry in technologies for sustainability. The starting point of our analysis is the Governments' PAEE presented in 2007.

By the Action Plan for Efficiency intervention guidelines were set out that regard mainly (about 75%) the thermal uses, in particular more efficient heating systems and building insulation and for 25% the electric uses, which would allow a reduction of 34 Mt of CO2. In reference to the intervention sectors the main target of the 2016 plan is furthermore subdivided between the domestic sector (4.9 Mtep), the industrial (1.8 Mtep), the tertiary sector (2.1 Mtep) and the transport one (2.0 Mtep). Graph 1 summarizes the main areas of PAEE intervention and the main industrial sectors involved.

Graph 1 – PAEE 2007 objectives and industrial sectors involved



Considering the main technological sectors involved in achieving goals of energy efficiency it is easy to identify a direct comparison with many manufacturing sectors that are already present in the Italian industrial scenario.

Making use of the Istat data on manufacturing divisions it is possible to trace back the macro categories of the Italian economic sectors involved directly or indirectly in these technologies. Table 2 reports a first elaboration of this data.

Sectors	N. of enterprises	N. employes ULA	Production mln €	VA mln €
Manufacturing of machinery and mechanical appliances	41.497	619.900	124.309	36.700
Manufacturing of electrical machinery and electrical and optical appliances	47.513	467.500	75.714	25.105
	7.648	266.300	73.373	14.170
Electrical energy, gas and water production and distribution	3.016	129.700	84.995	31.251
Constructions	615.862	1.970.900	204.802	86.975
TOTAL	715.536	3.454.300	563.194	194.199
based on ISTAT 2008 data				

Table 2 – Industrial dimension of macro-sectors involved in the policies for energy efficiency

From the previous table it emerges that the macro-sectors linked to energy efficiency represent a considerable portion in the Italian industrial sector with over 600.000 businesses and over 3 million employed people. It is about a relevant result on the potential plan that could be furthermore strengthened by the growing demand of technologies for sustainability in the Italian and European context.

At this point it becomes important to identify the guidelines for a correct *policy* action able to combine the orientation on choices of energy efficiency policies with an industrial policy that should stimulate innovation and growth in the Italian manufacturing sectors. To draw a correct policy in favor of energy efficiency, it is necessary to carry out a preliminary strategic analysis turned to:

- identifying the sectors that by dimension and by potential savings result more potentially interesting and more efficient in reaching targets by 2020;
- identifying the technologies that result being more promising on a potential plan and favoring investments in research and development;

- identifying technologies currently available for implementing programs of energy efficiency based on an analysis of costs/benefits.

It therefore becomes relevant to identify guidelines of a strategic environmental policy on the industrial plan, based on technology scenarios from which to draw useful indications of energy policy able to identify the relevant areas in which it appears more effective to incentive an improvement of energy efficiency.

Potentially, as reported in the previous table, the industrial development of energy efficiency can involve multiple manufacturing sectors, whose technological applications are related to the transport, the domestic and the electric switching sectors.

Nevertheless, without forgetting that the measures for energy efficiency are mainly traceable to the general tax system, it is necessary to evaluate its effects on the entire economic system, verifying the advantages for the Community and the consequences on the State balance and deepen the investment return analysis of efficient technologies.

6.4 The estimate of the economic impact of energy efficiency: general methodological aspects

To analyze the effects of the energy efficiency policies both under an efficiency profile (in respect to sustainability objectives) and in respect to economic growth objectives, an economic analysis has been carried out assuming a structural intervention aimed to reach the expected objectives in the action renewable plan by 2020.

The evaluation of the effects has been carried out keeping in consideration in a separate way the objectives of effectiveness both environmentally (primary energy saved and reduction of CO" emissions), and in terms of effectiveness of the incentive policies in the socio-economics', on the growth in domestic production between the different sectors involved and the impact of employment and the relative costs charged to the general taxation. On the basis of this assumption the PAEE outlined an analysis of impact that concentrated on the following industrial segments and technologies for efficiency:

1. Trucking (vehicles and light commercial vehicles)

2. Electric motors and inverters
3. Lighting in the industry, in tertiary and public lighting
4. Building upgrade in the domestic and tertiary sector
5. Air-conditioning systems (condensation boilers and heat pumps)
6. Household appliances (domestic appliances for refrigeration, washing and cooking: fridges, freezers, washing machines, dish-washers, ovens, heat pumps for hot sanitary water, fireplaces and biomass stoves, portable air-conditioners)
7. UPS systems (continuity static groups)
8. Co-generation
9. Power Factor Regulation

To facilitate the analysis of impact a scenario based on a structurally stable approach of policy for energy efficiency has been assumed, that is on methodological plan all the simulations were carried out adopting the assumption that the measures for energy efficiency existing in 2010 are to be kept steadily in force up until 2020.[9]

In the simulation it has been assumed maintaining by 2020, therefore for 10 years, the current incentive system and precisely: transport (no direct incentive, R&D structural support), lighting (20% deduction on sale price), housing (55% tax deduction), condensation boilers (55% tax deduction), co-generation (incentive of about 10 euro per MWh without impact on the State), household appliances (20% deduction on sale price), heat pumps (deduction of 55%), UPS systems (20% deduction on sale price), engines and inverter (deduction of 20% on sale price).

[9] Since the end of the '90s all the main studies on Energy efficiency have focalized attention on these industry sectors, see example of Jaffe et al (1999).

Table 3 – Incentive assumption for the different technologies for energy efficiency

Sectors	**Incentive needed**
TRANSPORTS	No direct incentives, R&D structural support
MOTORS AND INVERTERS	20% tax deduction on sale price for 10 years
LIGHTING	20% tax deduction on sale price for 10 years
RESIDENTIAL CONSTRUCTION	55% tax deduction for 10 years
CONDENSING BOILERS	55% tax deduction for 10 years
CO-GENERATION[10]	About10 euro per MWh incentive, without impact on the State, for 10 years
HOUSEHOLD APPLIANCES	20% tax deduction on the sale price for 10 years
HEAT PUMPS	55% tax reduction for 10 years
UNINTERRUPTABLE POWER SUPPLY (UPS)	20% tax reduction on sale price for 10 years

Such sectors, if correctly and adequately sustained by a serious and concrete policy in favor of the spreading of energy efficiency products, can give a substantial contribution to re-launch, also internationally, of the Italian manufacturing industry.

With reference to the evaluations relative to benefits from the introduction of incentives for the purchase of high energy efficiency goods, the impact analysis on energy consumption by 2020 has been led through a methodology subdivided in three phases of analysis. In the first phase the potential effects on end consumption of energy have been considered. The support of trade associations[11] have

[10] It should be stated that incentive to cogeneration do not have an impact on the general taxation but on para fiscal components of the component A3 through duty exemptions of green certifications. The assumed value is determined with reference to an incentive level in line with executive lines of the 20/2007 legislative Decree that that implements the European Directive on the Cogeneration at High Efficiency.
[11] Data has been collected by member associations to the Federations ANIE and ANIMA.

been worked out which have given the estimates relative to the increment of turnover (net of VTA) following the introduction of incentives in the production sector which they refer to[12]. In particular, the given data cover a period between 2009-2020 and indicate two alternative scenarios:

- BAU (Business As Usual) that indicates the "natural" trend of demand in the goods market reference to technology conditions already defined to this day and in implementation;
- BAT (Best Available Technology) which refers, instead, to increased consumption of goods favored by an improvement in energy efficiency (and therefore of technology) and to incentives linked to such progress[13].

Afterwards, in the second phase the effects of public finances of incentive policies have been evaluated. An increase in the demand of high efficiency energy goods produces effects on the State balance, in particular on tax revenue flows (direct and indirect taxes). In respect to direct taxes (IRES, IRAP, IRPEF), against a decrease in taxes paid by the industries of the energy sector (that have to reduce their own incomes) an increase has been recorded in the tax revenues of manufacturing companies that produce efficient technologies and of the subjects (workforce and suppliers) that work for these same. Concerning indirect taxes (TVA and excise duties), against a higher yield of TVA taxation for the sale of efficient technology, a significant reduction is recorded for the decrease of TVA yield and of excise duties paid on saved energy (and in the petrol/diesel for traction and gas for heating excise duties are equal to over 60% of the final price).

Finally, in the third phase, the overall socio-economic impact has been rated. An increase was charged[14] to the demand in the production of goods subject to incentives in the carrier of the final demand of input-output charts. A scheme was therefore obtained on the effects of such an increase in consumption in the entire economic system and more in detail, in the production of goods subject to incentives. The impact has been evaluated on some significant variables referred to both on the entire economy and on the single production branch[15].

[12] Each sector has worked out its own demand increase estimates in the assumption of continuative support policies and incentives for all the considered period (2010-2010).
[13] For methodological deepening, see the study "Confindustria's Proposals for the Extraordinary Plan of Energy Efficiency 2010".
[14] Thanks to the estimates given by interested associations.
[15] The impact analysis was carried out by the means of a matrix of the industrial sectors to thirty sectors of the input-output charts, the latest available in reference to the year 2005.
These give a systematic description of the inter-industrial relationships and of the Italian economic structure and enable to evaluate, through parameters that express the degree of the sectors' independency, as a variation of the demand of any good in a determined sector that develops and spreads to the overall economic system (cfr. Miller 1985).

1. Production value;
2. Employment, measured in thousands of ULA (employment standard units) overall;
3. Total added value and distinct in its components (wages and salaries, payroll taxes, other incomes and amortizations).

6.4.1 Effectiveness of measures for energy efficiency on environmental sustainability and the reduction of energy consumption

The first evaluation has been carried out with reference to the potential of trend saving in terms of energy efficiency. In other terms the evaluation brings back the effects of reduction on consumption of energy trend and of reduction on climate-altering gas (CO_2) as an effect of an incentive policy able to structurally promote the *best available technology* in the field of energy efficiency. In the evaluation the quantitative effects of reduction on final consumption of energy trend (table 4) have been considered separately, from cumulative effects, or else the overall energy saving in the period 2010-2020 (table 5).

Table 4 reports an estimate of consumption energy trend effects till 2020 comparing the values foreseen by PAEE of 2007 (column 1) and the relative biannual update till 2011[16] (column 2), with the possible potential incremental values (column 4) that could be obtained in the event of maintaining structural the incentive hypothesis foreseen for the different technology sectors in table 3. Along the

The advantages of these input-output charts are clear. They, however, contain limits that constrain the use or at least that risk to distort at a lesser extent the medium-long term estimates. In the case in point, three constraint limits are available:

1. The commitment of the input-output models has to be intended, in fact, in terms of comparative static analysis, in the sense that the differential impacts of variations of final demand on levels of production or of application of the primary factors are estimated *being equal to every other consideration*.
2. Moreover, the parameters in reference to the sectors' independence refer to a single year, till 2005. The assumption subordinate the impact analysis is that such integration degree is constant all along the referred to period (2009-2020). In other words technological and structural changes aren't kept into account which could be verified in the Italian productive system. A lack (obliged) of consideration of such changes could translate in a overestimation of the employment impact that is referred to, in our evaluations, to unvaried technology. Technological changes, in fact, lead to a redistribution in favor of the capital of intensity in use of the job factor. It must be underlined, however, that technological and structural changes occur very slowly in mature industrial systems such as the Italian one. The final effects on the estimates to 2020 could therefore also be rather low.

[16] Data taken from the National Action Plan for Energy Efficiency till June 30, 2011.

lines of table 4 the consumption reduction effects are subdivided by sector (Domestic, Tertiary, Industrial and Transport) separating the saving in final thermal and electric uses. In column 3 is reported also the estimated potential till 2020 evaluated by the Government in 2011.

Table 4 – Estimates of incremental energy efficiency potential in respect to PAEE 2007

		Action Plan Energy efficiency MSE 2007 *Scenario to2016*	PAEE 2011 - Additional savings not foreseen	Action Plan Energy Efficiency MSE 2011 *Scenario to2020*	Proposals Estimated potential Energy efficiency *Scenario ao2020*
		Potential savings (MTEP)			
Residential	Thermal usage	3,8	0,02	6,63	3,2
	Electrical usage	1,1	0,51		1,9
Tertiary	Thermal usage	1,4	0,03	2,55	0,6
	Electrical usage	0,7	0,34		0,7
Industrial	Thermal usage	0,8	0,21	2,47	0,4
	Electrical usage	1	0,21		0,5
Transports	Thermal usage	2		4,23	2,5
	Electrical usage				
TOTAL	Thermal usage	8	0,26		6,7
	Electrical usage	2,8	1,06		3,1
GRAND TOTAL		10,8	1,32	15,88	9,8

The results of table 4 have to be compared to the objective of 23.4 Mtep necessary to make compatible the final trend consumptions with the binding of renewable objectives (cfr. Table 1). Two data emerge on which it is worth pausing: the update on the plan of energy efficiency highlights (total sum of column 1 and column 2) that till 2016 with the in force measures the trend reduction of final consumption is equal to 12.12 Mtep, or else still 11.28 Mtep of energy saving are missing to make the objectives till 2020 compatible. Secondly, also along the projections of the potential saving estimated by the Government till 2020 (column 3) equal to 15.88 Mtep highlight however a distance equal to 7.52 Mtep. In other words, an increase in the renewable target to almost 23.9 Mtep in respect to 22.6 Mtep indicated as a maximum potential for our Country would be necessary. And it is striking that if we don't intervene structurally with new measures our Country wouldn't achieve more that 17% and more generally would see jeopardized the general targets of sustainability.

At this point the possible incremental results that our Country could reach by effect of a policy that aims at energy efficiency should be considered. Column 4 presents the result estimate made with the simulation model according to the assumptions previously illustrated. The total potential estimated in the analysis is equal to 9.8 Mtep. If we add the Governments' foreseen total till 2016 (columns 1 and 2) equal to 12.12 Mtep, we obtain an overall potential equal to 21.92 Mtep inferior however to the necessary potential target equal to 23.4 Mtep.

Table 5 reports, instead, the cumulated saving in terms of energy (first column) in the 2010-2020 period, with reference to the different technologies and the relative savings, in the same period, in terms of CO2 (second column).

From table 5 it emerges that through a correct incentive policy of energy efficiency in Italy, this could lead to achieving a saving on final energy consumptions of over 51.2 Mtep[17] in the 2010-2020 period, with a following reduction of CO2 emissions equal to 207.6 million tons[18].

Table 5 – Effectiveness of energy efficiency measures on sustainability

SECTORS	Saved Energy(Gross final consumption)	Saved CO_2	Saved Energy	Saved CO_2 2)
	Mtep	*Mt*	*milionis i €*	*milions of €*
Transports	12	36	4.926	900
Motors and inverter	2,7	12,6	1.108	315
Lighting	8,9	42,2	3.653	1.055
Constructions	8,8	20,4	3.612	510
Boilers	4,9	11,4	2.011	285
Heat Pumps	5,1	27,2	4.802	680
Hous.Applianc	5,3	25,1	2.175	628
UPS	0,7	3,5	304	88
Cogeneration	2,8	29,2	3.025	730
Rephasing	-	-		
TOTAL	51,2	207,6	25.616	5.190

(1)Calulated assumi ing 75 $ per barrel for oil and an exchange rate of Dollar/Euro of 1,25
(2) Caalculated assu suming the value of 25 €/ton of CO2

[17] The potential savings, equal to 51.2 Mtep as an integral value 2010-2020, are calculated in terms of final energy consumption, according to the methodology foreseen by the European regulation (2006/32/CE Directive annex 1): "Member States shall use the annual final inland energy consumption of all energy users within the scope of this Directive for the most recent five-year period previous to the implementation of this Directive for which official data are available, to calculate an annual average amount of consumption. This final energy consumption shall be the amount of energy distributed or sold to final customers during the five-year period, not adjusted for degree days, structural changes or production charges."

[18] To simplify the comparison between the different sectors considered it has been assumed that saved fossil fuel is always the natural gas (coeff. of emission: 2.32 tCO2/tep), except for the transportation sector where it's a mix between gasoline, diesel and gpl (coeff. of emission: 3 tCO2/tep). The efficiency of conversion, transmission and distribution of electric energy was hypothesized equal to 48%.

At this point it becomes important to make a first evaluation of the economic benefits that can derive in terms of saving on the energy bill and in terms of the avoided CO_2. A first estimate on economic benefits will have to be then compared to the relative structural incentive cost in time, so to determine the net benefit for the Community. To carry out this estimate it has been supposed a long term value of standard reference of the cost of oil estimated at 75 US$/Barrel and a perspective cost of CO_2 of 25 €/T[19]. Based on these values it has been possible to reach an evaluation of the cumulative benefit for the 2010-2020 period on the energy bill with a total saving of 25.6 billion euro, and of an avoided cost for effect of CO_2 emission reductions in the period equal to 5.19 billion euro. The estimated benefits will be compared to the incentive costs estimated in the following paragraph.

6.5 The socio-economic impact of policies for energy efficiency

The socio-economic impact analysis has been carried out considering apart the effects of general taxation of structural incentive mechanisms by the effects of growth of the industrial and employment sectors. The general taxation impact is surely the most delicate evaluation aspect of a cyclical trend where the majority of State Members of the European Union have had to face situations of crisis that have had a strong impact on public debt. As seen in the previous paragraphs the incentive mechanisms of energy efficiency are mostly related to fiscal instruments. For this reason it becomes extremely important to carry out an impact analysis on public accounts in relation to objectives of sustainability.

In table 6, the possible estimated effects on public Finance are shown. The typology of incentives assumed in table 3 is mainly of fiscal nature. Also in this case the impact analysis refers to two alternative scenarios (BAU and BAT). The evolutionary one (BAT) is based on the assumption of an increase in the demand for high energy efficiency goods due to a long term regulatory and statutory framework in favor of the spreading of high energy efficiency products. Therefore the overall estimated effects are the impacts on the various components of general taxation generated by a higher energy efficiency technological demand. Specifically it has been considered that: the State contribution, in the form of incentives in the consumption of high energy efficiency goods, the

[19] Long term oil values and CO_2 have been determined based on the values used by the main international research institutes. The values of reference are to be intended as prudential values for the 2010-2020 period.

higher TVA deriving from the increase in goods' sales, the increase of IRPEF for higher employment due to the development of the industrial sectors, of IRES and IRAP for higher earnings of the industry linked to energy efficiency, the reduction of excise and TVA due to less consumption of electric energy and gas[20].

Along the lines of table 6 the cumulative effects of the 2010-2020 period associated with the different technologies are reported. Along the column the items of impact on general taxation are shown. The "tax increase" impacts of costs for general taxation are represented by the supposed tax incentives "State contributions" (column 3) and those associated with the reduction of "Excise and TVA" as an effect of a lower energy consumption. The "reduction" impacts of costs for general taxation are represented by the increase of the "IRPEF" revenues as an effect of the increase of employment (column 1, based on the data reported in the following table 7), the greater VAT revenue (column 2), and the estimated increase of IRES+IRAP as an effect of a higher industrial growth (column 5).

Table 6 – Effects of energy efficiency policies on State budget

SECTORS	EFFECTS					
	Direct Taxes	Indirect Taxes				TOTAL
	IRPEF (+employment)	TVA	State Contribution	Excise andTVA(-consumptions)	IRES +IRAP	
	millions of €	*millions of €*	*millions of €*	*millions of €*	*millions of €*	*millions of €*
Transports	1.364	4.309	(1)	-8.759	471	-2.615
Motors and inverter	132	511	-346	-116	62	243
Ligthinng	141	570	-388	-383	67	7
Constructions	1.395	6.501	-14.931	-1.601	968	-7.668
Condens. Boilers	99	409	-2.036	-1.197	47	-2.678
Heat Pumps	12	49	-1.146	-4.479	6	-5.558
Househ. Appliances	866	3.860	-3.860	-917	450	399
UPS	22	110	-110	-220	13	-185
Cogenerazion	517	1.947	(2)	-103	224	2.585
Riphasing	7	36	-	-6	4	41
TOTAL	4.555	18.302	-22.817	-17.781	2.312	-15.429

[20] The rates of reference that have been applied in the analysis refer to medium reference values thus determined: IRES 27.5%; IRAP 3.9%; IRPEF 20.15% (calculated on gross pay net of workers' taxes).

Column 6 of the table reports the overall net effect on general taxation of incentive measures. In detail an increase of the IRPEF revenue, between 2010 and 2020, can be observed, by 4.55 billion euro, due to employment increase.

The highest yield of TVA, estimated equal to 18.3 billion euro, (always for the 2010-2020 period), is offset by Government grants that are equal to 22.8 billion euro. In terms of excise and TVA, the reduction of energy consumption in the considered sectors generates, instead, between 2010 and 2020, lower revenues for 17.8 billion euro. The net cost to the State budget is equal to 15.429 million euro. The cumulative total charge in the 2010-2020 period, will be then compared to the positive estimated effects with reference to the energy bill and to the cost of avoided CO2.

We then analyzed the impact effects on the industrial sectors both in terms of production growth and on employment. From the analysis carried out the presence in Italy of a series of sectors emerges, which already represented historically and traditionally, leading sectors in the manufacturing National industry, currently with innovative and advanced technologies in terms of energy performance.

The economic impact effects on the industrial sector and on employment have been estimated using ISTAT cross charts as illustrated in the previous paragraph. The effect cumulated in the 2010-2020 period, has been estimated assuming that the industrial sectors are interested in the increasing demand of energy efficiency technologies due to the incentive structural hypothesis considered in table 3. Table 7 reports the summary of results. In the first column are reported the estimate of the overall increasing demand at current prices in the 2010-2020 period, which has an impact on the various industrial sectors and that results in being overall equal to130 billion euro. It is appropriate to underline that the assumed increase is that of National domestic demand. Therefore the overall effect could be underestimated, as external demand isn't considered, which reasonably could occur by the effect of putting into force energy efficiency policies in all the main European Countries.

Table 7 – Cumulated socio-economic effects of energy efficiency policies

SECTORS	Demand increase	Impact on single sectors		Inpact on total economy	
		Production	Employment	Production	Employment
	Millions of €	*Millions of €*	*Thousands of U*	*Millions of €*	*Thousands of U*
Transports	55.305	42.712	196	106.567	625
Motor and Inverters	3.659	2.697	14	6.723	43
Ligthinng	3.333	2.519	18	886	38
Constructions	32.507	26.210	407	61.674	556
oilers	2.448	2.383	12	3.927	27
Heat Pumps	383	262	2	660	5
Hoseh. Appliances	19.518	15.798	98	31.998	220
UPS	1.498	1.106	7	2.462	17
Cogenerazion	10.924	8.511	42	22.646	131
Riphasing	543	399	2	886	6
TOTAL	130.118	102.597	798	238.427	1.667

In table 7, the "direct" increase effects of demand (column 2 and 3) and "indirect" ones (column 4 and 5) on the whole economy due to sector interdependences, are considered apart. Direct effects are relevant and result in an increase of the value of cumulated production in the period and over 102 billion euro with a potential increase of about 800.000 units of standard work. The overall effects on the total economy are estimated to almost 240 billion euro and over 1.6 million units of standard work. From a sector point of view, the impact in terms of production would be favorable for the transport sector (+43 billion euro); the construction sector, characterized by a high intensity usage of the work factor, would instead benefit more from an employment profile (+ 407 thousand ULA added).

The overall effect on the whole economy is particularly significant as it could give an important contribution to the GDP growth of 2010 values, for the period in reference by means of 0.3 percentage points. An important result that confirms how a structural approach towards *green economy* would lead to a concrete advantage in terms of economic and employment growth.

6.6 Overall effects of energy efficiency policies

In the previous paragraphs, the effects of energy efficiency have been estimated separately in reference to the impact on the energy bill, the general taxation and the socio-economic impact. At this point it is necessary to bring back all the elements to a unified synthesis for an overall evaluation of efficacy of the incentive policies' efficiency of energy efficiency. Table 8, reports the synthesis of the previous results analyzed in tables 5-6-7 and it enables us to evaluate the overall results compared to three effects:

- Net effect on the public budget, calculated considering direct and indirect taxes. Specifically it has considered: the Government grant under the form of an incentive to consumption of goods with high energy efficiency, the increased tax resulting from increased sales of goods, the increase of IRPEF for higher employment due to a development in the industrial sectors, the IRES and IRAP for more revenues of the industry linked to energy efficiency, the reduction of excises and TVA due to less electric energy and gas consumption. The net charge for the State budget is equal to 15.429 million euro.
- Benefits due to lower energy bill and environmental costs, calculated as an economic value of saved energy and of not produced CO_2. Such a value represents a positive impact equal to 30.806 million euro.
- Benefits due to economic and employment growth. The overall measures of energy efficiency in the various sectors would lead to a potential savings of our Country in the 2010-2020 period, equal to more than 86 Mtep of fossil energy, to achieve a socio-economic impact equal to about 130 billion euro of investments, an increase in the industrial production of 238.4 billion euro and an employment growth of about 1.6 million units of standard work engagements.

Table 8 – Overall effects of measures for energy efficiency of cumulated effects 2010-2020

Inpacts on State Budget	
Irpef on most employment	4.555
Ires e Irap greater industrial income	2.312
TVA for greater consumptions	18.302
State contributios for incentives	-22.817
Exise and TVA for reduced energetic consumptior	-17.781
TOTAL IMPACT ON STATE INCOMES	-15.429
Economical Impact on Energy system	
Economic valorization of saved energy *	25.616
Economic valorization of saved CO2 **	5.190
Effects on industrial development	
Demand increase	130.118
Production increase	238.427
Employment increase (thousands of ULA)	1.635
Overall impacts on country system	15.377
*Calculated assuming 75$ per barrel the price of oil and an exchange rate Dollar/Euro of 1,2	

In detail an increase of the IRPEF revenue, between 2010 and 2020, of 4.55 billion euro can be observed, due to higher employment. The most tax revenue, estimated equal to 18.3 billion euro (always for the 2010-2020 period), is offset by Government grants that are equal to 22.8 billion euro. In terms of excise and TVA, reduction of energy consumptions in the referred to sectors, instead, generates between 2010-2020, lower revenues for 17.8 billion euro. Nevertheless, it is appropriate to consider also the positive effect of the economic impact of efficiency measures on the National energy system in terms of primary energy saved and CO_2 emissions avoided. If we confer a medium value of 75 dollars a barrel of oil for the whole 2010-2020 period, it is possible to increase the value of the total primary energy saved in the period referred to, considering a Dollar-Euro change of 1.25. The value of this saving is equal to 25.6 billion euro. Giving a medium value of 25 Euro per CO_2 ton, it is possible to quantify economically the overall value of avoided emissions, equal to 207.8 million tons. The value of such a saving is equal to 5.19 billion euro.

Overall therefore, considering both the impact on the State budget and the economic impact on the national energy system, the effects of energy efficiency measures in the 2010-2020 period on the County's system is highly positive, with an economic value equal to 15.4 billion euro.

This result highlights clearly that the measures of environmental policies aren't a cost but represent an advantage and an opportunity for the growth of the Country.

6.7 Conclusions

The previous paragraphs highlight that energy efficiency is a very effective tool to reach objectives of environmental sustainability. Energy efficiency seems to satisfy all the main foreseen Community's objectives from the climate-energy package: reductions of climate-altering, security of supplies, technological development opportunities for the European industry.

From the results, it emerges that energy efficiency gives an undisputed support to the first two objectives. With reference to the first objective the reduction of CO2 avoided for over 200million tons, supplies a significant contribution to the 2020 objectives in the new foreseen targets at Community level with an overall savings that exceeds 5 billion euro. With reference to a reduction of the Italian energy bill the result is likewise significant as the possibility of reducing consumptions by 51.2 Mtep with a saving of 25 billion euro, becomes essential for a Country that by now imports over 90% of primary consumed energy from abroad.

Concerning the opportunity of industrial development, we have seen that the increase of energy efficiency objectives are able to engage a consistent increment in demand of high efficiency technologies activating involvement in a significant way of the Italian manufacturing sector. This is mostly due to the fact that the strategic positioning of the Italian manufacturing industry presents a strong growth potential on these technologies. For sure a phase of large debate on developing and growth policies would be extremely important to transform the general interest and environmental safeguard in an opportunity of growth. As we have seen in the simulations the direct and indirect effects are significant with a potential of an average annual contribution of GDP growth superior to 0.3 percentage points. Furthermore, even if it hasn't been an object of our survey, the positive effects that the reduction of energy consumption implies in terms of greater economic-productive efficiency on the industrial system has to be considered (reduction of productive process costs and increase of competitiveness on International markets).

The assumptions made on incentive mechanisms have focused mainly on general taxation a prevalent measure. In a Country with a high public debt like Italy, the particularly high level of public debt raises understandable concern.

For this reason hypothesis on additional mechanisms haven't been made, but all the evaluations have been carried out based on existing schemes but steady for the 2010-2020 period.

What our conclusion wants to highlight is that the real strength of policies for energy efficiency is the certain statutory *framework* and the definition of an incentive strategy with a temporal horizon in the medium-long term period, that enables operators to plan investments and the strategy of industrial growth in a context of stability. Such an approach cannot prescind from a strong action of administrative simplification and harmonization of the energy efficiency standards, not only at a European level but also at an international one, that allows companies to have a competitive even approach able to exploit strong competences already existent in the Italian industrial sectors. The incentive cost estimated borne by general taxation is superior to 15 billion euro in 10 years, but results greatly exceeded in terms of benefits almost double for 30 billion euro due to reduction of the energy bill and the avoided cost of CO_2.

If the objective of *green economy* is to become an engine for development and technological *leadership*, the policies for energy efficiency can bring our Country to win the challenge under a net social profitability for the whole Country.

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7. Strategic tools for the development of the energy efficiency sector

By Claudio G. Ferrari

Energy is a complex system, not linear. To analyze and to face the growing problems inherent to the energy sector, means having to take into consideration multiple aspects, some of which being only apparently not connected to the same.

In fact, we find fitting Albert Einstein's quotation - "We can't solve problems by using the same kind of thinking we used when we created them" – in defining that, one should have to try to improve and make the energy system sector evolve.

In Italy instead, energy issues are dealt with and managed by the same corporate groups since fifty years to date.

The scarcity of reserves and their restricted geographical location lead to the rise of diplomatic crisis and often too long and bitter wars to try to control their production and distribution. Exactly the use, ever increasing, of fossil sources to produce energy are the cause (scientists estimate it as *very probable*, or at least 90% sure) for global warming and for the related ongoing climate change.

Energy, therefore, is not only a purely economic issue. All the considerations that are made concerning this issue, in fact, must cover a wider sphere of interests as precisely climate issues, but also our relationship with others, the way we consume resources, and so on. To do something (and even a lot) is possible. All that is needed is the will (individual or collective)to do so.

7.1 A new energy paradigm

The current and predominant energy system (whatever energy it may be: thermal, electric, mechanical, from fossil fuel based sources) is characterized by at least two negative factors: the high inefficiency of the whole chain (from production to consumption), due to both technologies and low performance systems rather than to real and proper losses; the high social costs for generation (called externalities, such as those related to climate change, local and global pollution, wars for managing reserves, etc.) that, although difficult to measure, aren't accounted for, significantly distort the analysis of reality.

In figure 1, that illustrates the "chain of energy losses", it is highlighted how only 9.5% of initial energy to our disposal in an electric energy production carbon power plant is, then, actually used. With other fuels and different power plants, the final result is certainly better (if not much better), but the concept doesn't change.

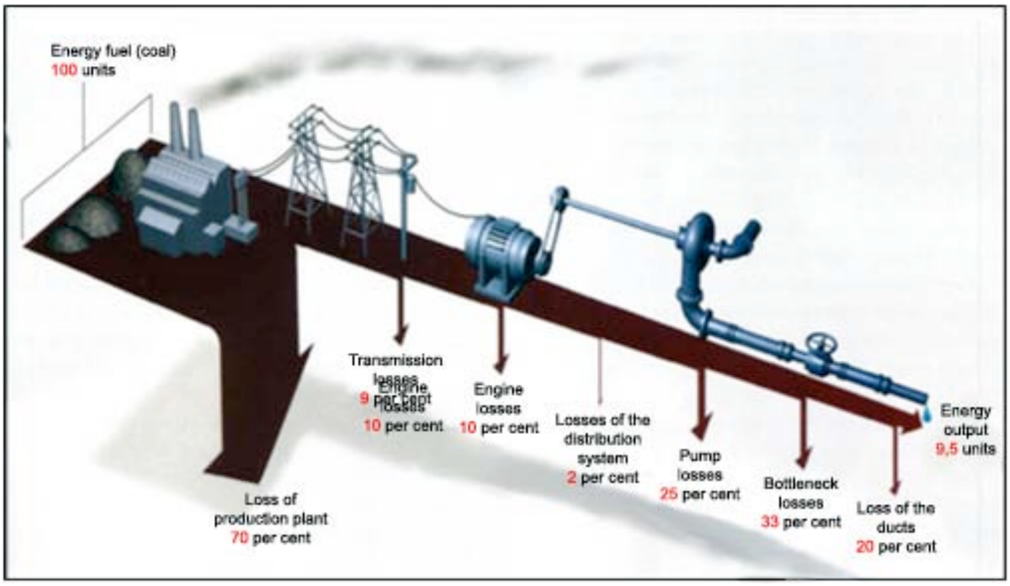

Figure 1 – The chain of energy losses. Source: Amory B. Lovins, "More Profit with Less Carbon", Scientific American Magazine, 09/2005

Improving the energy system, therefore, effectively means:

- increasing the performances of the current power plants of energy production;
- reducing losses along the transmission network, shortening also the distance between production and the location in which energy is consumed;
- modifying the behavior on the demand side, by making individual end users responsible.

Two different solutions can be identified to deal with such a complexity, but certainly a paradigm shift is necessary, as for example:

Developing energy efficiency;

Spreading the **distributed generation**, producing energy there where it is consumed, through small-very small plants;

Expanding the exploitation of energy from **renewable sources** (Sun, wind, water, biomasses and its derivatives, geothermal, etc.).

7.1.1 Energy efficiency

The 2006/32/CE[21] defines energy efficiency as “a ratio between an output of performance, service, goods or energy , and an input of energy” and its improvement as “an increase in energy end-use efficiency as a result of technological, behavioral and/or economic changes”.

There are enormous improvement margins of energy efficiency. Many studies to this regard, in fact, indicate a technical potential of reduction of energy consumption (without in the slightest decreasing the quality of life) of 40%. The European Commission[22] estimates that, implementing only half that potential (20%, target to 2020), 100 billion euro a year can be saved, resulting in cost savings for an average household between 200 and 1000 euro per year. The UN[23] has established a potential of energy savings of 25%-40%. In a study of the International Project for Sustainable Energy Paths (IPSEP) and the Ministry of Environment[24] states that the electrical savings obtainable in Italy can be of 26% in the residential sector, 35% in trade, 39% in the industry.

Assuming these estimates we can assert that **energy efficiency is the first source of alternative energy.** The European Commission[25], in fact, confirms that “energy savings represents without any doubt the quickest, most effective and efficient means in terms of costs to reduce greenhouse gas emissions and to improve the air’s quality, particularly in highly populated areas”.

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[1] 2006/32/CE Directive of the European Parliament and of the Council, April 5, 2006, concerning energy efficiency of end-usages and energy services and repealing of the 93/76/CEE Directive of the Council.
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[25] European Commission, “Doing more with less. Green paper on energy efficiency”, 2005.

In Table 1 is shown the potential energy and economic savings in a typical Italian household following energy efficiency interventions.

Table 1 – Analysis of potential savings in a typical Italian household. Interventions on heating include: isolation of roofs and walls; double glazing; self-adjustment systems. Sources ENEA

ITALY – ANNUAL ENERGY CONSUMPTION OF THE AVERAGE HOUSEHOLD (2,5 persons)				***SAVINGS DUE TO ENERGY EFFICENCY INTERVENTIONS***	
PRIMARY ENERGY FINAL USAGE	**TEP/YEAR**	**%**	**COSTS (€)**	**REDUCTION OF CONSUMPTION**	**ECONOMIC SAVING**
Heating (isolation of: roof and walls; double glazing; self-adjustment systems)	**1.09**	**57.6%**	**950**	**40%**	**380**
Lighting	**0.24**	**12.7%**	**282**	**20%**	**56**
Kitchen	**0.08**	**4.2%**	**75**	**0%**	**0**
Electrical appliances	**0.22**	**11.6%**	**258**	**15%**	**39**
Water heaters	**0.26**	**13.9%**	**216**	**80%**	**173**
TOTAL	**1.89**	**100%**	**1781**	**38%**	**648**

7.1.2 The Distributed Generation

The Authority for Electricity and Gas (AEEG)[26] states that "the Distributed generation" consists in the system of electric energy production composed of medium-small size production units (from some tens of kW to a few MW), connected, usually, to electric energy distribution systems as installed in order to:

[26] The Authority for Electricity and gas, Resolution nr. 106/06 "Monitoring the development of distributed generation and micro-generation plants. Impacts of distributed generation on the electric system".

a) power electrical loads for the most part near the site of electric energy production, very frequently in cogeneration for the exploitation of useful heat;
b) exploit primary energy sources (usually, of renewable type) spread throughout the territory and otherwise not exploitable by other large size traditional systems of production.

   The definition is adopted for which the Distributed Generation is the set of generating plants with a rated output less than10 MW.

   The Generated Distribution brings a number of advantages, including:

   - reduced line losses (transmission and distribution: 9-12%)
   - greater efficiency (up until 70% with cogeneration, instead of 30-35%)
   - less financial risk
   - environmental and social benefits
   - greater involvement of the territories and stakeholders
   - flexibility of operation and location

7.2 Energy efficiency is the first primary source

Energy production from renewable sources is the best way of using resources at our disposal. But producing this "noble" energy is of little use if it then goes to waste. Here it is to be defined a policy of close collaboration between renewable sources, distributed generation and energy efficiency. A common policy, united among public and private, able to allow the territories to share the benefits of electric revenue, first traditional, now renewable.

In Italy, the electric bill, at final consumption, is equal to about 80 billion euro. If you invest, with such a synergy, even only by reducing 10% of consumption, we would save every year 8 billion euro. To date, though, little or nothing is done to pick up strongly such a path. This because, as a fact, those who produce or distribute energy aren't interested (mainly from conventional sources) in energy efficiency, in distributed generation and in the exploitation of renewable sources. Who produces energy, moreover, has unlimited financial resources that can be used to "influence" the press, the politicians and therefore public opinion.

Günther Oettinger, European Commissioner for Energy, June 22, 2011:

“The cheapest energy is the one we don’t consume”. The countdown has begun towards the EU’s objective of reducing by 20% the energy consumption by 2020. If no change will be seen in the next few years, the target will be reached only by half, which puts at risk the competitiveness, the struggle to reduce CO2 emissions and the safety of EU’s supplies and still heavily affects consumers’ bills. To correct the delay and bring back the EU on the right path, **the European Commission proposed a new package of measures to improve energy efficiency.** Our proposal aims to make more efficient the use of energy in our daily life and to help citizens, public authorities and the industry to better manage their energy consumption. This should also result in lower bills and create a strong potential for new jobs throughout the EU”.

Energy efficiency is a formidable economic and social tool

- **it pays for itself**: interventions are paid by the substantial savings that they generate
- **it creates jobs**: the interventions, micro spread throughout the territory, are carried out by thousands of different operators. According to the European Commission[27], “investments in cost-effective energy-efficiency improvement will almost always have a positive impact on employment. In all cases, the number of jobs created is greater than those created from comparable alternative investments, including investments for the extraction, transformation and distribution of energy”.

7.3 The monitoring: Energy efficiency strategic tool

Energy efficiency is today the main primary energy source for Europe and, in particular, for Italy, as a Country characterized by a structural dependence on imports and from average prices higher than the European average. In European Communications COM(2008) 241 and COM(2009) 111 and in the Recommendation C(2009) 7604 the importance of the role that ICT technologies can play for the improvement of energy efficiency is emphasized:

- to ITC is recognized an important role in reducing energy intensity, understood as the amount of energy required to produce one unit of gross domestic product, and in increasing the energy efficiency economy;

[27] European Commission, “Doing more with less. Green paper on energy efficiency”, 2005

- it states that ITC can play a significant role in reducing emissions and contributing to sustainable growth;
- to ITC is assigned a role of control and direct management of energy consumption;
- it recognizes ITC's ability to provide tools and models for lifestyles and more efficient work and the ability to produce innovations that reduce energy waste.

  The Legislative Decree 115/2008 is currently in Italy, the main reference for production of ICT in improving energy efficiency:

- it emphasizes the importance of monitoring the results of energy savings following redevelopment;
- to Article 16 is attributed primary importance, for the supply of energy services, the development of an energy management system (ISO 50001), within which the monitoring consumption plan is essential.

  The monitoring of energy flows is crucial for the fulfillment of compliance audits of contracts for energy supplies and services required by the Presidential Decree 207/2010 (Regulations implementing the Contracts Code).

Through the continuous measurement of all relevant parameters (energy needs, power, microclimatic data, personnel attendance, hours of operation, etc…), it allows to take the best decisions (in terms of effectiveness and technical and economic efficiency) both in the design of interventions and in the subsequent management phase.

The energy measuring system allow to quantify the energy savings actually achieved with the assistance provided through:

- anti-intervention measures (una tantum)
- continuous post-intervention measures

7.4 The ESCO and the finance: key tools for energy efficiency

To ascertain the potential availability of funds (equal to 40% of consumption), that every moment is literally wasted, the society and the economy, arising from the massive and indiscriminate use of fossil fuels, the legislator has put in place a series of tools to simplify, streamline, accelerate and, in turn, encourage the recovery and reuse of such wealth, redistributing it among all the stakeholders. In order also to greatly reduce air emissions.

It is the same finance and the consequences on the ecosystems and the implicit and hidden in the distortions in the energy system, which, if properly researched and stimulated with specific financial tools, leads to the triggering of a virtuous cycle.

The tools that the legislator has laid down, fundamentally, are: ESCO and Third Party Financing. The sector is regulated at European level by **Directive 2006/32/CE** which among other things, obliges Member States to achieve a **goal of energy savings equivalent to 9% between 2008 and 2016[28],** from the **Plan of Action for Energy Efficiency** approved in October 19, 2006, and at the Italian **Legislative Decree 115/2008[29]** implementing Directive 2006/32/CE, by the **Ministerial Decrees of July 20, 2004[30]**, and resolutions of the Authority for Electricity and Gas[31], in addition to the **Legislative Decree 192/2005[32]** on the energy performance of buildings.

7.4.1 The Energy Service Company (ESCO)

The Legislative Decree 115/2008, implementing Directive 2006/32/CE on energy end-use efficiency and energy services, defines the ESCO as “any natural or legal person who supplies energy services or other energy efficiency improvement measures in the premises or in the users’ premises and by doing so,

[28] Directive 2006/32/CE – Article 4, (1): Member States shall adopt an aim to achieve an overall National indicative Energy savings target of 9% for the ninth year of application of this Directive, to be searched by way of Energy services and other Energy efficiency improvement measures. Member States shall take cost-effective, practicable and reasonable measures designed to contribute towards achieving this target. (…) The National Energy savings, in relation to the National indicative Energy savings target shall be measured as from 1 January2008.

[29] Legislative Decree 30 May 2008, nr. 115 “Implementation of Directive 2006/32/CE on energy end-use efficiency and its energy services repealing Directive 93/76/CEE”.

[30] Ministry of Industry, Decree 20 July 2004, 2New identification of quantitative targets for increasing energy efficiency in end-uses of energy”, pursuant to art. 9, (1), of Legislative Decree 16 March 1999, nr. 79 Ministry of Productive Activity, Order of 20 July 2004 “Identification of new quantitative targets of energy saving and development of renewable sources”, in the art.16, (4), of Legislative Decree 23 May 2000, nr.164.

[31] Authority for Electricity and Gas Resolution no. 103/03 “Guidelines for the preparation, execution and evaluation of projects under Article 5, (1), of the Ministerial Decrees 24 April 2001 and for the definition of criteria and procedures for the issue of energy efficiency”.

[32] Legislative Decree 19 August 2005, nr. 192, “Implementation of the Directive on energy performance of buildings there” and to the Legislative Decree 29 December 2006, nr. 311, “Corrective and Additions to Decree 19 august 2005, nr. 311, “implementing Directive 2002/91/CE, on the energy performance of buildings”.

accepts some degree of financial risk. Payment for the services delivered is based, in whole or in part, on energy efficiency improvements and the achievement of other performance criteria”.

The UNI CEI 11352:2010 also defines the general requirements of the ESCO.

ESCOs are subjects specialized in making those interventions in energy efficiency, distributed generation (small-scale production of energy close to places of consumption) and renewable energy, usually by relieving the customer from the need to raise funds for implementation of projects and technological risk by virtue of running both design and construction and maintenance throughout the duration of the contract (usually ranging between five and ten years).

ESCOs are based on four main principles:

1) The ability to have a strategic and operative approach on the whole chain of energy requalification process, following all the steps in an integrated way, coordinating it, optimizing it, contextualizing it, giving priority to energy saving and placing itself at the center of many interests;
2) Remuneration based on the energy savings actually achieved, the differences between the energy bills before and after improvement action is up to the ESCOs in all or in part until the end of the amortization period provided in the contract;
3) Direct or indirect financing of the operation, mainly using the methodology of the Financing Through Third Party (FTT);
4) Warranty to the customer’s energy saving.

The advantages in using ESCOs consist of:

- Implementing energy redevelopment, without the need for having or restraining the financial resources required for the investment;
- Assigning the work to specific technical expertise, which the Customer does not have, getting a service and an integrated 360 degrees approach;
- Management and maintenance entrusted to specialized expertise (“outsourcing”), with a global cost reduction and an improvement in quality of service provided;
- Reducing consumption and management costs with technological improvement, increasing of comfort, without investment costs;
- Ability to “certify” the energy saving measures by obtaining the Energy Efficiency Certificates.

At April 1, 1847 subjects resulted accredited as ESCO, at the Authority for the Electricity and Gas, with an increase of 25% over the previous year. It is to be noted, however, that only 295 of these (equal to 16% of those accredited) have obtained the emissions of Titles of Energy Efficiency (TEE)[33], namely they have submitted to the AEEG at least an energy efficiency project.

Of these, if derivations from ESCO utilities aren't taken into consideration, manufacturers of specific energy-saving technologies and the ESCOs of the former municipal utilities, only a few dozen are "pure" ESCOs that operate at 360 degrees.

7.4.2 Third-Party Financing (TPF)

Without financial resources, readily available, immediate investments needed to implement energy efficiency measures aren't possible.

Third-Party Financing[34], the use of which is widely supported by various international[35] bodies, is the financial tool that allows the end user to carry out energy efficiency measures without having to anticipate the least capital. ESCO carries out energy efficiency measures, **thanks to the anticipated resources from the banking system,** and agrees with the end user on how much of the savings achieved should serve to repay the investment, thus defining the repayment plan. At the end of the period of repayment, the end user becomes the owner of the action and enjoys in full the additional savings resulting from it, even if they have been immediately pulled down the climate-altering emissions.

Article 9 of Legislative Decree 115/2008, which foresaw a creation of a Revolving Fund for energy efficiency measures implemented under the Third Party Financing by the ESCO, with Legislative Decree 28/2011 was repealed.

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[33] Source: AEEG, annual Report on the status of services and activities carried out, July 6, 2011.

[34] The 93/76/CEE Directive defines it "The overall provision of auditing, installations, operation, maintenance and financing services for an energy efficiency investment, with recovery of the cost of these services being contingent, either wholly or in part, on the level of energy savings". Third-party Financing was reiterated by the 2006/32/CE Directive and by the Action Plan for Energy Efficiency: Releasing the Potential. It was finally provided by the 115/2008 Decree of transposition of Directive "006/32/CE.

[35] The 2006/32/CE Directive, point 22, states: "The sue of Third-Party Financing arrangements is an innovative practice that should be stimulated". The Intergovernmental Panel on Climate Change (IPCC), in the Fourth Assessment Report (Working Group III – Summary for Policymakers, Page 17), puts, among the effective environment tools, incentives to ESCO and , in the key factors for success, the use of the Third-Party Financing mechanisms.

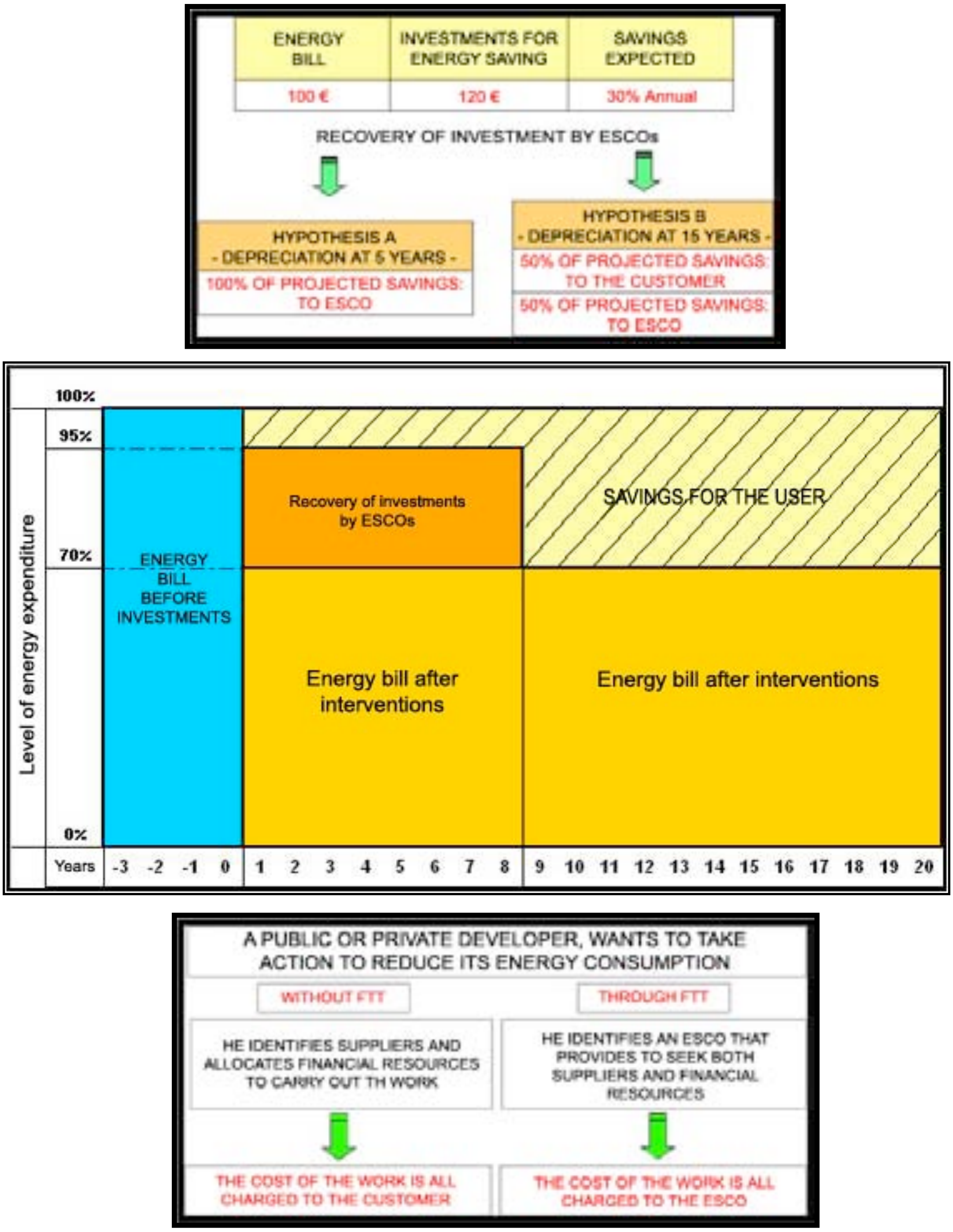

Figure 2 – The mechanism of Third-Party Financing

Global Energy Scenarios

June 20, 2011

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Summary

The role of fossil sources
In primary energy demand

- **The situation today**

The possible future scenarios

- ***In the absence of new policy***
- **In presence of new *policy***

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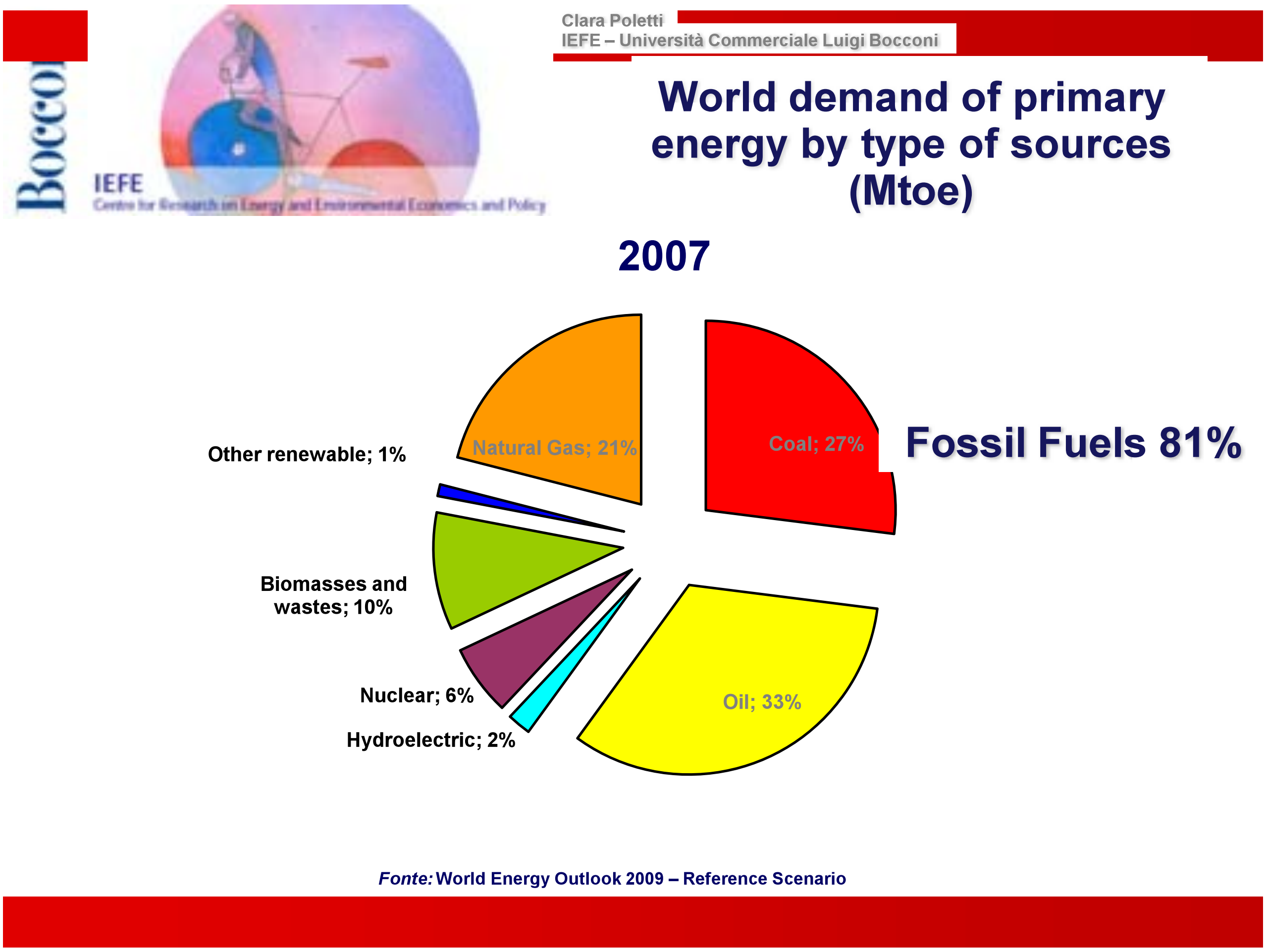
The role of fossil sources in the global primary energy demand

The situation today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Bocconi
IEFE
Centre for Research on Energy and Environmental Economics and Policy
World demand of primary energy by type of sources (Mtoe)
2007
Natural Gas; 21%
Coal; 27%
Fossil Fuels 81%
Other renewable; 1%
Biomasses and wastes; 10%
Nuclear; 6%
Hydroelectric; 2%
Oil; 33%
Fonte: World Energy Outlook 2009 – Reference Scenario

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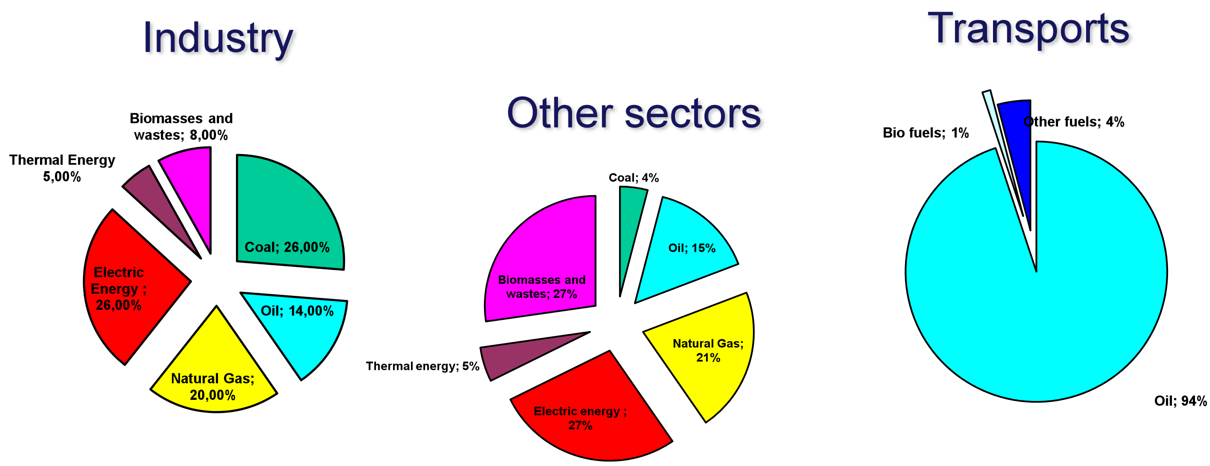
Primary energy consumption by source and by sector (Mtoe)

2007



Source: World Energy Outlook 2009 – Reference Scenario

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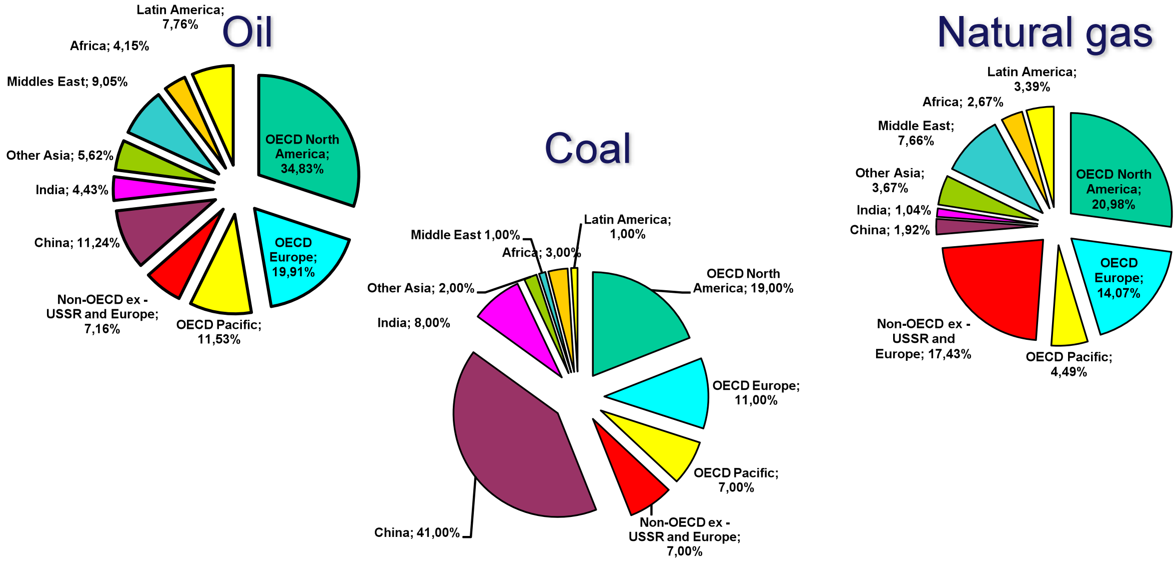
Shares by geographical area in the demand for fossil fuels (Mtoe)

2007



Fonte: **World Energy Outlook 2009 – Reference Scenario**

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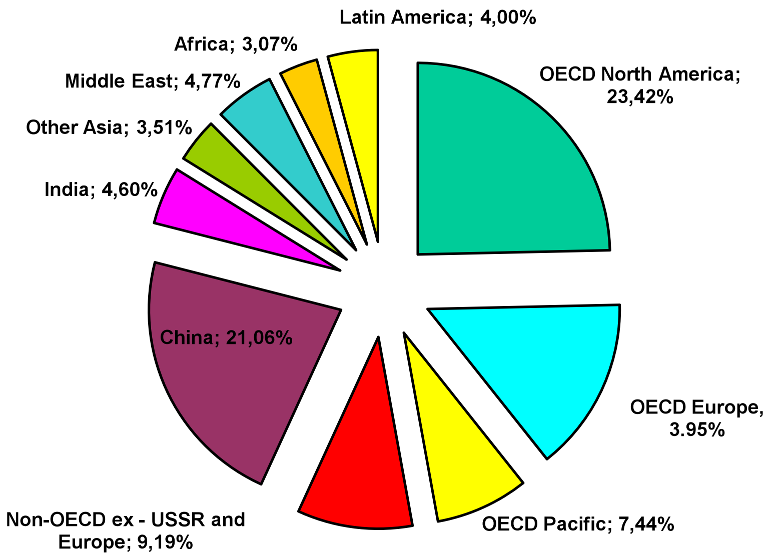
Carbon dioxide emissions from fossil sources (Mt)

2007



Source: **World Energy Outlook 2009 – Reference Scenario**

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The possible future scenarios
In *the absence of new policy interventions*

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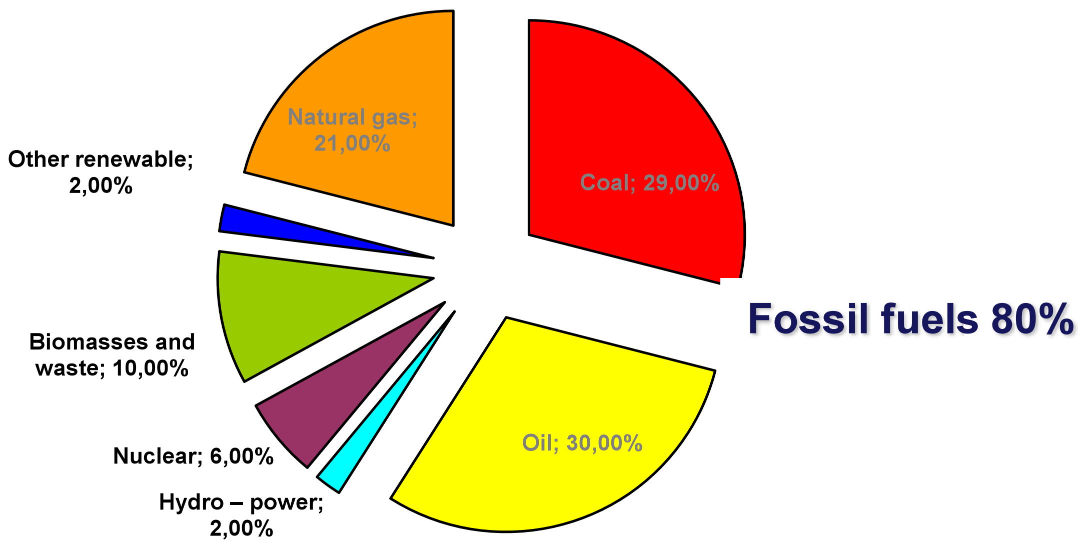
World demand for primary energy by type of sources (Mtoe)

2030



Source: World Energy Outlook 2009 – Reference Scenario

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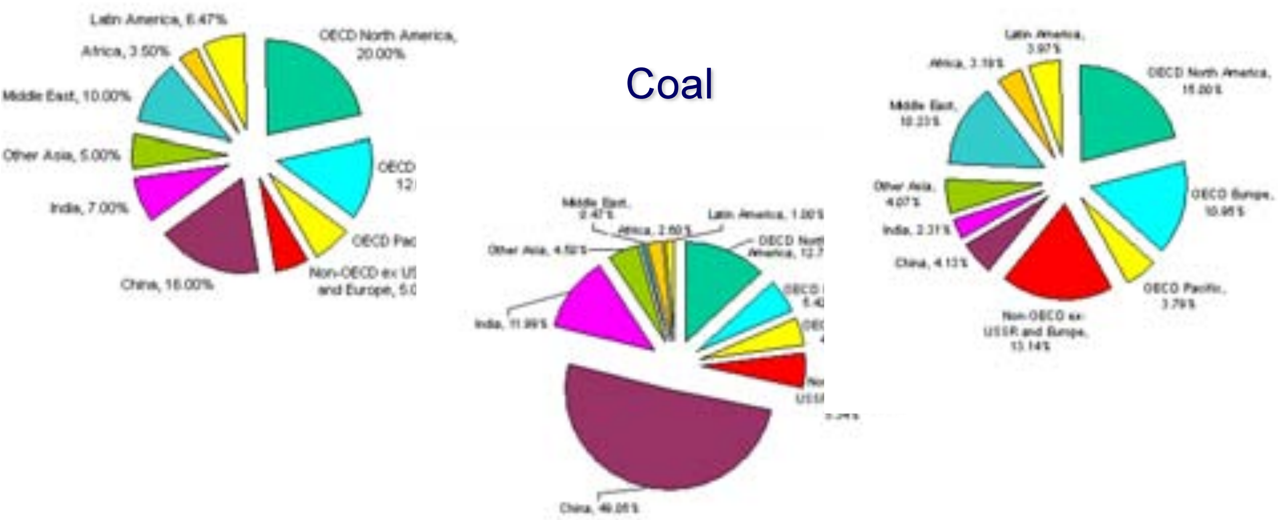
Shares by geographical area in the demand for fossil fuels(Mtoe)

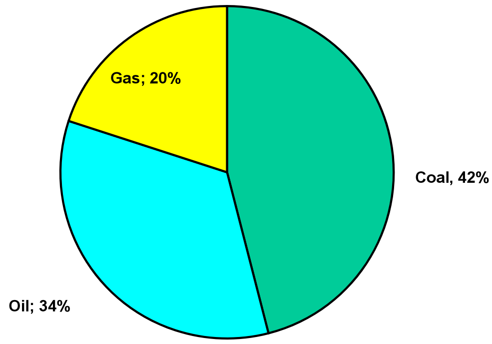
2030



Source: World Energy Outlook 2009 – Reference Scenario

Carbon dioxide emissions from fossil sources (Mt)

2030



Source: World Energy Outlook 2009 – Reference Scenario

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In 2030 in the absence of new policy measures…

- **Increase of global consumption of fossil fuels: +37% over 2007**

- **Growing global demand for oil: + 22% over 2007**
  - OECD Countries: - 14%
  - non – OECD Countries: +63%
  - China and India more than double oil demand

- **Growing global demand for coal: + 53% over 2007**
  - OECD Countries: -7%
  - non – OECD Countries: +86%

Source: **World Energy Outlook 2009 – Reference Scenario**

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In 2030 in the absence of new policy measures…

- **Growing global demand for natural gas: +42%**
  - OECD Countries: +15%
  - non – OECD Countries: +68%
  - China: goes from 61 to 202 Mtoe of consumption
  - India: goes from 33 to 113 Mtoe of consumption
- **Increase of CO2 emissions: +40% over 2007**
  - OECD Countries: - 3% compared to 2007
  - non – OECD Countries: + 57% compared to2007
  - China: +86% compared to 2007
  - India: more than doubles

Source: World Energy Outlook 2009 – Reference Scenario

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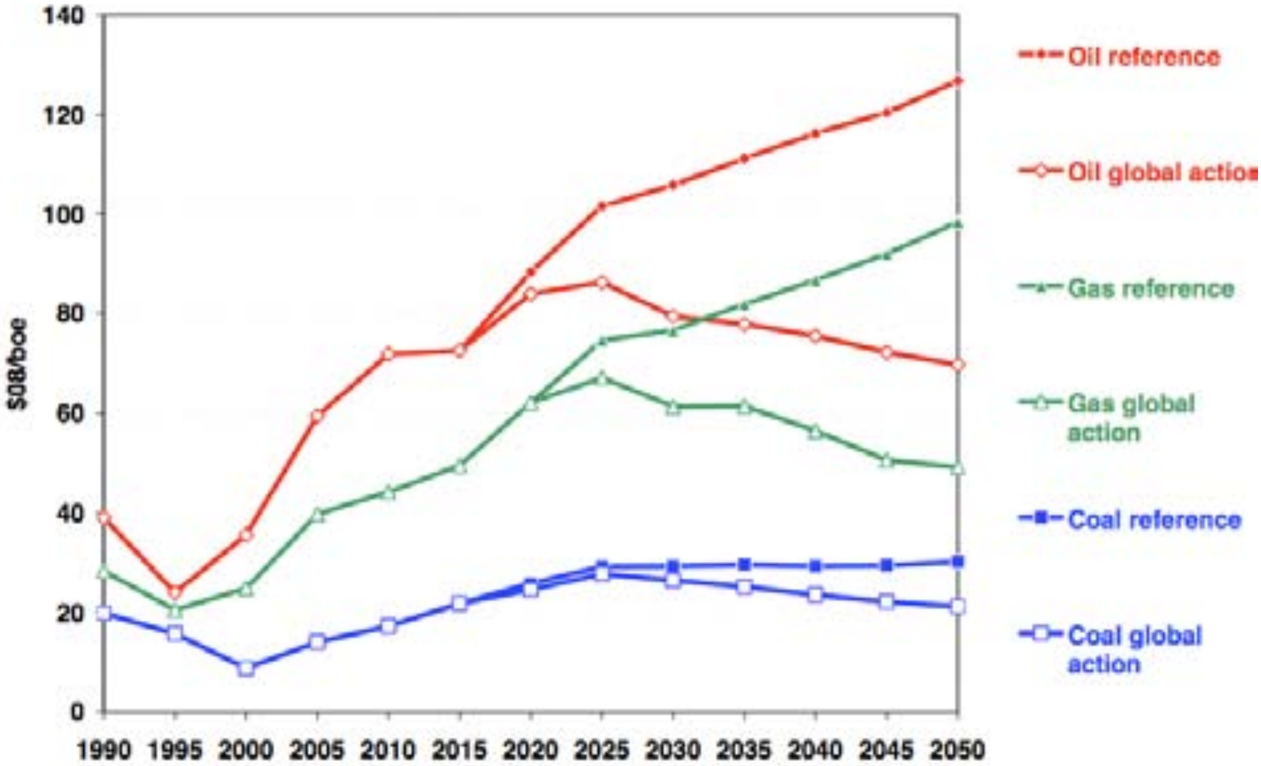
In 2030 in the absence of new policy measures…

- **Supply security**
  - Increase in the price of fossil fuels as a result of increased demand
  - Increase in the volatility of oil prices due to conflicts in Iraq and Libya
  - Increase of production costs of fossil fuels

Source: World Energy Outlook 2009 – Reference Scenario

Source: Impact assessment Road Map 2050 EC

Figure 9: International energy prices in reference and in the context of global climate action



Possible future scenarios

In the presence of new policy interventions

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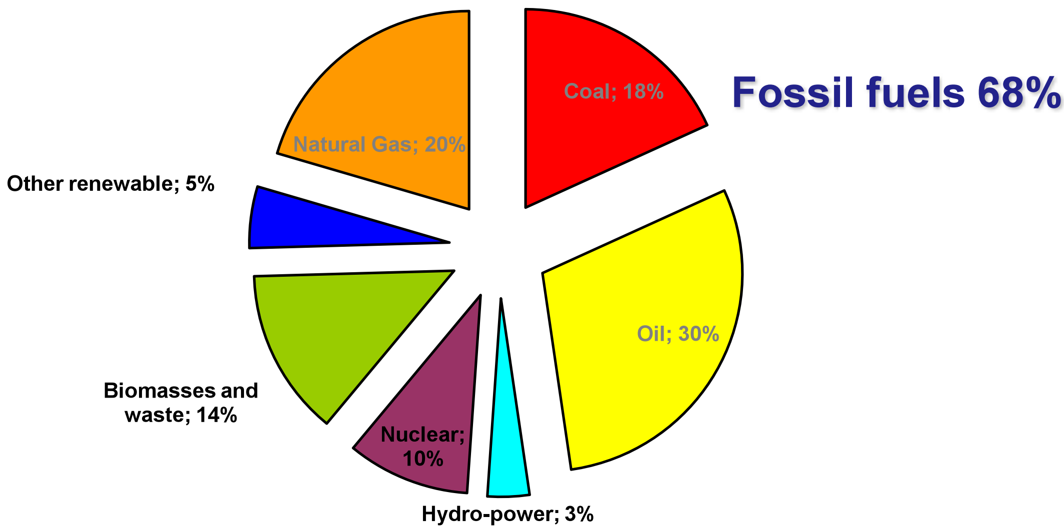
World demand for primary energy by type of source (Mtoe)

2030



Source: World Energy Outlook 2009 – Reference Scenario

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In 2030 with new policy interventions…

- **Share of coal in primary energy demand: from 27% in 2007 to 29%**
  - De-carbonization through CCS
  - Sharp drop in demand from industry
- **Oil share: drops from 33% in 2007 to 30%**
  - Oil demand in the United States, the European Union and OECD Countries outside EU gradually decreases
  - Demand in China rises steadily by 2.7% yearly

Source: **World Energy Outlook 2009 – Reference Scenario**

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In 2030 with new policy interventions…

- **Share of natural gas: unchanged compared to 2007**
  - OECD Countries: steady demand compared to 2007
  - non – OECD Countries: +33% compared to 2007
  - Unconventional gas

- **CO_2 emissions decrease by 2.2% compared to 2007**
  - OECD Countries: -41%
  - non OECD Countries: steady increase in emissions
    - China: + 16% compared to 2007 (vs 86%)
    - India: + 65% compared to 2007 (vs 100%)

Source: **World Energy Outlook 2009 – Reference Scenario**

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In 2030 compared to projections of the *Reference Scenario*…

- The share of fossil fuels compared to the global demand for primary energy is reduced by 14 percentage points
- **Coal share:** from 29% of BAU to 18%
- **Share of natural gas and oil:** almost unchanged at *BAU*
- **Shares of nuclear and renewable sources: increase compared to** BAU*:*
  - Nuclear: from 6% to 10% compared to BAU
  - Hydroelectric: practically constant
  - Biomasses and wastes: from 10% to 14% compared to BAU
  - Other renewable sources: from 2% to 5% compared to BAU

Source: **World Energy Outlook 2009 – Reference Scenario**

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All scenarios agree on growing demand for natural gas…

- Wide availability of the source, geographically dispersed
- The basis of conventional resources can cover current needs for over 120 years; unconventional resources can cover more than 250 years
- Driving the demand are mainly: (i) power generation, (ii) industry; (iii) domestic heating
- In perspective the development of CCS becomes necessary
- In 2035 electricity generation with CCS will represent ¾ of total electricity generation (*International Energy Agency, 2011*)

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However there are uncertainties about CCS . . .

- Uncertainties about the cost of CCS technologies:
  - Recent estimates of combined cycle plants show a cost ranging from 120$ to 18'$ per Mt
  - Costs for capture and storage have been estimated at 10 – 15$ per Mt
- Adjustment costs:
  - Define the subjects responsible for the stored CO2
  - Regulate the consumption of the pipeline
  - Overcoming any regulatory barriers to the creation of infrastructure for CO2 storage

Source: International Outlook Scenario 2010

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The nuclear. . .

The main pre-Fukushima scenarios

- Important role of nuclear energy for limiting emissions
- The strongest growth in the use of nuclear power concerns primarily non – OECD Asian Countries
  - Continuous rise in costs from new security standards and the possible increase in the price of raw materials

Post-Fukushima

- A slowdown in the EU, what about the non OECD Asian Countries?
- Continuous rise in costs from new security standards and the possible increase in the price of raw materials.

…. but Greenpeace …

- It is possible to reduce of 50% CO_2 emissions in 2050 without resorting to nuclear and divesting power plants in use

- By 2050 almost 80% of electricity could be produced by renewable sources

    - 34%will be produced by wind energy
    - 18% by photovoltaic
    - 14% by hydroelectric
    - 9%by fossil fuels
    - The remaining 20% will be produced again by fossil fuels of which 85% is represented by natural gas.

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Conclusions

- ✓Which is the “correct” scenario?
- ✓Problems of all scenarios:mechanisms of implemetation aren’t considered as constraints
- ✓Example: energy efficiency