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Astana *Italy*

Interview
with Stefano Ravagnan,
Italian Ambassador to Kazakhstan

Editorial

 

by **Ilaria Bertini** *and* **Michele Marrocco**

Future energy is the subheading announcing the main theme of the international Expo 2017 taking place from June 10 till September 10 in Astana (Kazakhstan). Undoubtedly, in a world increasingly greedy for energy the Expo appears to play the crucial role of a melting pot for key ideas about upcoming uses of energy resources. Innumerable specific interpretations of the main theme will be on display in Astana, each with peculiarities and prospects whose full coverage is out of the scope of the present publication. On the other hand, emerging solutions to the problem of energy supplies meet ENEA's mission in full and, for this reason, this issue of our magazine entitled "Astana Italy" is focused on some Italian technologies and innovative concepts or practices that fall within the hot theme of future energy.

First of all, the Expo makes us raise an immediate question, rather obvious in its disarming simplicity is: what is future energy? In a wider context, this question has a precursor in the crucial doubt on whether the energy, as we know it, has a future at all. As a matter of fact, several urgent constraints, such as the preservation of the natural environment and the pursuit of clever uses of energy resources, have already pushed us to modify our view about energy and, indeed, new forms of energy production and consumption that are user-friendly, or close enough to being credited so, have been explored in recent times. Some examples have become familiar over the years (e.g., biomass, thermodynamic solar power, wind power, photovoltaics, and so on) and they all suggest the tendency for broader understanding about our dependence on energy.

More importantly, one essential requirement for the definition of future energy is the guarantee of future for all users, especially those in the years to come. It means that production and consumption have to be thought and realized in terms of measures inclusive of ecological principles. This objective can be met if and only if a coherent action is undertaken by those that merge innovation and technology into the vision of a long-term (if not perpetual) solution to the energy problem. Thus, the fundamental question on what is future energy can only be answered if we define innovation as related to the broader problem of mind-boggling complexity where scientific and technical solutions fit into reasonable consumers' needs, inescapable environment protection and forward-looking political choices. These factors of development are intertwined on long time scales but, in this fast-moving world, decision makers have to act on short notice and understand swiftly where the threads go. This implies that fundamental (if not crucial) decisions could be taken on the basis of the so-called "usable ignorance" rather than "usable knowledge" (J. R. Ravetz, "Usable knowledge, usable ignorance: incomplete science with policy implications", Science Communication 9, 87-116 (1987). Let's get deeper into the concept.

Innovation recalls at its Latin stem the introduction of new approaches or new practices in scientific and technological procedures as well as in daily life. In other words, innovation pairs with novelty in a very loose and yet ample sense. Yet, is innovation a synonym for advancement or progress? Something new could be for the better or for the worse. There should be no doubts on the two options taking place alternatively or simultaneously, even though on incredibly different time scales. For instance, nothing to question about the novelty introduced by internal combustion engines when they were conceived and put on the market. Great invention! They have sped up the world so that any distance has become shorter if not much shorter. But, after about one hundred years of traffic, waste gases are diffused in any single corner of our globe and now exhaust emissions bear a serious health risk in many polluted cities so that, on the long run, those uncontrolled emissions could become one of the main triggers of that dramatic scenario framed under and evoked by the well-known term of global warming. This is just a clear example telling us that we cannot take for granted that innovation comes with its all-around progress. Regress could always appear as thorns on roses. Something similar is happening in these days of our western society, where the increasingly open outlook on social life encouraged by the advent of more and more sophisticated and fast means of communication is gradually eaten away by threats coming from several menaces (terrorism, uncontrolled migration fluxes, economic crisis) grown on the ground of the world wide web.

The two sides of the coin are not for the specialist to ponder. Indeed, scientists, practitioners, technicians, professionals act on a different basis. They are, in most cases, highly skilled people

and deliver their exclusive knowledge to the object of their expertise. In other terms, if innovation is promoted by specialized researchers, these ones cannot take the function that is entitled to decision makers. Politics has to establish the role of science in the advancement and preservation of our industrialized civilization, especially when innovation does not come up with its untwisted tangles. It means, furthermore, that politicians must be able to develop an intuitive power to grasp downsides of seemingly advantageous scientific or technical steps forward, which could also be prone to open and popular debate (paradigmatic, here, is the case of landfills and the handling of wastes in incineration plants). Such a capability involves the trait that only men and women of vision have. What is more, it demands the burdensome ability of working on partial ignorance about the foreseeable occurrence of endings that are not always so happy as the promises made by new scientific and technical knowledge. And the balance between the two opposite poles (i.e., useable ignorance and knowledge) is hard to achieve if the road towards it is not seriously walked through by our local and national leaders. For sure, best choices stem from that balance and, in this sense, "ignorance is bliss" (as reads an old English saying). But, to get to that point, representatives of our ruling class have to be trained to challenge with competence the stimulating questions that innovation recurrently carries and for which there might be no clear preference among complex answers all the same predictable or, at least, justifiably presumable.
In the end, it appears that future energy does not only have the connotations of revolutionary or, to a lesser degree, incremental advances that science and technology pursue and pile up on the global scene of our erratic world. Future energy is the resulting all-embracing design about our energy-dependent and energy-oriented destiny shaped by the concerted effort made by all the actors involved in the mission of securing the broadest availability of social advantages of new technologies by minimizing in the extreme the potential risks of adverse circumstances. Along the same lines, future energy is much more than technological choices made by the promotors of technology. It is the playhouse where the plot is going to be written down by the hands of several experts of scientific and human provenance and whose respective contributions will forge and prepare a forthcoming time of sustainable lifestyles.

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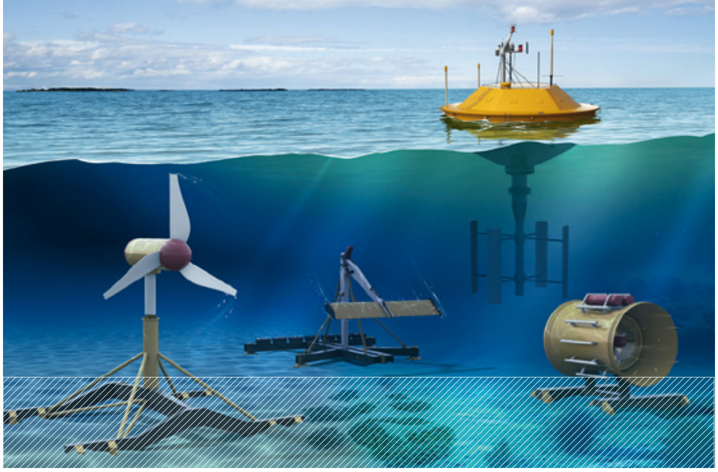

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Interview *Edited by Gaetano Borrelli*

with **Stefano Ravagnan**, *Italian Ambassador to Kazakhstan*

Innovation is among those boosters driving economy at large, what is its role in promoting the Italian economy in eastern countries, like the one you have a direct experience of as Italian Ambassador?

The Kazakh market is rich in opportunities for Italian companies, at the same time we have objective and evident disadvantages in the competition with countries like China, Russia and Turkey, which are closer to Kazakhstan or, like in the Russian case, partner of it in an economic integration process. In such circumstances innovation-based products and services are essential to fill the gap and keep the "made-in-Italy" attractive. The around 8% increase of our exports last year, although in a period of well-known difficulties, testifies to the strength of our production, with an important increase specifically in machineries and construction materials.

According to your valuable opinion, what is the international ranking of the Italian productive system? Could you mention the relevant strengths and weaknesses?

As seen from here, the "made-in-Italy" still enjoys a strong reputation and the local consumer or businessperson values it a lot; the brand and the flexibility of our SME's system in adapting to the changing needs of the market are our strengths. In this context I draw attention to the many Italian projects of joint ventures with local companies in order to localize part of the production, transfer technologies and promote skills, an approach which perfectly fits in with the Kazakh Government's strategies and is in line with the "made-with-Italy" promoted also in other countries of the region.

As weakness I'd mention the still insufficient capacity of our companies to act as a "system" in partnership with public institutions; besides I'd invite our businesspeople to carefully analyze the opportunities offered by the projects financed by the IFI and to pay attention to the initiatives – in terms of privatizations and joint projects – promoted in Kazakhstan by the State holding Samruk Kazyna.

Do you think that Astana Expo2017 or events of this sort can make the Italian companies operating abroad perform better?

Any Expo is a peculiar event, being a huge platform open to business, people and culture. In the Astana case there's a unique opportunity to learn about the country, and Central Asia as a whole, which until now had mainly a strong reputation as an oil producer. As innovations are supposed to be presented and companies from all over the world will be present at or visit the exposition, I think that everyone is stimulated at the best of his capacities; creativity being an Italian national feature, I can assure that we can be among the main actors.

What opportunities does Astana Expo2017 create for Italy with respect to the emerging countries?

An oil and coal producing country choosing clean energy as the theme of its Expo symbolizes its willingness to move to a different development path, which includes renewable energies, currently less than 1% of the energy production in the country. It's a huge challenge for Kazakhstan: just remember in comparison that ExpoMilan chose a theme, food production, which was a pillar of our economy and even of our cultural system. Therefore our visitors, business people or tourists, will have the chance to see the changes going on in this part of the world, not only in Kazakhstan, but rather in Central Asia as a whole, a Region willing to be better connected with the global networks, i.e. through the ambitious project of the New Silk Road.

These international events make it possible to celebrate the "Countrywide system" and provide opportunities for seeing together public and private enterprises as well as research and production actors. In this regard, how would you assess the relationship between our domestic research and production system in view of Astana Expo2017?

For long ExpoAstana was known only among experts, now I see a broader interest among our companies, research centers and individuals. I can't anticipate any figure in terms of visits from Italy, realistically I don't expect huge numbers, but I really appreciate the quality of proposals we are receiving for business, scientific and cultural initiatives, which will enrich our participation. And I want to underline the fruitful cooperation established in the preparation activities among the public entities organizing the pavilion (Ministries of Foreign Affairs and of Economic Development, ICE Agency), the ones participating (Ministry of Environment, ENEA), the companies - big and medium - and the 15 Regions which decided to be present as well. Each Region will be given a week during Expo, an opportunity for B2B activities, cultural events, general presentations.

***"Real progress happens only when advantages of a new technology become available to everybody."* (H. Ford). Do you think that events like this one fit in with such a perspective? And, if so, could they actually stimulate the progress invoked by Ford? If not, what do you think is really needed?**

I'd like to point to an apparently minor development, just recently the Astana Municipality started the separate collection of waste, recycling plastic materials and batteries. This is an anticipated side-effect of Expo, the average citizen is given the chance to contribute to a cleaner environment and education programs are held in schools. Expo will spread awareness among individuals, being it about energy saving, cleaner production processes, power generation. Therefore, I agree with the assumption, though admitting that it's just the start of a long-time process.

After Astana Expo2017, what are the choices to value more the Italian contribution to the international deployment of energy and innovation?

Our pavilion will present the experience of a country which became highly industrialized despite being poor in hydrocarbon resources. Ingenuity and creativity fostered and continue to foster innovation in the exploitation of renewables, from hydro to wind and solar, and in implementing energy efficient production processes. At the same time, we'll present our important contribution to multilateral initiatives in the field of new energy technologies. Our participation will therefore be an important step in asserting the Italian role in the global trends towards a green economy, and I hope that Expo will also be useful as a concrete platform for discussions among politicians, academicians and experts of an issue which is such a priority for anyone of us.

Low-emission mobility is an essential component of the broader shift to a low-carbon economy. Thanks to advance in fuel and vehicle technology, transport today has a huge potential to contribute towards reducing the emissions. What is Italy's role in this shift?

Sustainable and cleaner alternative fuels in transport is a huge issue in Italy. In many countries, electric mobility is being pursued as a catchall solution. Instead, when we launched our strategy in late 2016, the result of a public consultation in 2015, we wanted to understand how much various modes and uses of transport can contribute to our efforts towards decarbonization and cleaner air. The importance of technological neutrality emerged as a concept to hold on to in the coming years, as new technologies for new vehicles are still being refined and as solutions for the existing stock of vehicles are key for our decarbonization targets in 2030 and 2040. In some sectors, clear developments are underway: in shipping and heavy-duty vehicles, LNG seems to be the only viable solution in the medium to long term. In all sectors, advanced sustainable biofuels, not competing with food and feed production, blended with gasoline and diesel, will contribute to the overall decarbonization effort and progressively replace first generation biofuels that today make up about 5% of fuel in Italy. Existing bio-refineries, today a small minority, will become mainstream refining. Furthermore, compressed natural gas, with over one million vehicles circulating in Italy, is particularly suited for urban public and private transport (such as light duty transport, busses, and passenger cars): our strategy provides for the complete replacement of fossil methane with biomethane. In the coming years, electric mobility too will develop its potential, particularly in urban private and commercial modes. We look forward to this development as a driver for further technological advances and for economic growth.

With a growing number of ratifications of the 2015 Paris Accord, many countries are developing strategies that will guide energy policy decisions by 2030 and set the stage for a substantial decarbonization by 2050. Where is Italy in this process and are there opportunities for bilateral collaboration with Kazakhstan in this field?

Italy, like many other countries, is in the process of updating its National Energy Strategy in 2017. The previous strategy, published in 2013 had a 2020 and 2050 time horizon, consistent with the so-called EU 20-20-20 energy and climate package, and with the EU 2050 Roadmap to decarbonization. The new strategy will have the same double time horizon, but with advanced targets for 2030, consistent with the 2050 objective. We have established a well-functioning process of consultation with the public, from industrial stakeholders to civil society to the benefit of the quality and the soundness of the strategy. Granted, Italy and Kazakhstan are very different countries in terms of energy and the strategic objectives in this field would look very different. Nonetheless, I am sure that an exchange with the Kazakh authorities on our experience of setting up the national energy strategy would be beneficial for both our countries.

Innovation as sustainable source

Innovation, energy efficiency, sustainable sources: these are the fundamental challenges for our Country in the years to come

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by **Teresa Bellanova**, *Deputy Minister of Italian Ministry for Industry and Economic Development*

Innovation, energy efficiency, sustainable sources: I am deeply convinced that these are the fundamental challenges for our Country in the years to come. Challenges that undoubtedly have to do with the country's economic and productive growth, yet they are above all cultural. The stakes are enormous: a shift in the employment paradigm to address the challenge of climate change. An unprecedented challenge.

In recent years, our Country has recorded significant growth in the renewable energy sector. At the end of 2015, the share of gross final consumption stood at 17.5% versus 13% in 2010, and this percentage is expected to grow. Italy has met the 2020 targets in advance, so that the new national energy strategy ha set a new target share of 27% threshold by 2030. Decarbonisation itself, which still remains one of the priorities of energy policies, is considered as an achievable target by 2030. This means a considerable effort, both in terms of policies to be put in place and of economic investment, which should be made and encouraged if we believe – and personally I do - that this is the best way, I would say the only practicable way, to get an energy efficient system, accessible to all – citizens, families, businesses – at sustainable cost.

This commitment determines a change in culture and vision, in order to fully grasp the opportunity offered by the increasing sensitivity and attention of citizens to the issues of environmental protection and, specifically, the balance between economic development, emissions reduction and energy saving. Wide-ranging strategic vision and planning capability, resources, innovation: these are the keywords. Translated into actions they mean sustainable mobility, urban and historical-cultural heritage regeneration, energy efficiency, development of useful and necessary skills to govern and manage such important change.

In this sense, I am convinced that a 'culture' of energy efficiency should be based on greater information and awareness raising of businesses and families. Italy boasts the European primacy for the largest number of energy diagnoses of large enterprises: more than 15,000 have been run by over 8,000 companies. Also Italian families, in less than 10 years, have invested almost 28 billion euros in order to make their homes more energy efficient, with 2.5 million requalification actions. It is not enough, perhaps, but it is the sign of that growing attention to sustainable urban systems that can allow and support the necessary change of the paradigm.

In this framework, the dynamics

of urban complexity takes on an increasingly remarkable role that needs to be properly considered and understood in its implications. Today more than 50% of the world's population lives in the cities. Over the next thirty years this share could reach 70%. Finding an intelligent energy mix, based on the use of innovative technologies applicable to different areas of city government – from waste management to public lighting to transportation – is not only necessary but mandatory in order to be able to reason in terms of a system based on efficiency and energy saving. These are the areas in which technological innovation and research activities have multiple connections and increasing possibilities of application, also in terms of providing advanced services to businesses, public administrations and citizens.

In this context, above all I recall the commitment to the implementation of Legislative Decree 102/2014, and therefore the Program for Energy Regeneration of Public Administration buildings: 350 million euros in the period 2014-2020. So, in May 2016, the revision of the Thermal Account that simplified access to incentives for businesses, households and public entities; the decree on white certificates recently published in *Gazzetta Ufficiale*, with the new national energy efficiency targets; the Stability Law 2017 extending, and in some cases increasing, the tax deductions for energy-saving interventions on buildings.

Urban regeneration, however, in my opinion, also means a way to contrast energy poverty. It seems incredible, and it is certainly unacceptable, that even today a share of Italian families cannot afford any access to energy because of its high costs. I say it straightforwardly: access to energy is a right to be protected and guaranteed quite as much as others already recognized. The efficiency of the energy market is also measured on this, in terms of fair distribution of benefits between producers and consumers. In this direction, the Government has taken important steps. I am thinking about popular buildings and the interventions provided for in the 2017 Budget Law, with the release of the tax deduction for energy adjustments of common parts and works on ordinary buildings and the possibility to actually extend the scope of the measure to numerous families in the state of energy poverty. However, and I like to stress the concept in view of Astana's Expo, this is a challenge we have also posed globally. Just a few weeks ago, during the side G7 event on Africa's energy development, I emphasized the role of access to sustainable resources, which the continent is rich in, as

an important tool for increasing the energy capacity of population and, consequently, the economic development and overall growth of that territory.
Urban regeneration also means, however, stating the urgency of a clean, efficient and, therefore, more sustainable mobility. This is a hot topic in Europe, also as a development factor. It is precisely in this sector – involving more than 11 million workers at European level – that research and innovation are and must be strongly supported to achieve ever less polluting transport systems. Efficient, secure, sustainable transport policies, with important impacts on the development of a more competitive industry capable of generating new employment and well-being. It is in this framework that the European Directive no. 94 of 2014 on the development of a large alternative fuels market was adopted by Member States, which have established their own National Strategic Framework aimed at implementing the relevant infrastructure and introducing a series of minimum measures set out by the directive. In Italy, the EU Directive has been transposed by means of Legislative Decree No. 257/2016 which identifies the minimum requirements for the realization of alternative fuel infrastructures and presents the National Strategic Framework. The Budget Law itself has set out a National Strategic Plan for sustainable mobility aimed at renewing the local and regional public transport bus fleet and promoting and improving air quality through innovative technologies. In addition, the Plan provides for a set of interventions to implement the competitiveness of goods and services companies in the production of tire public transport vehicles and intelligent transport systems, encouraging investments aimed at the transition to more modern and sustainable forms of production. All this is witnessed not only by the strong attention of our Country and Government to the subject, but also by the concrete and financially significant commitment.
On this front, the Government is investing a lot – even in terms of resources: the evidence is, among other measures, the decree of June 23, 2016 on renewable resources other than photovoltaic. An investment of around 430 million euros annually for the next 20 years, of which 50% for near-equilibrium technologies such as wind power, 25% for frontier technologies such as thermodynamic solar power, and another 25% for circular economy, such as biomass and waste resources. Energy efficiency measures from 2005 to 2015 led to, nearly 10 million tons of oil equivalent per year saving, avoiding 26 million tonnes of carbon dioxide emissions and 3 billion euros of fossil fuel expenditure.
In this context, energy efficiency developed with the support of advanced technologies appears to be an essential infrastructure for what, without fear of exaggerating, we have called the Fourth Industrial Revolution, Industry 4.0. We are investing energy, resources, expertise, on digital and technological growth of our production network. 2017 and 2018 will be decisive years: the stakes are worth 20 million euros this year, of which 10 are to be invested in technological transformation, innovation and creation of new skills. For this to happen, companies have to rely on advanced energy systems that will enable them to be competitive not only in terms of costs but also of production efficiency.
This is, I am sure, the role of Institutions throughout the whole chain: to definitely focus their action on the conditions enabling enterprises to work, experiment and develop.
From this point of view, the government of change puts forward the theme of competences and (old) new occupation. We will inevitably face the shift in employment which will mean an increase in new sectors - renewables, intelligent networks - and decrease in traditional sectors - e.g., thermoelectric energy from fossil resources or the upstream productive sector. According to GSE data in Italy, between 2012 and 2015 partial-time (direct and indirect) jobs given in terms of full-time equivalent jobs have experienced a sharp decrease due to the switch toward the full operation of the plants. However, in the same period, there was a positive variation for permanent employees engaged in maintenance and management activities. This is to say how much attention needs to be paid to the enhancement, updating and development of new skills essential to address the energy transition and the epochal change that is already at hand, and that the new national energy strategy evokes very clearly. Infrastructures, economic resources, and material conditions are just one side of the issue.
Industry 4.0 can be the driver for the development and the enhancement of expertise and talents on very advanced research frontiers on which, I say with pride, we have excellences that are unmatched in the global scenario. Only recently I did appreciate the presentation of the supermagnet for nuclear fusion, created by an Italian company together with ENEA: the confirmation of the excellence and the high degree of specializa-

tion that our enterprises are capable of in a context as advanced as that of nuclear fusion, and the confirmation of the great opportunity offered by partnerships between private and public actors. In this case, a real strategic alliance between companies of the private sector and advanced public research. The fact that strategic components, made in Italy on the basis of leading technologies, are exported all over the world under the stimulus of great international research projects, is a source of great satisfaction and confirmation of the quality we are capable of.
It is with this wealth of experience, resources and investment in the future that Italy is participating in the Astana Expo. A precious opportunity for knowledge, comparison, dissemination and at the same time learning of good practices for institutions and enterprises. But, above all, Italy takes part in this international event to highlight our excellences, to support them in winning even more and better the global scene, to emphasize the outstanding examples of our research, to identify and support new international partnerships, to bring out our talents and know-how.

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The Italian Regions in Astana

Today's Italy's transition toward new more sustainable modes of energy production and consumption sees the regions start to take on a leading role within a European and national policy framework

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by **Aldo Bonomi**, *Director of Aaster and* **Giulia Pavese**, *Director of the Committee of Italian Regions*

What brings Italian regions to a universal exhibition devoted to the energy of the future? The first reason lies in the historical discontinuity which differentiates today's universal expositions from those which, in the previous two centuries, preceded them. While the Universal Exhibition of the 19th and 20th centuries were events celebrating economy and science as engines of unlimited and continuous progress, the historical phase we live in raises the issue of the limits to the development and the necessity to rethink the use of the enormous overall increase in the productive, technological and cognitive capacities of society. At the heart of Expo is increasingly the concept of *power of the limit* as a factor of a new social, economic and cultural organization, resource for producing, living, thinking in a new manner. Now this new frontier needs to be declined not only through broad objectives and global policies, but also via political and cultural transformations and local technology infrastructures. Today's Italy's transition toward new more sustainable modes of energy production and consumption sees the regions start to take on a leading role within a European and national policy framework.

There is also another important reason that is important to justify the regional presence at the Expo. Today's global scenarios depict energy as a flow which connects nations and continents through global infrastructural networks, technological development and socio-cultural developments, decentralising and pluralizing the forms of management and organization. That is why the field of energy is structured by a dialectic between global flows and places. Starting from the centrality that territorial factor plays in his historical model of development, Italy can offer the world interesting experiences. During the first and second industrial modernity, the production, distribution and consumption of energy was characterised by forms of public-private management consisting in large public national operators or large private players, both characterized by a centralization logic: by contrast, today the growth of network technologies favors the emergence of diffused, decentralized and polycentric energy modes of production, according to new community logic between public and private sectors. To date, energy systems are based on fossil resources developed according to the logic of concentration and linear development: extraction of the resource, its transformation, combustion and emission into the atmosphere of the residues of the use. One of the technical drivers of the current transition is the availability of artificial intelligence and network technologies which can potentially collect, accumulate and store the energy that is available in the natural and/or anthropic environment by reducing the costs of its production and accumulation. The sources can be multiple: wind, currents, sea, geothermal energy, energy from transformation of biomass and commercial waste; in addition to the energy from sunlight. Therefore, one of the basic characteristics of the actual era is that the maturation of a new generation of technology allows not only to experience unprecedented solutions in the market sphere, but also social and transformational uses of the same technologies. Energy today is one of the major areas in which this dialectic is at work. For this to happen, however, it is necessary to develop forms of social network and kind of policies that enable the widespread use of technological innovations: we need to develop forms of active citizenship and of public intervention on territorial units. Today the territory and local Community networks, operating according to a logic of concurrency through digital space, may constitute new organizational governmental arrangements of energy that must be supplemented by the market and by the public actor. *The territory can thus become a third regulatory model that grows*

beside and/or in connection with the market and the state.

The issues by the regional system

The presence of the region's system at the Expo, with the coordination of the Committee of Italian Regions, is fulfilled in two ways: the contribution to the national representation in the exhibition-tale of Italian pavilion, and a schedule of events, workshops, exchange of good practices with a weekly rotation. The theme of energy has been dealt with by focusing on two major transformations that characterize today›s societies: the transition toward a model of circular society based on mechanisms for networking knowledge, innovation and exchange to achieve sustainability targets; the emergence of the green economy and first of all the emergence of circular economies that put the environmental limit at the center as new possible value. At the heart of the elaboration by Italian regions are indeed the experiences of energy innovation working in the territories. The plot of the regional narrative thus has developed through some keywords: the relevance of territory, of human landscape and the identity of places; the emergence of an active citizenship as leading actor of decentralised experiences of sustainability; a widespread geography of innovation and hence the centrality of the notion of smart land beyond that of smart city; the importance of a network capitalism made of utilities and energy companies; the sustainable transformation of productive sectors; the soft power of creativity as a means of country representation and of territorial narration toward the world; the importance of the regions as an institutional system that accompanies the territories towards an Italian model of future energy. This shared pattern of thought is the basis for many concepts elaborated by the 15 participating regions and referable to five macrothemes:

- **The transition to a low-carbon economy** through policies of efficiency and energy saving. An objective declined through efficiency and energy saving projects in the building sector, sustainable mobility, reduction policies for emissions and dependence on fossil fuels.
- **The circular economy and energy from renewable sources**, that is the leap forward of the regional green economy in the field of renewable energy production (wind, photovoltaic, hydroelectric, biomasses, wave motion, geothermal).
- **The "third industrial revolution": networks and smart infrastructure for decentralised development of energy systems premises**. Regional proposals focuses especially on the presentation of territorial good practices of decentralised production, distribution and accumulation platforms through smart-grid, micro-grid, storage technologies, urban regeneration projects for energy sustainability (*smart city/smart land*), clusters and networks of local authorities or active citizenship;
- **Access to energy as a vehicle for social cohesion and inclusion**: This is a theme strongly linked to the previous one, but in this case the emphasis is on the social infrastructure rather than the technological one. The regional narration is divided into topics such as energy mutualism, experiences of community energy companies, *social housing*, etc.
- **Clusters of innovation and sustainable energy supply chains**: in this case regional topics tell of networks of research and innovation, regional energy clusters, research centers and universities, incubators, start-ups and spin-offs and innovative SMEs, energy efficiency in individual companies and/or systems of industrial chain, the regional excellences in the energy field on the side of enterprises and territorial utilities.

The regional content in the exhibition of the Italian Pavilion

Starting from the five themes mentioned above, the regional presence is organized into a series of contents distributed in the different spaces of the *Padiglione Italia* (Italian Pavilion) on the basis of two keywords: on the one hand, the close relationship between social and economic history of territories and technological innovation in the field of energy; on the other hand, the presentation of a series of community experiences and technological excellences for which Italian regions play leading roles.
On the first point, the main content is the relationship between what we could define as "consciousness of place" and ingenuity, described by means of a collective story of 50 places symbolising the value of sustainability from the point of view of the interweaving among landscape, urban culture of 100 cities, and energy infrastructure for production and distribution. Next to this regional video-tale, 90 video-interviews with ordinary citizens from the 15 regions will tell us how the Italians had understood, in their everyday experience and in cultural perceptions, the

theme of the energy of the future. In parallel, each region will tell its own territorial experiences of social and technological innovation in the field of energy. Thus 73 experiences have been selected, referred to the idea of smart land and smart communities and to local examples of circular economy.
Close to these contents that define a space of representation in which the territorial element and the conscience of place are prevalent, the regional system leads some experiences to Astana that clearly bring out the levels of technological excellence achieved in territorial systems in the field of energy research. Here it is not possible to give a complete overview of the variety of experiences. At the end of this article we limit ourselves to indicate an experience which seems to us well representing an Italian way to the energy of the future: the case of «Watly». Watly is an Italo-Spanish startup developed between Udine and Barcelona and constituted by a team of young researchers, who created the first thermodynamic solar powered computer in the world, that purifies water from any contamination (nuclear) and, at the same time, generates electricity and allows internet connectivity. A machine able to tackle the themes of circular economy (is a closed circuit that allows you to save up to 2,500 tonnes of greenhouse gas generating 1 GWh of clean and free electricity) and water crisis determined by environmental and economic changes trying to take action to tackle the mass migration from the countries of the South of the world. A project that for its creativity and ability to tackle the issue of energy sustainability, can well describe an approach to global issues that has always characterized the Italian approach: on the basis of its territories, Italy is a country that can exert its soft power on the international scene.

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The role of women in the clean energy transition

The paper presents a new Technology Collaboration Program (TCP) on the role that women can play in the energy transition, named Clean Energy Education and Empowerment (C3E TCP). Launched by Canada, Sweden and Italy, the initiative is under the International Energy Agency (IEA) legal framework. The background, the rationale for creating an IEA TCP as well as the program of work will be described

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by **Alicia Mignone**, *Chair of the IEA Committee on Energy Research and Technology*

The Clean Energy Education and Empowerment (C3I) initiative was launched at the Clean Energy Ministerial (CEM) in 2010 [1]. The 24 countries and the European Commission, that are CEM members, account for about 90% of the global energy investments and 75% of the global greenhouse emissions. Current CEM members are Australia, Brazil, Canada, Chile, China, Denmark, the European Commission, Finland, France, Germany, India, Indonesia, Italy, Japan, Korea, Mexico, Norway, Russia, Saudi Arabia, South Africa, Spain, Sweden, the United Arab Emirates, the United Kingdom and the United States. Since 2016, the CEM Secretariat is hosted by the IEA in Paris.

Background

The C3E initiative was born out of recognition that the ideas and talents of all members of society are essential to meeting our future clean energy challenges. Women make up substantially less than half of the workforce in science, technology, engineering and math (STEM) fields and across the clean energy sector. Closing the gender gap and increasing women's participation and leadership in these fields are the goals of the C3E program that seeks to both inspire more women to enter into clean energy careers and retain the current female clean energy workforce. Without engaging women, countries are leaving half of the potential energy workforce out of the talent pool, hampering the current and future STEM driven economy and economic growth (see box "World Economic Forum – The Global Gender Gap Report 2016").

The C3E initiative will formalize its activities using the IEA's TCP mechanism. The TCPs are independent, international groups of experts that enable governments and industries from around the world to lead programs and projects on a wide range of energy technologies and related issues [3]. C3E will be the second CEM initiative to take this approach; the first one was the International Smart Grid Action Network (ISGAN) that has been operating successfully since 2011.

World Economic Forum – The Global Gender Gap Report 2016

Women graduating from tertiary education courses have acquired a similar range of skills and academic subject knowledge to their male colleagues. However, one area in which women continue to remain under-represented is among STEM graduates, for which the global gender gap stands at 47%, with 30% of all male students graduating from STEM subjects, in contrast to 16% of all female students. That gap is commonly attributed to negative stereotypes and lack of role models, lowering girls' performance and aspirations vis-à-vis science and technology. It represents a key emerging issue for gender parity, since STEM careers are projected to be some of the most sought-after in the context of the Fourth Industrial Revolution. [2]

Advantages of the TCPs mechanism

Establishing the C3E as a TCP provides several distinct advantages. The TCP model of cooperation is a time-proven, flexible instrument that enables participants to work towards common goals:

- The scope may be adjusted to meet the ongoing needs and interest of all the participants (work is organized in different Tasks)
- Participants may choose to take part in different Tasks and activities in line with their respective priorities
- Governments, the private sector, international organizations, Non-Governmental organizations, academic institutions and other entities may participate.

Governed by a common set of rules:

- IEA framework for International Technology Cooperation

Supported by the IEA Secretariat:

- Providing advice and guidance
- Raising awareness of activities
- Facilitating cooperation with other TCPs.

One advantage in particular to establishing the C3E as a new TCP is the potential to significantly broaden outreach worldwide. In addition, the C3E TCP would be given greater visibility within IEA member countries through the 6000 experts participating in the IEA Energy Technology Network.
The TCP would build on existing programs, pulling together initiatives in IEA and CEM countries (and beyond when appropriate) to create an international platform to focus on issues related to gender in the clean energy sector.

Membership in the C3E TCP is voluntary and will be subjected to fulfillment of the criteria set out in the C3E legal text. At present, Canada, Sweden and Italy have adhered to the TCP C3E.

Scope and objectives

The aims of the C3E are to recognize and build a community of women leaders in the field of clean energy across diverse sectors; create a framework for cooperation and information sharing among participating countries and share best practic-

World Economic Forum – The Gender Global Gap Report 2014

Time passes slowly when change is overdue. The World Economic Forum in its Global Gender Gap Report 2014 estimates it will take until 2095 to achieve global gender parity in the workplace. Eighty more years until companies and governments are equally led by men and women. And 80 more years of talent pipelines and professional promise not fully realized.

es for effective strategies to advance women in the clean energy field.
The objectives will include, but are not limited to:

- *Building workforce skills and knowledge*: C3E seeks to inspire more women to enter into clean energy careers, equip women for success in pursuit of these careers by preparing women for these opportunities, and evaluate barriers to career entry;
- *Creating leadership bridges and opportunities for women in clean energy:* In addition to the lack of women overall in the clean energy sector, the percentage of women in leadership positions is even smaller. Women are severely underrepresented on boards of energy companies, in senior level positions over energy and clean energy offices in governments, leading start-ups, and finance companies. A recent Ernst & Young survey [4] found that women made up only five per cent of board executives across the global power and utilities sector in 2015;
- *Increasing recognition and celebration of women in clean energy:* The lack of women in leadership positions in the clean energy sector compounds difficulty of recruitment and retention of female leaders. Research [5] shows that visible role models and success stories can help to reduce gender stereotypes and inspire younger generations to pursue STEM careers;
- *Establishing robust networks*: Operating independently, countries are lacking the full potential to move the needle when it comes to gender equality in the clean energy workforce. Building a platform for international collaboration and dialogue, sharing expertise, and facilitating exchange on best practices, supporting policies, programming, and career development and knowledge exchange will be instrumental to the success of the goals of C3E. This includes leveraging C3Enet.org, a global website to connect women in clean energy.

Deliverables

For the first five-year term, the C3E TCP will deliver the following:

- Disseminating results, best practices, databases, and research.
- Developing a leadership program for mid-career women in clean energy and learning exchange program between C3E Participants.
- Hosting an International C3E Summit.
- Expanding the International C3E Ambassador Corps (Box 3) and establishing International C3E Awards.
- Leveraging C3Enet.org and C3E social media groups to enable women in clean energy to

Ambassador Corps

One way C3E works to shift the status quo is by naming accomplished, senior-level women as C3E Ambassadors to leverage their power as role models. CEM partner governments have been invited to name C3E Ambassadors from their countries to serve in the C3E International Ambassador Corps. Named Ambassadors to date are listed in the CEM website [6]. The list of Ambassadors will expand as new members are nominated.
To date, 11 CEM governments have named a total of 61 C3E Ambassadors; more than 900 women have become members of C3Enet.org; and in the first five years of the U.S. C3E program, 37 mid-career women have been recognized with C3E Awards for their accomplishments and leadership in the sector, as well as 5 lifetime achievement honorees.

exchange information and find mentors, employers, employees, partners, funders, and other opportunities in the field.

Activities

The activities organized in Tasks will support the four elements of the C3E scope and the deliverables, both outlined previously. All Tasks areas are open to participation of Sponsors.

- *Global Women in Clean Energy Resources and Needs Inventory.* The objective of this Task Area is to collect information on women's participation in the clean energy sector workforce. To this end, it will include designing both short-term and long-term methodologies for providing consistent, usable data measuring clean energy sector job growth including a breakdown of *gender participation levels and pay***,** if available; analysis from the perspective of both employers and applicants on any barriers to hiring women in the clean energy sector; and analysis of existing strategies to eliminate or minimize these barriers .

- *Women in Clean Energy Career Development Network*. The objective of this Task Area is to support and enable learning opportunities for women in the clean energy sector to prepare them for leadership positions in the sector. It includes developing a leadership program for mid-career women in clean energy in economies that are Participants in the TCP. It also includes engaging *Ambassadors – senior level women in clean energy* – to serve as role models and mentors in clean energy career development (see box "Ambassador Corps").

- *Annual International C3E Recognition and Awards Program*. The objective of this Task Area is to increase visibility of mid-level women in clean energy and provide recognition, role models, and advocate for women in clean energy. Participants in this Task Area will create an annual recognition and award program, with the option of utilizing the model of the U.S. *C3E Awards*. The recognition and award program will set categories of work to recognize (i.e. advocacy, education, law & finance, research), and determine a procedure to solicit nominations, vet nominations, solicit prizes, announce winners, and celebrate the winners.

- *Global Women in Clean Energy Communications Hub*. The objective of this Task Area is to build a *platform for international collaboration and dialogue* to share expertise, facilitate an exchange of best practices and international policies that support women in clean energy. These efforts will work to increase the C3E initiative visibility within the IEA Energy Technology Network. The Communications Hub can also enable impactful programming and career development and knowledge exchange. Deliverables will include exchanging information among Participants and leveraging C3Enet.org and C3E social media groups to enable women in clean energy to exchange information and find mentors, employers, employees, partners, funders, and other opportunities in the field.

Final considerations

The IEA C3E TCP starts to present with three countries - Canada, Sweden and Italy – and aims to increase participation of partner countries as well as find sponsors interested in the role of women in the clean energy transition. It builds on the sound experience gained by the C3E initiative launched by the CEM and the US DOE program, and will benefit of the support of the IEA Secretariat. *The extraordinary and recognized capacity of women to handle complex and multivariable contexts and their openness to innovation will certainly be an asset to the success of the IEA C3E TCP.*

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Smart grid and Super grid

Traditional electrical grids are not able anymore to support the needs of a rapidly evolving electricity sector. The convergence of many factors –including the generation of electricity from renewable sources and distributed generation as a whole– promotes the development of smart grids and the related continental interconnections, the super grids

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by **Giorgio Graditi**, *ENEA*

In recent years, depletion of fossil energy resources and global warming problems have prompted international awareness about sustainability of energy supply on a worldwide scale. According to the latest forecast, the global electricity demand will outstrip the supply by 2020, due to several key trends, such as migration to cities, increasing levels of wealth, and growing number of appliances and equipment used. In such a context, there is a pressing need to accelerate the development of low-carbon energy technologies, in order to address the global challenges related to energy security, climate change and economic growth. Smart grids offer ways not just to meet these challenges, but also to develop a cleaner energy supply, which is more efficient, more affordable and more sustainable. A smart grid is an electricity network, which uses digital and other advanced technologies to monitor and manage the electricity transport from generation sources to meet the end-user electricity demand. Smart grids coordinate the needs and capabilities of generators, grid operators, end-users and electricity market stakeholders to operate all parts of the system as efficiently as possible, by reducing costs and environmental impacts, while increasing system reliability, resilience and stability. The main characteristics of a smart grid are summarized in the following:

- Allows active participation of consumers, based on their increased interaction with the grid. This active participation brings tangible results for both the grid and the environment, while reducing the cost of the delivered electricity.
- Offers the possibility to involve several generation and storage options, which represent new opportunities for a more efficient, cleaner power production.
- Supports the process for a larger penetration of renewables into the transmission and distribution networks, thereby promoting the transition towards a low-carbon energy system and its sustainable economic development.
- Enables new products, services and markets, by offering new consumer choices such as green power products, and a new generation of electric vehicles.

- Optimizes asset utilization and operates efficiently. Desired functionality at minimum cost guides operations and allows fuller utilization of assets. More targeted and efficient grid-maintenance programs result in fewer equipment failures and safe operations.
- Anticipates and responds to system disturbance through self-assessments to detect, analyze and respond adequately to restore grid components or network sections.
- Operates resiliently against cyber-attacks.

The smart management of the grid is the key point, allowing significant development perspectives of smart grids at local scale, and super grids at continental scale. This key point faces several challenges related to grid strengthening, enhanced intelligence, communication technologies and standardization, interoperability between different components and systems, integration of intermittent generation, moving offshore, and capturing the benefits of distributed generation and storage.

ENEA Research activities

In order to deal with the challenges mentioned above, the ENEA research activities mainly focus on three specific areas related to smart grids and super grids, as discussed in the following. All these R&D activities are carried out within several National and European projects, and in national and international organism and networks, working in the field of energy technologies and systems, integrated energy networks and renewables.

Smart grids and microgrids
In the context of smart grids and microgrids, research focuses on the modeling, operation and design optimization of Distributed Energy Resources (DER) (shown in Figure 1), in presence of renewables, poly-generation systems such as Combined Heat and Power systems, and electrical/thermal storage, through multi-objective approach, by considering both economic and energy savings/environmental aspects [1, 2, 3, 4]. The main goal of this research is to investigate configurations and operation strategies of DER systems through multi-objective approach, in order to provide decision support to planners and/or operators based on short- and long-run priorities. The developed optimization models are both deterministic and stochastic. In this latter case, uncertainties of supply side, including renewables and demand side, are included.
Demand side management (DSM) is also integrated in smart grid modeling through Demand Response (DR) programs. These latter allow to transfer the customer load during periods of high demand to

off-peak periods, with the aim of managing the required demand to match the available energy resources, without adding new generation capacity. By reducing the peak loads on the electricity network, DSM has various benefits, including the mitigation of electrical system emergencies and the increase in the system reliability. Benefits also include the reduction of dependency on imports of fuels, as well as the reduction of energy prices and environmental impacts.
The research interests also focus on the technologies, systems and strategies, which allow to promote an active electric network and the transition from the "fossil-fuel-based" energy generation system to a distributed and smart "renewable-based" scenario.
The most important outcome of this research activity is the POLISTAR (POLIgeneration and STorage for smARt green islands() Project, based on the collaboration between ENEA and the University of Palermo's Department of Energy, Information Engineering and Mathematical Models(DEIM). The goal of the project is to design a smart grid for Pantelleria island (South Italy), based on renewables (solar photovoltaic, wind, geothermal), power generation from urban waste, and electrochemical storage, with the aim of reducing the dependency on fossil fuels, thereby increasing the island energy autonomy.
Moreover, research activities also address the management and control of combined systems based on renewable (solar photovoltaic) generation plants, and electrochemical storage, integrated into smart grids and energy networks, in order to foster a larger penetration of renewables into the electric grids, as well to offer ancillary service for the network and end-users.

Super grids
ENEA is also involved in research on super grids . In detail, research activities are aimed at testing, implementing and demonstration of a VSC-HVDC (Voltage Source Converter - High Voltage Direct Current) pilot plant, with the aim of promoting the creation of interconnected Pan-European Network (super grid).
High voltage direct current (HVDC) transmission systems can transport enormous amounts of electricity. Such systems have been widely introduced in European countries in order to stabilize and strengthen power grids and also respond to the increased use of renewable energy. The main challenges are related to their realization, reduction of operation and maintenance costs, increase in operation reliability and security, and reduced environmental impact.
This research activity is based on a scientific alliance between ENEA, Toshiba Corporation and Toshiba Transmission and Distribution on advanced technologies for electricity grids and renewables, and on a Memorandum of Understanding signed by ENEA and NEDO (New Energy and Industrial Technology Development Organization of Japan). The new HVDC interconnection employs innovative multilevel converters based on the VSC technology, and provides a higher efficiency, flexibility, security and grid stability, as well as lower environmental impacts [5].
The high-voltage VSCs allow to reduce energy losses and mitigate carbon dioxide emissions, which is difficult to attain with conventional VSCs. It is estimated that the high-voltage VSC devices can reduce energy losses on the transmission lines by about 60%, as compared to the conventional VSC devices. In addi-

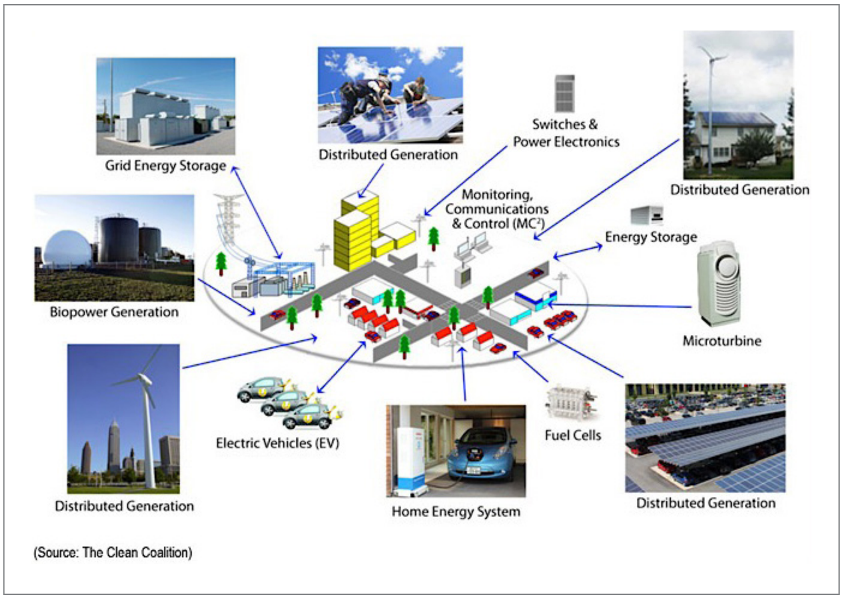

Fig. 1 Example of DER systems analysed

tion, using superconducting cables allows to increase the carrying capacity and reduce power losses.
The demonstration plant, to be set up at the ENEA Casaccia Research Centre, concerns an innovative technology considered among the most promising for long-distance electrical power transmission. The objective of the demonstration plant is to promote the dissemination and expansion of HVDC transmission systems in such areas as offshore wind power, which are promising end-use areas for the VSC's project, as well as to experiment and validate advanced solutions to modernize the existing grid, by promoting a new energy system based on distributed generation, the use of renewables, smart grid and super grid.
The experimental results will be also integrated in an European impact analysis with the purpose to demonstrate the applicability of the proposed solutions and their potential for replicability in the Pan-European electric power transmission network.

Smart PV systems

In the context of smart PV systems, research activities focus on the study, modelling and design of innovative components and solutions for photovoltaic applications in residential/industrial construction and micro-grids contexts. The aim consists in taking advantage of PV plant capillary distribution in the whole country for the creation and development of new energy contexts. These new energy models base their success on communication and cooperation among various devices and technologies. ENEA pursues this objective carrying out modeling, designing and experimental activities concerning innovative devices capable of constituting a constellation of "talking" nodes and of providing ancillary services useful to the PV plant users and/or grid operators.
In this area, research activities are organized into three lines:

- Distributed Maximum Power Point Tracking converters
- Smart Maximum Power Point Tracking Converters
- Microinverter and Multilevel Converters.

In detail, Distributed Maximum Power Point Tracking converters (DMPPT) are able to optimize the energy extracted from a single PV generator, also in presence of continuous variable operating conditions and mismatch phenomena. They are DC-DC converters capable of adapting the impedance in order to ensure the maximum transfer of power from the photovoltaic generator. Each converter is equipped with a digital control type for tracking, instant by instant, the Maximum Power Point of the photovoltaic module. In this way, there is improvement of performance even in those hours of the day when the yield of the photovoltaic generator decreases due to shadowing phenomena. In such a context, the research focus is on the circuital study and the benefit-cost trade-off analysis of applicable simple, hybrid or interleaved topologies [6,7]. The goal is to obtain optimized solutions both in terms of efficiency and reliability performances and in terms of necessary economical budget. The attention is also concentrated on affordable DMPPT control techniques for tracking the PV generator Maximum Power Point.
The research interest is also in Smart Maximum Power Point tracking Converters (SMPPC), as innovative solutions to enhance renewable integration in new energetic contexts such as Net Zero Energy Buildings (NZEBs), DC microgrids and smart grids [8,9]. In addition to DMPPT features, the SMPPC integrated approach allows to implement some auxiliary functions on board, such as data communication, alarms, di-

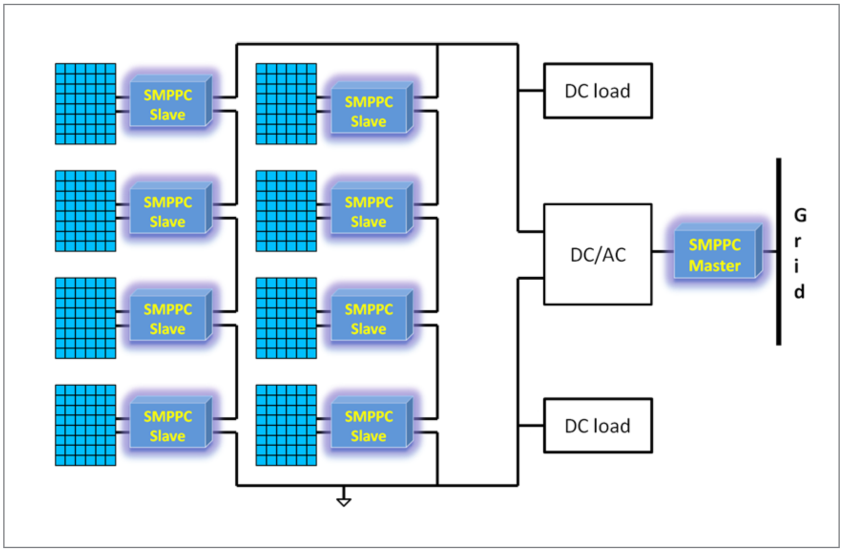

Fig. 2 SMPPC Master-Slave architecture

agnostics, monitoring and plant reconfiguration. In detail, a hierarchical SMPPC architecture (Figure 2) is presented. Each SMPPC Slave is dedicated to optimize a specific PV generator power and to provide suitable information to the higher architectural level. Each level is equipped with data acquisition and communication boards able to monitor and transfer data by suitable interfaces. Similar slave devices are dedicated to DC loads to acquire data about their power consumption and their interruptible capacity. The data exchange among SMPPC Master and Slaves nodes permits to implement services useful for both PV plant users and grid operators. Actually, in the future electricity grids (smart grids), data exchange and transmission will play a decisive role to decision and action making. The research focus is on the analysis and application of communication protocols to transfer necessary information for balancing the delivered and the consumed energy, ensuring the security and reliability of the whole system.

This research line is concentrated on the development of a SMPPC Master operating as an energy manager. It could be able to continuously receive microgrid generation and consumption data and make appropriate decisions to match and optimize supplies and load requirements. For instance, depending on the specific scenario, it could improve the micro-grid service quality and reliability deciding to immediately provide the generated energy to high priority and uninterruptible loads, to use it for storage devices recharge or to feed it into the grid. In addition, analysis and application of suitable digital techniques are carried out to improve microinverters performances and to develop multi-level converters ancillary services.

Open research issues

Beyond the research activities described above, open research issues regard several aspects in the context of smart grids. Among others, smart grids interoperability is a key point allowing the diverse devices and systems to interoperate within the smart grid. A key requirement is the interoperability of the cyber systems used to manage the power system. Interoperability among disparate devices and systems can only be achieved through the use of internationally recognized communication and interface standards. Another open research issue regards the need for a high number of demonstration plants to test and validate the technological and technical solutions found through the optimization models, as well the upgrading of technologies, components, and methods developed. Last but not least, open issues also concern the development of a capillary information/formation campaign for customers, with the aim of promoting and fostering their active role within the new energy scenario, based on smart grids and distributed generation from renewables.

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Photovoltaics: A leadership to regain

A great effort from Europe is needed in order to regain market share and rebuild the credit of its companies. Italy and, in particular, ENEA is ready for this challenge pointing to the evolution of c-Si solar cell, new thin film absorber and new PV components

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by **Ezio Terzini**, **Paola delli Veneri**, **Mario Tucci**, **Giorgio Graditi**, *ENEA*

Photovoltaics (PV) is the most popular source of renewable energy today. It offers an important option to address the environmental issue of reducing CO_2 emissions, but it is still heavily demonized because of the high cost and the need for incentives for its full market penetration. However the relative figures worldwide tell us of a healthy market with two-digit annual growth, even if in some countries, mainly in Europe, it is suffering a reduction because of reconsiderations of government support policies. In Italy –which is the leading country for PV contribution to the national electric demand (8.2%)– the end of incentives has led many to declare the death of PV which however, after suffering from the initial shock, is re-stabilizing at more reasonable values, far from the past years insane growth (370 MW installed in 2016; 600 MW annual installation expected in 2020). World market data and projections, even in conservative scenarios, seem to agree about the possibility of reaching the installation threshold of 100 GW/year by 2020, taking advantage of new technology options. A quick overview of the PV status worldwide indicates that global installations, in the year 2016, have exceeded the cumulative power of 300 GW (305 GW).

PV market: The Asian kingdom

The annual installations reached the value of 75 GW, scoring yet a growth of 50% compared to 50 GW of 2015. China leads the ranking of annual installations with 45.6% of the global market, thanks to its 34.2 GW of installed capacity in 2016, followed by USA with 13 GW and then by Japan, that has added 8.6 GW in the year. To notice the 5 GW installed in India, an increase of 150% compared to 2015. Europe, already in sharp decline in the previous years, sees its market share (8.6% in 2016) to lose about 5 points, despite a moderate decline of total installations of 0.5 GW compared to 2015 (total European installation in 2016 hits 6.5 GW). To be pointed out the installations in the United Kingdom with 1.9 GW, followed by Germany (1.2 GW), nowadays very far from the 7.5 GW recorded in 2010-2012.

A closer look to the market indicates that about 70% of module production is localized in China and Taiwan while only 5% is in Europe and 3% in USA and Canada. The cell and module production is dominated by crystalline silicon (c-Si) with standard or advanced processes with a share of 94% of annual production, leaving the remaining 6% to thin film technologies. So it is not surprising that the ranking of the top 10 world producers shows 3 Asian companies in the top 3 positions and 8 Asian companies in the full list. It is interesting to observe that the huge supremacy of Asian firms was built on a tremendous growth of production capacity based on standard c-Si solar cell technology (c-Si p-type Multi, Al-BSF), with costs reduction realized by scale economy. Only recently companies are starting a transition to advanced c-Si cell processes like PERC, HJT and Rear Junction solar cell. Without modifications, this evolution will allow the persistence of the Asian supremacy for the years to come, with a marginal role of European companies in the PV scenario. The concerns of European stakeholders resulted into the activation of different bodies for the goal of regaining a "Global Leadership in Photovoltaics". This target is the current strategy of the European Strategic Energy Technology Plan (SET-Plan) aiming to synergize the actions of bodies like EU PV Tech Platform (PVTP), EU Construction Tech Platform (ECTP), EERA Joint Programme on PV (EERA-JP-PV), EU Platform of Universities in Energy Research & Education (EUA-EPUE). It is a coordinated action with ambitious and clear objectives for Europe, among which:

- Growth of research and innovation investments.
- Challenging PV system cost and performances targets (+20% by 2020 and +35% by 2030 module efficiency; -20% by 2020 and -50% by 2030 system cost compared to 2015 values).
- Strong synergy with key sector of building industry.

The latter objective is driven by the innovations needed for the Zero-Energy Buildings and Plus Energy Buildings (PEB) which require new materials and concepts and innovative combination of Building Integrated Photovoltaic (BIPV) with energy efficient building materials. The building is going to be the elemental component of the future smart grid in which PV generation, energy efficiency, storage and management can transform a current niche market into an huge business opportunity for European companies. Italy will contribute to this effort working on almost all the components of the PV value chain, thanks to the high wealth of knowledge and technological skills in its research centers and universities. In particular, ENEA –the Italian public research body having the highest commitment in PV for human resources and investment– is working on new technological options embracing both the evolution of c-Si solar cell and new thin-film absorber as well as BIPV with new vision of photovoltaics in the living environment. In what follows, a more detailed description on ENEA activities is given.

Towards high efficiency solar cells

Solar cells based on silicon achieve a high sunlight conversion efficiency due to the material quality and widespread technological know-how. Silicon is abundant raw material with low toxicity and its technologies are scalable for mass production, as demonstrated by the photovoltaic market share of silicon-based cell higher than 90%. Improving the efficiency of Si solar cells is key to further reduce the energy cost and the surface of photovoltaic field, thus leading photovoltaics to the 20% share of the global primary energy demands by the year 2050 [1].
Amorphous/crystalline heterojunc-

tion (a-Si:H/c-Si HJ) cell has recently demonstrated to be the most effective way to achieve the theoretical efficiency limit of 29.1% on c-Si based solar cell [2]. Indeed, the HJ cell efficiently merges the advantages of widespread technological know-how on c-Si material and capability of thin amorphous films to produce, with a low thermal budget, high surface passivation with recombination velocity below 10 cm/s. Indeed the great amount of hydrogen content within the amorphous film, useful to passivate network dangling bonds, at the same time represents a reservoir of hydrogen available to passivate, under certain conditions, the c-Si surface on which the amorphous thin film is deposited by Plasma Enhanced Chemical Vapor Deposition (PECVD) technique. To this aim, an intrinsic layer about 5-6 nm thick is used as a buffer before doped film to reduce defect density at the a-Si:H/c-Si interface. Emitter and base contacts of the cell are then performed by 10 nm of doped a-Si:H film. While very effective base contact can be obtained by n-type a-Si:H/i-a-Si:H/n-type c-Si due to optimal work function alignment at interface, tunneling mechanism is instead required to ensure the same performance of p-a-Si:H/i-a-Si:H/p-c-Si base contact. Poor lateral conductivity of doped a-Si:H films is overcome by Transparent Conductive Oxide film commonly deposited on top and bottom sides of the cell by sputtering process of Indium Tin Oxide film. Its thickness is chosen also to work as antireflection coating. The metal electrodes of the cell are commonly performed by expensive screen printed Ag grid as obtained by low temperature sintering Ag pastes. On the other side high c-Si material quality with a minority carrier lifetime of 10 ms and prolonged durability have been recently demonstrated by n-type doped c-Si wafer leading to less than 0.5% per year total efficiency reduction under sunlight exposure for at least 35 years.

To enhance the cell efficiency and reduce the cell costs, several approaches can be suggested.

One of the most effective is moving both base and emitter contacts to the rear side of the cell, as suggested by the Interdigitated Back Contact cell that frees the cell front side from the shadow grid. Even this approach has been successfully demonstrated by homojunction c-Si based cell of Sun Power, the use HJ technology for both contacts allows higher Voc values with respect to the homojunction and a thermal budget lower than 250 °C that allows to use thinner wafers with respect to the conventional ones.

To further enhance the cell efficiency, thin film a-Si:H undesired absorption of the sunlight can be reduced by introducing wider energy bandgap a-SiOx for both surface passivation and emitter or base contacts. Recently, studies are demonstrating this new material is more stable to higher temperature steps useful to overcome the issue of cell interconnections within the module. Actually this is obtained by tape instead of soldering to avoid thermal stress at the interfaces, but the tape interconnections leads to lower module fill factor due to higher series resistance with respect to the conventional technology of module manufacturing. Furthermore, to reduce the cell cost and simplify the cell fabrication, the doped thin amorphous films, commonly formed by toxic PH_3 or B_2H_6 gasses, can be replaced by transparent not stoichiometric oxide as MoO_x or NiO_x, WO_3 for p-type and SnO_x or TiO_2 for n-type contact. These promising materials can be obtained by conventional technologies as Sputtering, Thermal Evaporation or Spin Coating that can be easily scaled up to large industrial mass production at lower cost with respect to PECVD systems.

Finally the expensive silver grids electrodes will be soon replaced by copper plating, thus reducing the cell costs and enhance electrodes conductivity, indeed the screen printed silver grid has a conductivity one order of magnitude lower than plated Cu.

Moreover, the HJ technology easily approaches cell and module bifaciality, indeed perfect passivation is obtained by thin film on both front and rear sides of the cell and both contacts are completed by transparent conductive oxide followed by silver grid electrodes, therefore the cell is always ready to be bifacial. Bifacial module can produce even more than 20% energy per year with respect to monofacial and this value can be further enhanced considering that the HJ thermal coefficient is lower than that of c-Si homojunction leading to a higher amount of energy under the same sunlight and thermal conditions.

All these suggestions are under investigation in ENEA Labs to enhance the cell efficiency above the current 18%. This road is the core of the Horizon 2020 Ampere project, leaded by Italian PV company, aiming to get modules with 23% efficiency at 0.45 €/Wp using a bifacial configuration.

Future efficiency enhancement will be achieved by tandem cell design in which two cells will be stacked in series. To this aim the top cell is devoted to the UV/visible part of the sunlight spectrum and the bottom

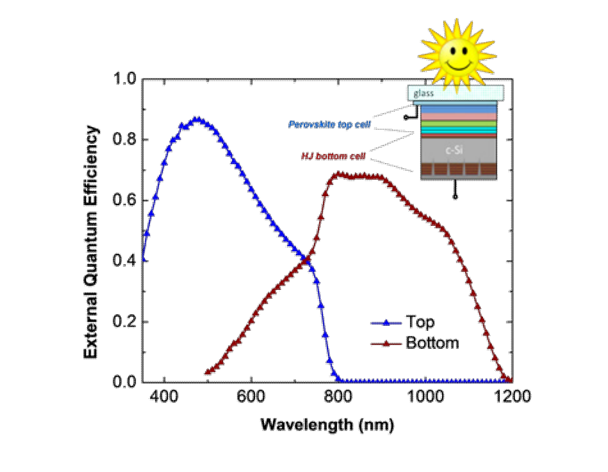

Fig. 1 Quantum efficiency of a tandem cell

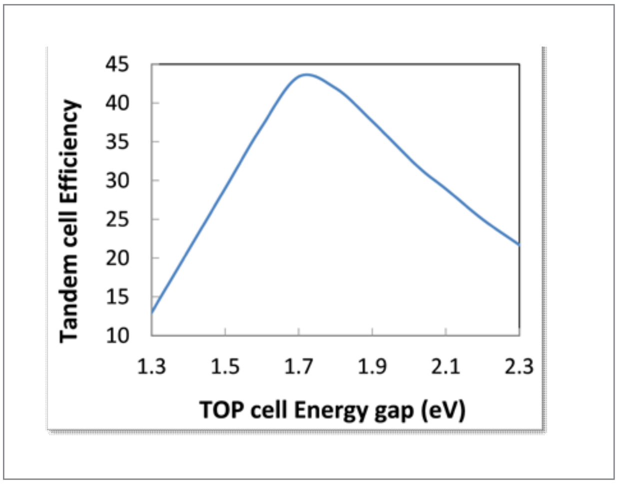

Fig. 2 Tandem cell efficiency as a function of top cell energy bandgap with c-Si bottom cell

cell is specialized to Near-IR light collection, as shown by the quantum efficiency of a tandem cell born from a collaboration between ENEA and CHOSE (Centre for Hybrid and Organic Solar Energy - University of Rome Tor Vergata) and reported in Figure 1.

Both cells have to be tuned, in terms of absorption and thicknesses, to achieve at least half of the total photocurrent of a single c-Si based cell, while the total cell voltage must be higher than the double of a single c-Si cell. Following this approach, solar cell efficiency as high as 40% can be theoretically demonstrated rightly choosing the energy bandgap of the absorber material in the top cell while the bottom cell is c-Si based, as shown in Figure 2 [3].

Perovskite and kesterite for the top cell of a tandem device

Aiming at the described high efficiency tandem cell, the challenge is the synthesis of absorber material for top cell which is flexible in tuning to the desired bandgap for the best matching with c-Si bottom cell. Several class of materials have been proposed such as chalcogenide semiconductors, organic-inorganic perovskite, and III-V semiconductors (such us GaInP). The research in ENEA is focused on the development of Cu_2ZnSnS_4 (CZTS) and hybrid organic-inorganic perovskite solar cells because of the potential advantages of these absorber materials in term of costs and availability of the constituent elements with respect to other possible options. These activities are mainly supported by the Italian Ministry of Economic Development in the framework of the Operating Agreement with ENEA for the Electric System Research and are carried out in cooperation with several Italian Universities.

Earth-abundant CZTS photovoltaic devices

All successfully commercialised non-concentrating photovoltaic technologies to date are based on silicon or on chalcogenide thin-films (semiconductors containing Group VI elements, specifically Te, Se, and S). The success of this last option can be ascribed to the high device performance reached with this class of materials: the record efficiency of CdTe is 22.1%, while $Cu(In,Ga)(Se,S)_2$ (CIGS) presents a record value of 22.6%, making it the highest-efficiency thin-film solar cell material to date [4]. Unfortunately Cd and Se are toxic "heavy metals", while Te and In are among the 12 most scarce elements in the Earth's crust, factors that would seem to clearly limit the long-term potential of the established chalcogenide technologies. However the compound Cu_2ZnSnS_4 is similar to CIGS involving earth-abundant, non-toxic elements (the scarce element In is replaced by Zn and Ga replaced by Sn). CZTS can crystallize to form either a kesterite or stannite crystal structure, with kesterite being preferable for PV applications. Despite the relatively small effort so far devoted to the development of this material, initial results have been promising with a group at IBM reporting 12.6% efficiency for small cells, obtained replacing part of sulphide with selenide (CZTSS), while an efficiency of 9.5% has been obtained with CZTS

absorber by University of New South Wales (Australia) [4].
The CZTS bandgap is 1.5 eV, a value very close to the optimal bandgap for a single junction solar cell of 1.35 eV. Moreover, alloying with related compounds to replace, for example, Sn by Si will increase the bandgap making values more suitable for the top cell in a two-cell stack on silicon. Polycrystalline films of CZTS are made using sputtering or evaporation from the constituent elements and are typically deposited onto a Mo film that is sputtered on a soda-lime glass substrate. The typical active layer thickness is ~1 to 3 μm. The cell is finalized by the chemical-bath deposition of CdS to form a heterojunction followed by an intrinsic ZnO buffer layer and a transparent ZnO:Al conducting layer.
The main research activities in ENEA are focused on: 1) improving the control and the reproducibility of the CZTS growth process (the CZTS films are prepared by sulfurization of precursors, co-sputtered from SnS, ZnS, and Cu targets); 2) evaluating the effect of the disorder in the distribution of Cu and Zn cations, which gives rise to band gap fluctuations that reduce carrier mobility and increase recombination; 3) evaluating buffer layers alternative to CdS, such as for example Zn_2SnO_4, in order to improve the device performance and avoid the use of toxic Cd. At present, the best CZTS solar cell developed in ENEA presents an efficiency of 7.8%.

Perovskite solar cells

Hybrid organic-inorganic perovskite solar cells have recently taken the PV research world by storm, with efficiencies above 20% achieved after only 5 years of substantial work: the present record efficiency of 22.1% has been obtained by the Korea Research Institute of Chemical Technology (KRICT) [4]. Perovskite-based solar cells are generally fabricated with organic-inorganic trihalide perovskites with the general formula ABX_3, where A is the methylammonium (CH_3NH_3) (MA) or formamidinium $[HC(NH_2)_2]$ (FA) cation, B is commonly lead (Pb), and X is a halide (Cl, Br, or I). Depending on the halide used, the band gap can be continuously tuned from ~1.5 eV (pure I) to 3.2 eV (pure Cl), with the smaller–band gap materials providing better solar cell efficiencies. Mixed-cation perovskite solar cells have consistently outperformed their single-cation counterparts: The first perovskite device to exceed 20% of efficiency was fabricated with a mixture of MA and FA [5]. Recent reports have shown promising results with the introduction of caesium mixtures, enabling high efficiencies with improved photo-, moisture and thermal stability [6].
The perovskite salts form polycrystalline films with a perovskite structure at or near room temperature by precipitation from a variety of polar solvents (commonly dimethyl formamide or dimethyl sulfoxide). The typical device is realized on FTO-coated glass substrate coated with an electron selective contact (usually TiO_2). Subsequently, the perovskite is deposited using various methodologies such as sequential deposition, solvent engineering, vapor-assisted deposition, vacuum evaporation, etc. Finally, the hole-selective top contact (usually Spiro-OMeTAD) is spin-coated on top, and the back contact (usually gold) is evaporated to finish the device.
Despite their excellent initial performance, hybrid perovskite solar cells are known to degrade under standard operating conditions; at present this is the greatest barrier to commercial implementation. The origins of perovskite cell instability are currently a topic of active research, although photoreduction by ultraviolet light and reactions with water have already been identified as likely candidates. Also, measurements of the current-voltage characteristics can suffer from hysteresis, making efficiency analysis complex. Because of Pb toxicity, encapsulation and recycling are important for this technology to become viable for large-scale application.
ENEA is currently developing perovskite solar cells under ambient conditions, studying the effect of the relative humidity on the device performance. The best efficiency of 12% has been measured on cells prepared at a relative humidity of about 40%. The devices have been realized in collaboration with CHOSE that, in particular, has optimized the electron selective contact in TiO_2. ENEA is also studying the possibility to improve the properties of the electron selective contact using materials and processes compatible with the tandem architecture by developing ZnO nanorods grown on sputtered AZO (Figure 3). Preliminary tests on devices have shown very promising results. Furthermore, ENEA and CHOSE are involved in the development of a single-junction perovskite solar cell with a transferable architecture for monolithic tandem solar cells on silicon. Preliminary prototypes of perovskite/Silicon tandem devices have been already realized with efficiencies of about 16%, by mechanically connecting the two component cells (quantum efficiency shown in Figure 1).

Use of photovoltaics in the living environment

In the context of the possible uses of photovoltaics in the living environment, main focuses of research activity are architecture and landscape issues, as well as measurements, testing and standardization issues. The use of photovoltaics is investigated with regard to technological and design issues, and to cultural issues too (social acceptance of new technologies). Attention is also given to new methodological and theoretical frameworks for the implementation of photovoltaics in the living environment. Since 2000, research has been carried out about the use of photovoltaic technologies in buildings, and the main results are patents, innovative prototypes, and scientific publications and books.

Some of these prototypes are installed in the ENEA Research Centre in Portici (Naples), such as a coloured glass-glass photovoltaic façade and a street lamp (StapeliaTM), which integrates photovoltaic cells and LEDs, and having an innovative design as its main feature. Moreover, in the same Research Centre since many years, the laboratory "Test over Photovoltaic Modules", is also in operation, which has obtained the accreditation certificate no. 1421 by Accredia in January, 2014. Its activity is focused on module quality evaluation, reliability, and life time estimation.

More recently, the topics of the integration of photovoltaics with the landscape, and the use of photovoltaics in net-zero-energy and smart buildings, have been included in the research domain.

In this framework ENEA participates in several European research programmes and in a number of international networks. In particular, significant activities have been carried out under the International Energy Agency (IEA), on the following topics: Solar technologies and architecture; Solar energy and urban planning; Net Zero Energy Buildings design; Acceleration of BIPV. Among other activities, ENEA is a frontrunner on the design of photovoltaics as an element of the landscape. In this regard, since 2011 ENEA organizes a thematic event –Photovoltaics | Forms | Landscapes– on the occasion of the European Photovoltaic Solar Energy Conference (EUPVSEC), within the framework of a memorandum of understanding with the European Commission, JRC. Moreover, ENEA is actively involved in the COST action RELY, on Renewable Energies and Landscape Qualities.

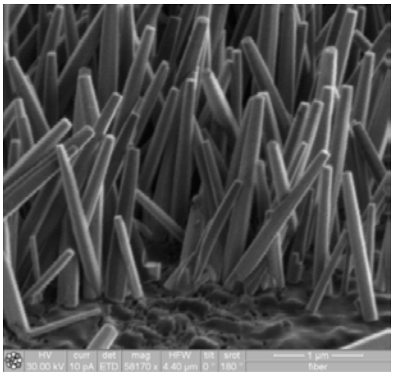

Fig. 3 SEM image of ZnO nanorods for perovskite solar cells

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Experimental and numerical investigations on renewable energies at CNR-INSEAN: Challenges and future perspectives

The exploitation of renewable energies from the oceans requires an interdisciplinary approach to solve all the problems linked to a hostile environment and to the need to limit the frequency of operations and maintenance processes. The development of renewable energies from the sea relies not only on classical mechanical, electrical, electronics, control and systems engineering but also on material engineering and on hydrodynamics and fluid structure interaction science. CNR-INSEAN contributes to the latter two

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The exploitation of renewable energies from the oceans requires an interdisciplinary approach to solve all the problems that are linked to a hostile environment and to the need to limit the frequency of operations and maintenance processes.
The development of renewable energies from the sea relies not only on classical mechanical, electrical, electronics, control and systems engineering but also on material engineering and on hydrodynamics and fluid structure interaction science. CNR-INSEAN, the Marine Technology Research Institute at the Italian Research Centre, has an almost centenary experience in these latter two fields and is now active in sustainable exploitation of the marine environment, providing its support to overcome the challenges posed by these new technologies.
The main marine renewable energy sources are offshore wind,

tides, ocean currents and waves. The estimated power of the oceans is 2 million TWh/y [1] but only a very small part of it is harvested at the moment. To enlarge the quantity of energy that can be actually extracted, it is necessary to overcome some of the technological challenges that each one of the different resources implies.

The research work at CNR-INSEAN supports technology developers with the most advanced expertise and capabilities in model testing and computational modelling of device hydrodynamics.

In particular for the experiments, it is possible to use large-scale facilities as the circulating water channel (10m*x*3.6m*x*2.2m test section), the towing tank n. 1 (470m*x*13.5m*x*6.5m) and the towing tank n. 2 (220m*x*9m*x*3.6m) equipped with a wavemaker.

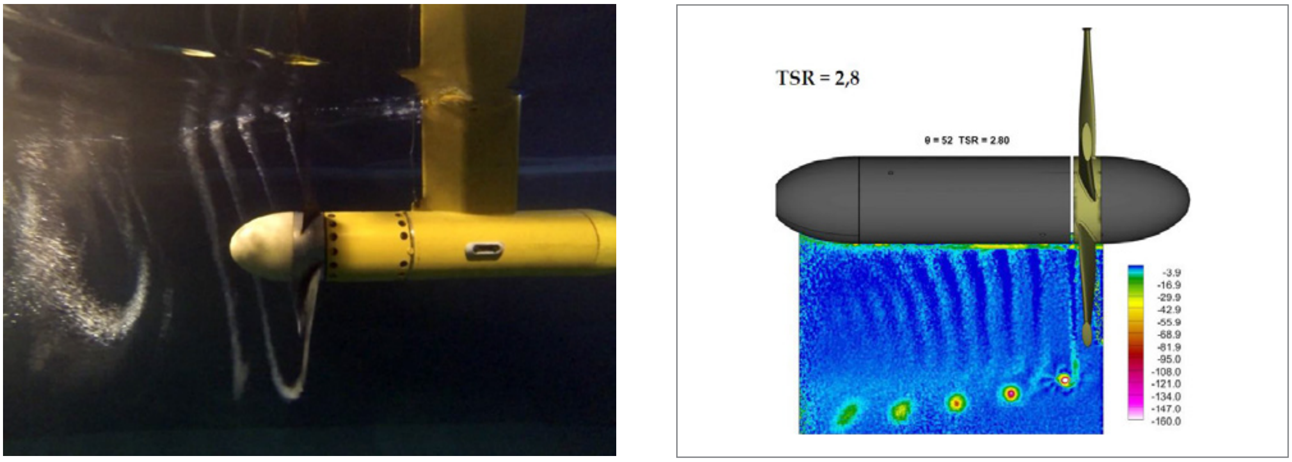

Fig. 1 Left: Air entrained by the tip vortex of a 1.5 m diameter model turbine during towing tank test; Right: Vorticity distribution in the wake of a SABELLA model turbine from PIV measurements in the Circulating Water Channel [2]

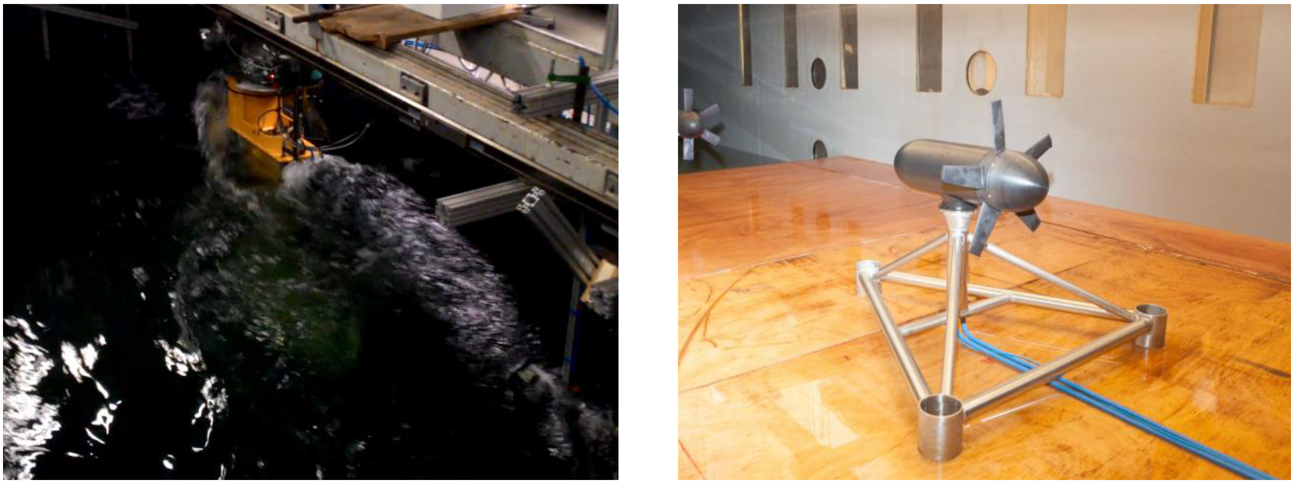

Fig. 2 Left: 1.5 m diameter model turbine during wave/current interaction tests in the wave tank (Courtesy Schottel Hydro GmbH); Rigth: Two 0.4 m model turbines during simulated turbine operation in array in the Circulating Water Channel (Courtesy SABELLA SAS)

In the following, selected contributes of CNR-INSEAN to research in this field are detailed.

Tidal energy concepts

At CNR-INSEAN, tidal turbines in different layouts are developed in collaboration with the most important test centers, and specific test protocols are proposed to the community as new standards. Activities are carried out within research projects as EU-FP7 MaRINET and H2020 MaRINET-2, and commercial projects with key industrial players as SABELLA, Schottel-Hydro, Abengoa.
Most efforts are spent to test devices in conditions that are as much as possible representative of the real environment of a tidal site. The hydrodynamics of medium sized marine current turbine models (Figure 1) are deeply addressed in the circulating water channel. There, single turbine performance, as well as the effect of the flow misalignment, the turbine submergence and the sea bottom proximity on loads are addressed. Energy conversion mechanisms are investigated through the turbine wake flows characterization (right plot of Figure 1) by applying state-of-art velocimetry techniques (LDV, PIV, Stereo-PIV).
Wave tank no. 2 is suited to investigate the effect of waves impinging onto the towed turbine. In particular, measurements are performed to assess the wave-forcing of the blades and of the floating structure (Left, Figure 2).
Towed large-scaled models in complex array configuration are studied in the towing tank no. 1 in calm water conditions.
The device reliability over the lifecycle is assessed with limited uncertainty on the risks associated to commercial projects. The array planning and the device operating points can be determined at relatively low costs and time, before stepping over into deployment of full-scale units at sea (Right, Figure 2).
The development and application of computational hydrodynamics models is complementary to the

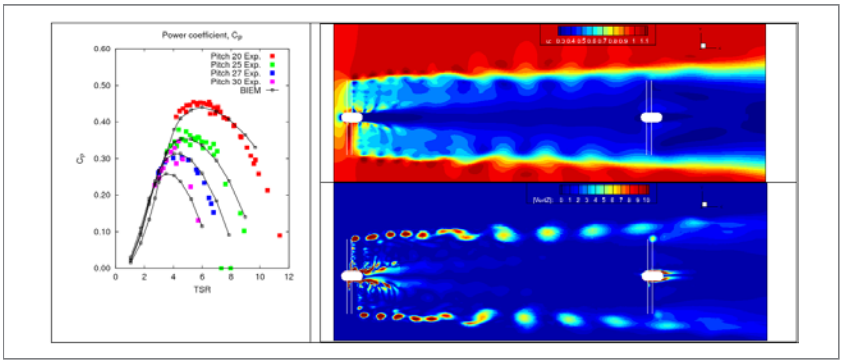

Fig. 3 Left: Turbine performance predictions by BIEM, power coefficient predictions for different blade pitch settings [3]; Right: Computational study by Hybrid RANS/BIEM model of flow around two coaxial turbines spaced d = 4 diameters. Instant axial velocity (top) and vorticity intensity

experimental work at the CNR-INSEAN.
Variable-fidelity models are developed according to the hydrodynamics investigated. Blade Element and Boundary Integral Equation Methods-based computational tools with results validated by using dedicated benchmark data (Left, Figure 3) provide fast and robust predictions envisaged in the preliminary design and optimization of single rotors.
A variety of viscous-flow solvers based on the numerical solution of the Navier-Stokes equations with turbulence modelling (RANS, DES, LES) allows a deep investigation of the turbulence effects on the fluid-dynamics of the turbine. In this case, high-performance computing resources are used to simulate experiments.
A new computational tool based on hybrid N-S/BIEM models is used to analyse turbine wakes and turbine/turbine interactions in arrays (Right, Figure 3). Inherent limitations due to the complexity of studying tidal arrays by physical tests in hydrodynamic facilities are expected to be overcame by the use of such a new computational tool.

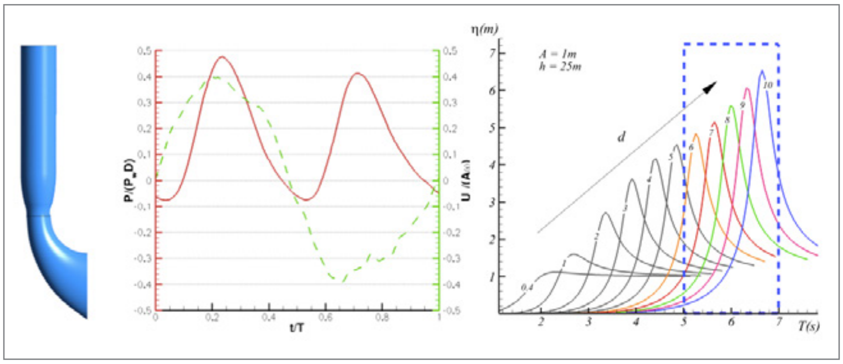

Fig. 4 Left: Sketch of the WaveSax geometry; Centre: Experimental extracted power, made non-dimensional by the wave power correspondent to the device width, and velocity of oscillation inside the device made non-dimensional by the wave amplitude multiplied by wave period; Right: Effect of the immersion as a function of the deployment site

A wave energy concept

Numerical and experimental investigations have been performed on a new technology of Oscillating Water Columns (OWC), the WaveSax. The name of the machine comes from its shape; it resembles a saxophone semi-immersed in the water to "play" the waves. As shown in the first plot of Figure 4, the bell of the sax is immersed into the water and it captures the movement of the fluid particles below the free surface [4].
It is thought to exploit a resonant phenomenon that was first studied for artificial islands, practically a partially immersed hollow cylinder can cause a resonant effect that amplifies the incoming wave inside the cylinder itself. This amplification is looked for to increase the velocity of the oscillating flow across the sax and above all trough its bow, where a Wells turbine is positioned.
Differently from the classical OWC, here the turbine does not make use of the air-flow but of the water-flow, so it is invested by a flow with higher density than the air but at a smaller velocity because of a geometrically-limited Venturi effect.
The use of the Wells turbine allows the extraction of energy in both the directions of motion of the flow across the turbine as shown in the second panel Figure 4, where the instantaneous extracted power and the velocity of water inside the WaveSax are plotted in the wave period.
Numerical and analytical analyses complete the experimental studies, an analytical study can be carried on to increase the performance of this OWC as a function of the deployment site. The third panel of Figure 4 shows the effect of the WaveSax immersion *d* on the amplification of the water oscillation and of the incoming wave period. Once the deployment site has been chosen and the features of the characteristic waves are known, the immersion of the device can be chosen to maximize the resonance in the region of interest as the box highlighted in the plot.
Moreover the numerical studies allow to take into account the effect of vertical surfaces that are positioned just behind the device as harbours structures, in that case the reflections of the waves by the solid surface increase the amplification by up to 40% if a suitable geometry is chosen, that is the extracted power almost doubles.

A concept of hybrid wind and wave energy convertor

Within the EU-FP7 Project "Marinet", CNR-INSEAN has been involved by NTNU-CeSOS in the physical test and numerical simulation of a combined wind and wave energy converter concept, called STC. The prototype is composed by a spar floating wind turbine, moored at the sea bottom through a mooring line and a torus-shaped wave energy converter (WEC) heaving along the spar. The model, which reproduces the prototype in 1:50 scale, has been designed and built at CNR-INSEAN, along with the realization of a complex experimental set-up, necessary to measure the independent motions of the two bodies, the contact forces between the spar and the WEC, and the horizontal loads along the mooring line. Wind forcing was included using a wind drag disc, in order to model the effect of the thrust force on the rotor. The experiments have been conducted in two different configurations: a) with the torus fixed to the spar, to measure the hydrodynamic and the contact forces acting on the torus, both in mean water level and in submerged modes; b) with the torus free to move, with and without the PTO system. Two pneumatic PTO systems in the model reproduce the damping of the corresponding hydraulic PTO in the prototype. Tests in regular and irregular wave, the latter both for operational and survival modes, have been carried out at the wave basin no. 2.

For the configuration a), violent water-entry and exit phenomena, along with green water on deck were observed during the survivability model tests, claiming for a detailed numerical investigation involving complex flows and non-linear physical phenomena. This has required the non-linear numerical model developed at CNR-INSEAN, based on a blended station-keeping potential-flow solver with a local impact solution for bottom slamming events and an approximated model for the water shipped on the deck. This has been validated in several applications in the naval and offshore field, demonstrating its efficiency and ability in reproducing so high complex phenomena even in the STC application.

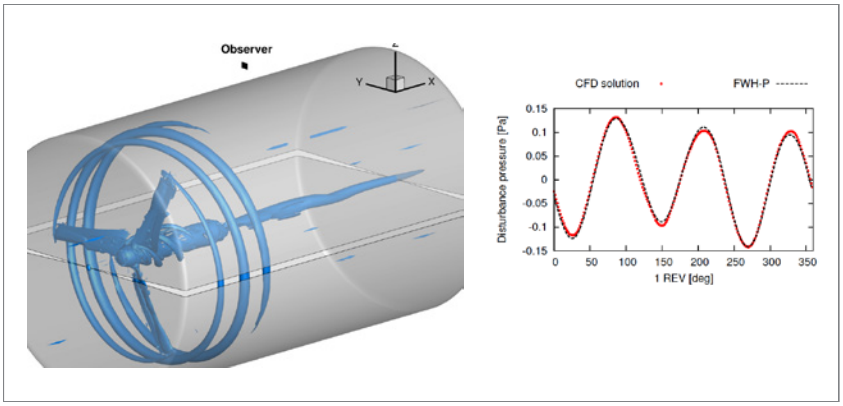

Fig. 5 Left panel: FWH-P surface and vortices core detection; right panel: Acoustic pressure near field

Aeroacoustic Analysis of a Horizontal Axis Wind Turbine Model

Among the many theoretical and numerical models used to predict fluid-dynamically generated noise signatures, the Ffowcs Williams and Hawkings Equation (FWHE) represents a well-known and widely used approach. It extends the Lighthill theory for turbulence generated sound, to account for the presence of solid moving bodies. The noise generation mechanisms are expressed as linear body surface distribution of monopole and dipole and non-linear quadrupole field source terms within a volume of suited extension around the body. The latter contribution may be acoustically relevant for configurations, like Horizontal Axis Wind Turbine (HAWT), characterized by the presence of massive turbulence or vorticity fields. The actual HAWTs have diameter of more than 150 m and more than 7 MW installed power, thus the acoustic impact is an issue.

In this context, the use of the FWHE for porous (fictitious) surfaces (FWHE-P, see left panel of Figure 5) surrounding the body and the corresponding field noise sources is certainly the most suitable and effective way to include the influence of field sources on noise avoiding, at the same time, cumbersome computations of volume integrals. The hydrodynamics features of the flow, representing the sources of noise, are provided by a RANS simulation upon a cylindrical surface rigidly moving (co-rotating) with the blades, chosen as the integration domain of the FWHE-P.A zero-th Boundary Element Method (BEM) is used to solve the integral formulation. The reliability of the predicted acoustic pressure is evaluated by the comparison with the disturbance pressure extrapolated by the near field RANS data, depicted in the right panel of the Figure 5 [6].

Conclusions

The maturity of the concepts extracting renewable energy from the sea is growing in time; some of them are almost ready for the commercial stage, others are still at a concept stage. Nonetheless, all of them still require a large amount of research work from adaptation of the concept to the deployment site to definition of survivability to severe sea conditions, environmental impact and so on. This requires a considerable effort for research to meet these industrial needs.

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Energy from seas and oceans

Marine energy can represent an important source of renewable energy in the near future. In Italy, activities performed in this sector are growing rapidly both in terms of assessment of the resource and of development of new devices

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by **Gianmaria Sannino**, **Adriana Carillo**, *ENEA*

The growing interest in the Blue Energy sector represents an opportunity for sustainable growth of maritime economies, sustainable development of marine areas, and sustainable use of marine resources. The EU's Renewable energy directive has established a target of 20% of energy production from renewable energy by 2020. Seas and oceans have the potential to become an important source of clean and renewable energy contributing to reach such a target, the contribution of ocean energy to the EU power demand has been estimated to be around 10% by 2050. Five different marine resources have been identified as liable for ocean energy exploitation:

- **tidal current** extracts kinetic energy from tidal flow;
- **tidal range** captures the potential energy created by the difference in sea level between high and low tides;
- **wave** converts kinetic energy transmitted by the wind to the upper surface of the ocean;
- **ocean Thermal Energy Conversion** exploits the temperature difference between deep and surface ocean layers;
- **salinity gradients** exploits the chemical potential due to salinity gradients in water bodies.

These resources are not uniformly distributed on the globe; moreover the degree of maturity of the technology necessary to their exploitation is different. In the Mediterranean Sea, the two most interesting ocean sources are represented by tidal currents confined in the Strait of Gibraltar and Messina and by waves. Concerning the exploitation of tidal energy, devices based on tidal range technology have been operating since 1960s. Devices are based on barrages that harvest energy from the height difference between high and low tide, converting potential energy into electricity. A tidal power plant with maximum capacity of 240 MW has been operating since 1966 at the Rance River estuary in France. In the tidal currents technologies, instead, energy is derived by water currents and is exploited by means of horizontal or vertical axis turbines. Tidal current converters have not yet reached the same level of maturity as tidal barrages, however an intense research activity is actually carried out. Many large industrial companies are deploying pre-commercial arrays and new technical solutions are under study.

Research in the wave energy sector started in the 1970s, and was initially devoted to the design of large-scale devices to be installed in regions characterized by the largest amount of energy. Due to costs and problems related to the survivability of the devices to the most intense wave extremes, in the last few years research moved on small-scale devices and to exploitation of lower energy sites. These smaller devices present some operational advantages such as lower costs of installation and maintenance; moreover they are generally designed to operate in farms, ensuring energy production also during maintenance activities.

Actually, there is a variety of devices based on different technologies but none of them has taken a leading role. Many different methods have been used to classify wave energy converters. Based on their operating system, the following main classes can be considered:

- oscillating Water Columns (OWC) are located on the shoreline or near shore and are constituted by a submerged structure that contains a chamber with air that is alternatively compressed and uncompressed following the entering waves. The pressure of the air is then converted into energy by a turbine. Some floating devices have been developed on the same principle;
- oscillating body systems are offshore devices constituted by oscillating bodies, either floating or submerged. To induce an oscillatory motion between two bodies they use the incident wave mo-

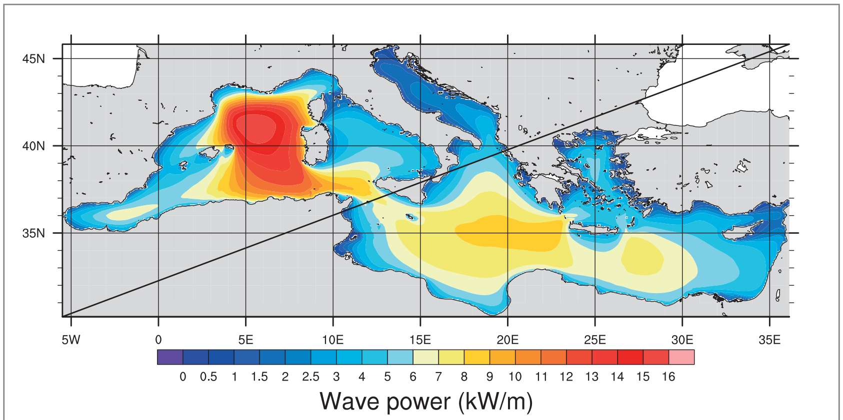

Fig. 1 Distribution of wave power for unit crest, averaged over the period 2001-2010

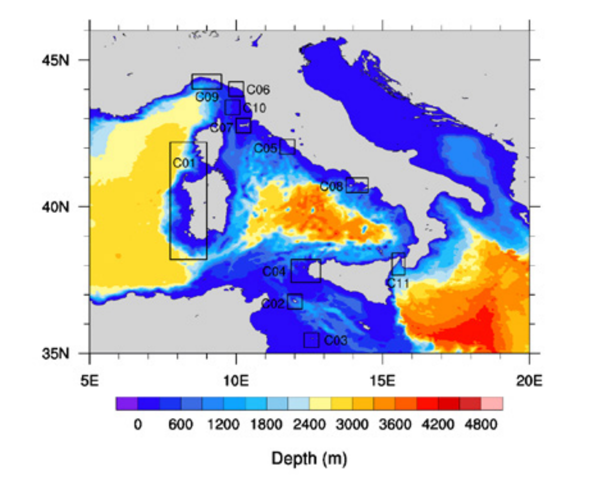

Fig. 2 Bathymetry of the Mediterranean model in the area around Italy with indicated the areas of the highest resolution models

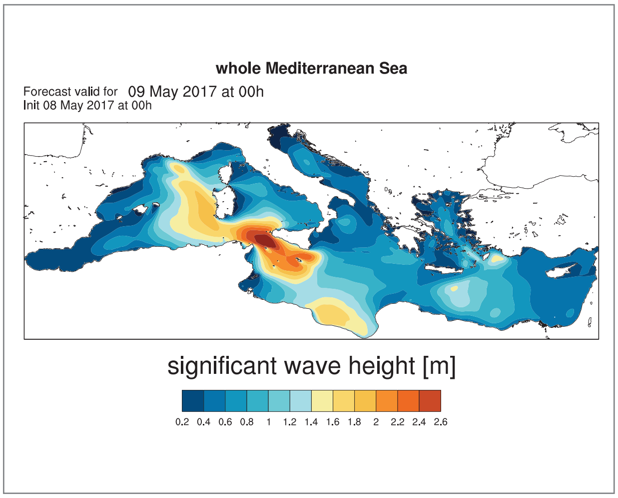

Fig. 3 Example of significant wave height forecast for the Mediterranean basin

tion, that drives the power take-off system. Their main disadvantage is the distance from the coast that requires solving mooring problems and needs long underwater electrical cables;

- overtopping converters are based on the use of a reservoir of water at a level higher than the free surface of the sea; the potential energy of the water is converted into energy through low-head hydraulic turbines. Overtopping converters can be floating structures or incorporated into breakwaters.

Resource assessment

Feasibility studies of wave energy plants require a detailed knowledge of the available energy and of its distribution among different sea states. Wave energy atlases are based on wave measurements obtained from buoys, satellite data and output from model simulations. Wave buoys are the most accurate and reliable data, however time series from wave buoys describe wave climate only locally and often present large data gaps, caused by temporary failure or by routine maintenance operations. In enclosed seas like the Mediterranean, where wave generation and propagation shows a high spatial variability due to the surrounding lands topography, wave models represent the most important tool to assess wave energy distribution.

At ENEA the available wave energy climatology, for the entire Mediterranean Sea, covering the period 2001-2010 has been performed using a state-of-art wave model (WAM) at the horizontal resolution of 1/16° [1]. The model has been forced with six-hourly wind fields obtained from ECMWF operational analysis. An accurate validation of the wave parameters obtained from the model simulation has been performed against available buoys data, collected by the Italian Data Buoy Network (RON), managed by ISPRA; wave heights have also been compared against satellite radar altimeters data. Both comparisons have shown very good statistical agreement. A map of the available wave power flux per unit crest averaged over the entire 10 years of the Mediterranean simulation is shown in Figure 1. The most productive area is located in the western Mediterranean, between the Balearic Islands and the western coast of Sardinia; as for the Italian coasts, other areas characterized by high levels of wave energy are the north-western and southern coasts of Sicily.

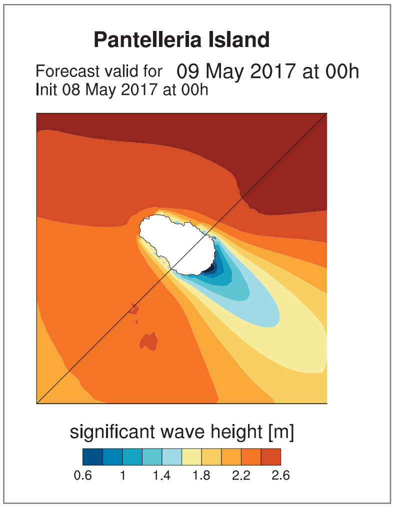

Fig. 4 Example of significant wave height forecast for the area of the island of Pantelleria

While the wave assessment is crucial to design the devices and define the place where to install wave converters, the operational phase can be supported by forecast of wave conditions. The performances of some devices can be optimized by calibrating some parameters to meet the characteristics of the incoming waves. Moreover, high-resolution forecasts are necessary in the operational stage for the management of the energy network in which the wave energy will be inserted and in the planning of maintenance operation on the device.

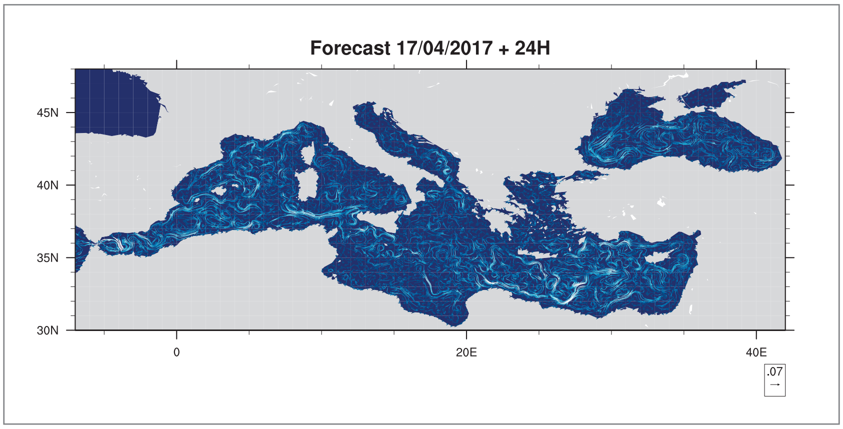

Fig. 5 Example of circulation forecast

A high-resolution wave forecast system for the entire Mediterranean Sea has been developed at ENEA, at the spatial resolution of 1/32° using WAM model. The surface forcing is represented by winds from the meteorological operational system SKIRON, developed by the Atmospheric Modelling and Weather Forecasting Group of the University of Athens [2]. Higher resolution models have been developed in eleven areas around the Italian coasts, particularly interesting for the installation of wave converters.

In Figure 2, the domains of the highest resolution models are shown with the bathymetry of the Mediterranean model. The largest area includes the western coast of Sardinia, identified in the wave energy climatology as the most interesting area in the Mediterranean Sea. Other high-resolution models are centred on some minor Italian islands, where wave energy can represent a significant contribution to the energy independence. These simulations are performed with the SWAN (Simulating Wave Nearshore) model [3], that was specifically designed to be used in shallow water, at the resolution of 1/124°. In order to take into account waves propagating from outside the domain, boundary conditions provided by the Mediterranean model are used to force laterally these models. The forecasts cover a period of five days. All the principal wave parameters are saved hourly.

The forecast system has been running since summer 2013 and a validation against data derived from satellite measurements has been performed [4]. In Figures 3 and 4 examples of forecasts of the significant wave height for the Mediterranean Sea and for the island of Pantelleria are shown.

As already said, tidal currents represent the other source of ocean energy that can be exploited in the Mediterranean Sea. An accurate knowledge of the hydrological conditions in the basin is mandatory for the development of this resource. Therefore a new circulation model covering the Mediterranean and the Black Sea has been developed based on MITgcm [5]. The model presents a series of peculiarities with respect to the existing models developed for the area. The complex bathymetry of the Strait of Gibraltar at west and that of the Turkish Strait System at east control the exchanges of water of the Mediterranean Sea with the Atlantic Sea and Black Sea, respectively. Moreover the two-way exchange with the neighbouring seas is highly variable due to the intense influence of tides. Both these elements have been considered in the construction of the new model, that includes directly the effect of tides and is based on a numerical grid characterized by a horizontal regular resolution of 1/48° in the central part of the domain, increasing both in the Strait of Gibraltar and in the eastern straits, where it reaches a resolution of the order of hundreds of meters.

The model, after a testing phase, is running in operational mode providing forecasts for the next 4.5 days. The surface forcing data are derived


Fig. 6 PEWEC 1:12 prototype during test operations in the towing tank in Rome

from the same SKIRON atmospheric simulation used to force the wave forecast system. Moreover data from a coarser Mediterranean forecast system (MFS) are used to initialize the model and to obtain lateral boundary conditions in the Atlantic and in the Black seas.
Hydrological fields are produced hourly over the entire grid of the model; in Figure 5 an example of the water circulation forecast obtained over the entire model domain is shown.
Waves in the Mediterranean Sea can represent a profitable resource if energy converters are designed specifically to face its characteristics. In the last years, ENEA has contributed to the wave energy development in Italy collaborating with different Italian Universities both in the development of new devices and in the support to field activities.
Among the different prototypes actually under development or in the prototype phase in Italy, ENEA has developed a prototype designed for coasts characterized by waves of low height and low frequency. The study was performed in collaboration with Politecnico di Torino in the framework of the Programme Agreement between the Italian Ministry of Economic Development and ENEA on the Electric System Research. The PEWEC (Pendulum Wave Energy Converter) is a floating system similar to a raft to place offshore, that can produce electric energy from the oscillation of the hull due to the incoming waves.
A 1:12 scaled, prototype with weight of 3 tons, and dimensions of 3m x 2m x 2m (see Figure 6) has been realized and tested in the INSEAN's towing tank in Rome [6]. ENEA and Politecnico di Torino are working on the project of a device with a nominal power of 400 kW.

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Tuscan Geothermal energy, when underground resources are a development leverage for territories

An important example of territories pursuing their own development model, which meets life quality, conservation of the environmental and cultural heritage and new technologies, thanks to agreements between territories and the industrial subject

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by **Loredana Torsello**, *CoSviG and DTE2V*, **Riccardo Basosi**, *Università di Siena and DTE2V*, **Dario Bonciani** *and* **Sergio Chiacchella**, *CoSviG*

The two Tuscan geothermal areas, location of the Italian geothermal power plants, are in the south-central parts of the region. Thanks to these territories, Tuscany can be considered the world cradle of geothermal energy, since first experiments to use geothermal steam to turn on a light bulb were performed in 1904 in Larderello, whereas the world's first geothermal power plant (250 kWe) was installed in the same place, in 1913. In 2015, power plants installed in Tuscany, with a total capacity of 915.5 MWe, produced about 6,200 GWh, making Italy the main geothermal power producer in Europe.

Low population density, small villages, geothermal power plants, rural landscapes, historical evidences and poor infrastructures (roads, telecommunications, etc.) mainly characterize the Tuscan geothermal areas. This results in socio-economic marginalization problems, depopulation and unemployment, but also industrial specialization, high level of know-how in specific sectors, and niche and non-mass tourism flows. Until some years ago, small companies mainly represented local activities. Sectors of these companies are mostly represented by agriculture, followed by commerce, building and manufacturing industries. The number of companies operating in the tourism and hospitality sectors was lower and it concerned medium-low market segments, even if the sector is growing year after year.

The territories of geothermal energy in Tuscany can exemplarily illustrate a model of socio-economic-cultural-environmental development that has been peculiar over ages. Even today, in this part of Tuscany millennial memory, quality of life, beauties of historical and landscaping heritage, valuable natural resources from the bowels and the surface of the earth, heritage of knowledge and experiences constitute an *unicum* that deserves to be mentioned.

It is a polychrome area with territories bound by the *fil rouge* of subsurface resources (first a history of mines, then geothermal). The subsoil that has interacted with and characterized the surface in a wonderful way; from these guts resources, have emerged what have been a vehicle for the development of these territories and which can still act as an attraction for future investments.

A Living Laboratory, where the constant search for the right balance between natural resources, innovation, technology and historic and landscape heritage, has led the efforts of local communities.

It is difficult to imagine these lands as they are today without the work of the man who bent at their will the natural forces in valleys that were not always so sweet and welcoming. Human intervention has sometimes altered, plagiarized and subjugated natural resources. This landscape is the result of the millennial human transformation to make the territory more suitable to the needs of the communities that inhabited it.

It is not easy to imagine how these territories would be now, without industrial geothermal cultivation, but perhaps it is more interesting to imagine how these landscapes can become, without pursuing the utopia

View of Larderello

of stiffening everything in the space of a postcard reserved to a few.

Initiatives to promote the sustainable development of geothermal areas

In order to promote the local socio-economic development, also through compensations to municipalities where there existed geothermal exploitation permits, in 1988 local authorities of the traditional geothermal area founded the Consortium for the Development of Geothermal Areas (CoSviG), also with the aim of coordinating technical and financial fulfilments in charge to local authorities to manage these funds. Now the Consortium plays an important role as an operational arm of its stakeholders (14 municipalities, 3 provinces, 4 unions of municipalities, and the Tuscany Region) in initiatives aimed at proposing a model of local development in line with the vocations and economic activities of these territories.
Since the second half of the 2000s, mechanisms to redistribute revenues of the geothermal energy exploitation were set up, in order to advantage local populations but also to reduce the environmental impact of industrial activities. Geothermal Municipalities, the Regional Authority and ENEL signed the General Agreement on Geothermal in 2007, and the implementing Voluntary Agreement in 2009. The main goal of those Agreements is to propose a local development model on issues concerning topics in line with the vocations and the local economic traditions of these territories.
CoSviG has promoted the creation of development paths involving all economic and social actors in the territories. A roadmap for sustainability was conceived from the diversification in production and use of energy from renewable sources, combined with the social, cultural and environmental peculiarities of the area and technological innova-

Two infrastructures owned by CoSviG: CEGLab and Sesta Lab

CEGLab is a centre of advanced expertise in geothermal energy, created by CoSviG (the Consortium for the Development of Geothermal Areas) with the help of Tuscany Region, in order to contribute to the dissemination of innovation and to technology transfer for the promotion and direct use of heat from underground. CEGLab is conceived as an applied research laboratory for geothermal-related issues, to perform experiments and tests on prototypes and products which can contribute to improve geothermal technologies in terms of resources and plants. It operates in synergy with other infrastructures dealing with applied research on geothermal energy, so as to create a network of laboratories that may be expanded.
SestaLab is one of world's leading laboratory for "full scale testing" of gas turbine combustors to study the pressurized combustion process. Acquired by CoSviG in 2014, the experimental area's mission has been to replicate combustor real conditions in terms of pressure, flow and temperature since the beginning. A design based on test results allows to meet final users' need (emission, environment etc.). It is fundamental to get new Oil&Gas and Power Generation market shares. The most important Gas Turbine Manufacturers have run a test at least once in SestaLab.

tion. Actions related to this model can produce results for encouraging/multiplying design, even private, consistent with the Country's land development strategy.
The development model that CoSviG is experiencing in Tuscany is based on actions to support:

- Infrastructures for tourism and trade sectors;
- Restoration of some ancient villages, making them more attractive to visitors;
- Infrastructures for generating distributed energy from renewable sources (wind, biomass, geothermal):
  - wind farm (subsequently expanded);
  - installation and remodeling of installations of telescopic geothermal heating in urban centres;
  - biomass plants for buildings not reached by district heating networks;
- ICT infrastructure for innovation;
- Structures and tools for applied research and technology transfer on energy;
  - creation of a centre of excellence for geothermal energy and technology transfer on renewable energy sources;
  - creation and management of CEGLab (Laboratory of the Centre for Excellence for Geothermal Energy-Larderello);
  - acquisition and management of SestaLab (Sesta Testing Laboratories), one of the world's leading real-time gas burning labs;
  - coordination of the activities of the Regional Technology District on Energy and Green Economy - DTE^{2V};
- Infrastructures for production areas;
- Territorial marketing projects, territorial promotion and investment attraction;
- Support to local entrepreneurs with disbursed grants and guarantee funds for access to credit bank;
- Training Agency;
- Renewable Energy Food Community (the first in the world) consisting of agrifood producing companies using renewable energy and Tuscan raw materials, founded by CoSviG with Slow Food Toscana and Slow Food Foundation for Biodiversity.

CoSviG's development model, thus, allowed the *promotion of the territory* in its peculiarities and characteristics, by the promotion and dissemination of initiatives linked to RES, energy saving and efficiency in the respect of local communities and their traditions and vocations.
Besides promoting RES plants and energy efficiency measures through research, innovation and technology transfer activities, the final aim of CoSviG is, therefore, to build a local development system, which can result in an integrated and homogenous growth model. Thus, actions related to this model can produce results for inducing/multiplying complementary projects, including private initiatives, consistent with the strategy for sustainable development and dissemination proposed by the territory. In this context, CoSviG and Enel Green Power signed, in January 2017, an agreement to support one-year experimental cultivation of the cyanobacteria Spirulina (*Arthrospira platensis*), in order to test techno-

economic sustainability conditions to produce, in a geothermal environment, this microorganism used in nutraceutics. Cultivations are using waste heat and CO_2 from a geothermal power plant and are monitored by properly trained technicians. This staff will be available to subjects wishing to enter this sector, once the experimentation is completed. The final aim of this project is indeed to make these territories more appealing to companies intended to invest in these territories using locally available resources, as well as to expand the production chains that geothermal heat can support.

From the promotion of local resources to the promotion of sustainable energy and energy efficiency at regional and international level

In order to promote the use of sustainable energy and energy efficiency, CoSviG also carries out several activities at regional and international level.
In this connection, CoSviG has coordinated the Innovation Pole on Renewable Energies and Energy Saving (PIERRE) and is now the managing body of the Technology District on Green Energy and Economy (DTE2V) of the Tuscany Region. The DTE2V is a regional technology district grouping about 80 subjects among companies, laboratories and research centres (as well as universities) working in the energy and green economy sectors. Its main aim is to increase the competitiveness of Tuscan companies working in the latter sectors, through:

- technology dissemination, forecasting changes in the reference sectors;
- business matching/matchmaking, promoting matching among economic players, in activities for technology innovation and for the adoption of strategies for marketing and to approach to new markets;
- creation and enhancement of know-how in the reference sectors;
- searching for funds for innovation in regional or European funding programmes, through ESCOs, financial intermediaries, etc.

The DTE2V acts, therefore, as a bridge between research and companies, in order to promote their innovation capacities and competitiveness in the market.
The Technology district acts in 4 different technical-scientific areas:

- Introduction of the liquefied natural gas (LNG) as a new energy carrier;
- Increasing the penetration of the electricity carrier;
- Increasing the production of energy from renewables, with focus on geothermal energy, its direct uses and integration with other renewables and energy efficiency measures;
- Interconnection of systems, such as electricity grid, electrical and thermal systems, hydraulic and electrical systems.

At international level, CoSviG and part of its territories, with their long-standing experiences, participated in Geothermal Communities and GeoDH: two projects co-founded by the European Commission and aimed at promoting the use of geothermal heat in district heating and other systems such as heat pumps.

Sustainable exploitation of geothermal resources

Geothermal plants provide a significant contribution to the electricity balance from renewable sources in Tuscany. However, this electricity conversion is not exempt from environmental drawbacks. Thus, there is a need for the development of appropriate technologies to reconcile the geothermal electricity plants with the renewable nature of the energy resource.
Geothermal energy should be considered globally as a renewable resource, the use of which contributes positively to the energy and environmental balance of the countries where it is cultivated.
In Italy, according to a leading history of experience and expertise in using this resource in its various aspects and with the different features it manifests itself, fears and rejection have grown in recent years. Whilst believing that geothermal a renewable and strategic energy source for our Country, can be cultivated in a context of sustainability, the problem of environmental impacts improvement should be addressed. The destiny of geothermal energy cannot be left in the hands of business ventures or local committees. The property of the geothermal resource – a public good – belongs to the territories where it manifests itself. If used well, it can directly and indirectly create a development driver in vast areas of a country. Acceptability problems related to this source of energy - at least the use of high and medium temperature – partly derive from an industrial past, where, although within regulatory constraints, the occupational data was prevalent in relation to environmental issues. The Tuscan Region, where the main

geothermal potential is concentrated, has also moved not to vanquish the great work it has done since the 1990s to ensure a correct and sustainable use of this resource.
In order to not to give up definitively a resource that can be decisive in future energy and environmental balances, alongside the development of technologies that will ensure more efficient use of geothermal energy, strong sharing paths are needed to choose plant locations and in the authorization procedures.

Conclusions

The development model being experimented in Tuscan geothermal areas is based on efforts to foster a sustainable way to develop territories characterised by geothermal energy, and where geothermal energy can be helpful to local communities and at national level. Indeed, a natural resource, if well managed, may represent an important development driver, rather than a source of negative externalities.

This model, built around the industrial use geothermal energy, can be exported to other territories characterized by the exploitation of important locally available resources, in order to generate a source of opportunities for both business actors and local communities, and with the final aim of promoting a development system that meets the criteria of sustainability.

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Archimede's mirrors and the parabolic dish

Archimede Solar Plant and the parabolic dish with micro gas turbine: two milestones of ENEA's research on concentrating solar energy aiming for the future

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by **Tommaso Crescenzi**, **Simona De Iuliis** *and* **Alfredo Fontanella**, *ENEA*

Concentrating solar power (CSP) plants produce electricity just as the conventional power stations, i.e. using high-temperature steam or gas to drive a turbine. However, in the CSP plants, the hot fluid is produced by concentrating the solar radiation instead of burning a fossil fuel.

The CSP technology is also referred to as solar thermal electricity (STE), or even concentrating solar thermal (CST) if the solar heat is used for other applications such as industrial and residential heating and cooling, production of solar fuels, or water desalination.

There are four main types of commercial technologies (Figure 1): parabolic troughs (PT), linear Fresnel (LFR), central receivers towers (CR) and parabolic dishes/engine systems (PD). These technologies differ with respect to optical design, shape of receiver, nature of the transfer fluid and capability to store heat before it is turned into electricity. The first two systems concentrate the solar radiation along a line (the axes of the receiver), about 100 times with temperatures of up to 600 °C, while the other two ones concentrate the solar radiation into a point (the focus) as far as 1000 times, with operating temperatures of more than 1000 °C. The thermal energy is then converted into electric power by means of conventional systems such as steam turbine Rankine cycle.

In 2016, the total worldwide installed capacity reached 5 GW. Around 45% of the operational plants are in Spain, whereas 37% are in the United States. However, over the past three years, the market interest has shifted away from the traditional ones to emerging ones like South Africa, Morocco, Chile, and China due to their high solar resources and political commitment to solar energy.

Most (90%) current plants are based on trough technology, but tower technology is increasing and linear Fresnel installations emerging. Trough technology can be considered "mature" since several manufacturers are available for erecting entire plants or subsystems. There is good experience in engineering procurement and construction and 20-year operating experience allows for good confidence on the operation. Commercial CSP plants in operation are between 5 and 392 MW in size, with efficiency in the range of 14%-

18% and capacity factor from 20% to 50%, depending on technology, configuration and solar resource. By 2020 the efficiency is expected to increase of 2 absolute points.

Parabolic trough systems are suited to a hybrid operation called integrated solar combined cycle (ISCC), where the steam generated by solar is fed into a thermal plant, which also uses fossil-fuel generated steam, generally from natural gas. Examples of operational ISCC CSP plants are 25 MW-Hassi R'mel in Algeria, 20 MW-Al Kuraymat in Egypt, and 20 MW-Ain Beni Mathar in Morocco.

Linear Fresnel systems are based on solar collector rows or loops as the PT technology. However, the parabolic shape is achieved by almost flat linear facets. The radiation is reflected and concentrated onto fixed linear receivers mounted over the mirrors, combined or not with secondary concentrators. Water flows through the receivers and is converted into steam. Since the steam is the working fluid, LFR technology is usually fitted with steam storage system, but molten salt and phase changing material (PCM) storage systems are currently demonstrated at pilot plant scale. LFR technology has lower optical performance compared to other technologies, but this is offset by lower investment and operation and maintenance costs.
Compact LFR technology uses a design with two parallel receivers for each row of reflectors. This configuration minimizes blocking of adjacent reflectors and reduces required land area. Another advantage is that, depending on the position of the sun, the reflectors can be alternated to point at different receivers, thus improving optical efficiency.
Increasing the overall efficiency depends on superheating the steam. Superheated steam at about 380 °C has been demonstrated, and there are proposals for producing steam up to 450-500 °C to enable higher power-cycle efficiency.
There are almost 200 MW plants in operation and around 200 MW under construction. After a first pilot scale application in Australia, a few new pilot plants have been tested in Spain and in the United States. In 2012, the first commercial 30-MW Puerto Errado 2 plant started its operation in Spain. While, in 2014, 125 MW of the total 250-MW Dushar project, were connected to the grid in India; and is by far the largest CSP plant using LFR technology.
In addition to electricity generation, linear Fresnel technology is quite useful for direct thermal applications such as heating/cooling or industrial process heat.

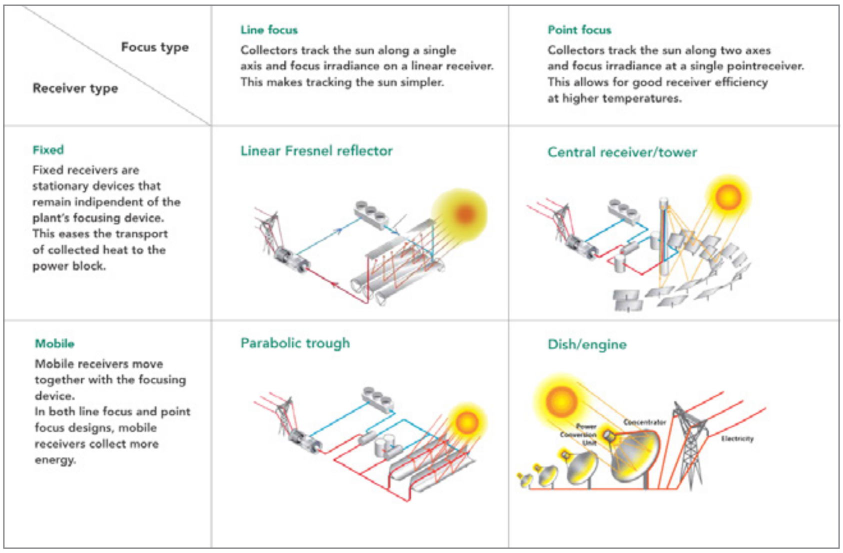


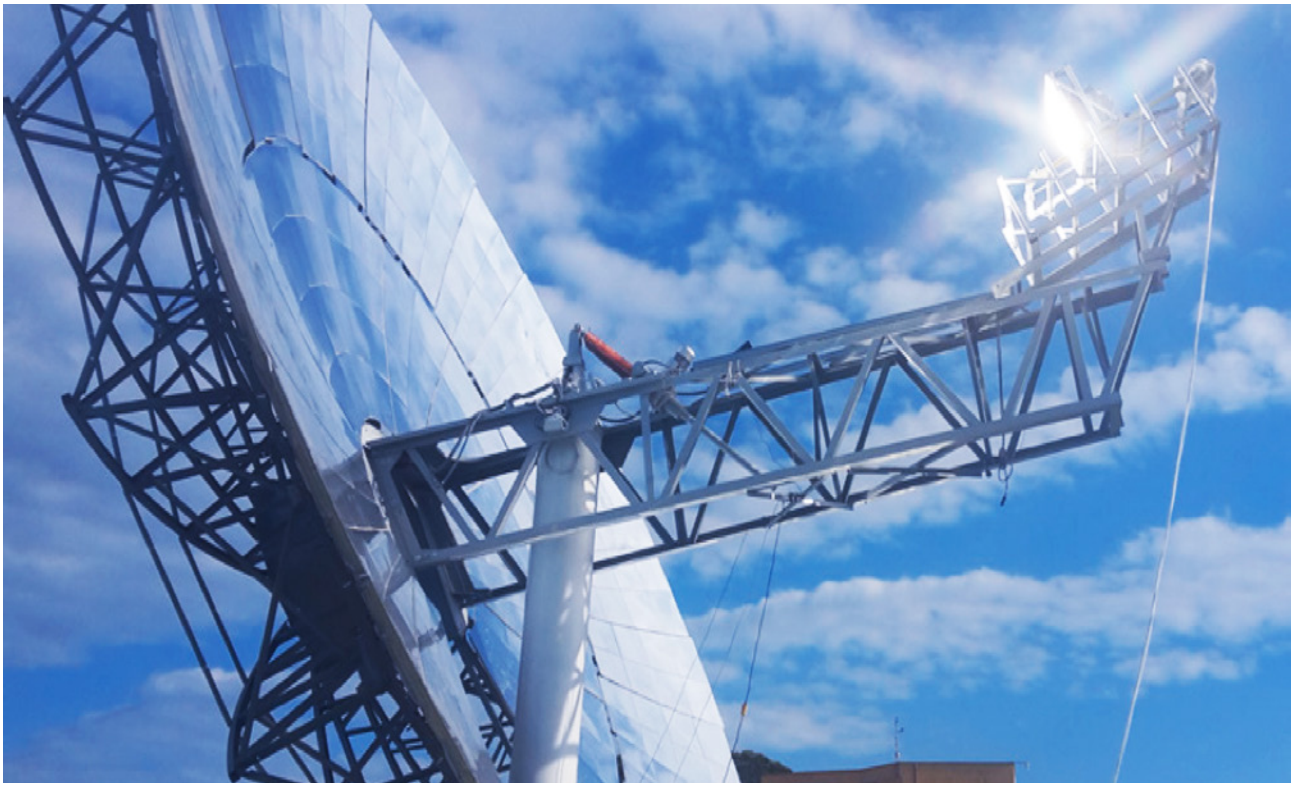
Fig. 1 The main CSP technology families

CR, or *central receivers towers*, or solar power towers, or simply tower systems use a field of distributed mirrors – heliostats – that individually track the sun over two-axis and focus the sunlight onto a receiver mounted on the top of a tower. A heat transfer fluid in this central receiver absorbs the highly-concentrated radiation reflected by the heliostats and converts it into thermal energy that is used to generate superheated steam to drive a conventional turbine.
The temperature level of the primary heat transfer fluid determines the operating conditions (i.e. subcritical, supercritical or ultra-supercritical) of the steam cycle in the conventional part of the power plant. Depending on the primary heat transfer fluid and the receiver design, maximum operating temperatures may range from 250-300 °C (using water-steam) to 390 °C (using synthetic oil) and up to 600 °C (using molten salt). Temperatures above 1000 °C can be obtained using gases, which in turn can be used to directly replace natural gas in a gas turbine. This application makes use of the excellent efficiency (60%) of modern gas and steam combined cycles. Direct steam

generation in the receiver eliminates the need for a heat exchanger between the primary heat transfer fluid and the steam cycle, but makes thermal storage more difficult. Tower plants can be equipped with thermal storage systems whose operating temperatures also depend on the primary heat transfer fluid. Today's best performance is obtained using molten salt at 565 °C for either heat transfer or storage purposes. This enables the use of efficient supercritical steam cycles. In addition, the TES may be less than half the cost of salt TES in commercial trough plants because the larger temperature range across the storage system enables more energy to be stored per mass of salt. The combination of salt density, salt specific heat, and temperature difference between the two tanks allows economic storage capacities of up to 15 hours of turbine operation at full load. Such a plant could run 24 hours per day, 7 days per week in the summer and part-load in the winter to achieve a 70% solar-only annual capacity factor.

Early test plants were built in the 80s and 90s in Spain (Planta Solar 10 and Planta Solar 20) using water as HTF. By far the biggest solar power plant in the world is the Ivanpah Solar Electric Generating System, with a total capacity of 392 MW. It gathers three separate units, each with its own turbine, based on direct steam generation technology, without storage. The first molten-salt power tower is the 20-MW Gemasolar plant in Spain, designed for 15 hours of thermal storage; while the 110-MW Crescent Dunes Solar Energy plant, located in Nevada, is the biggest utility-scale plant to feature advanced molten salt as both heat transfer fluid and heat storage medium. The plant delivers 500 GWh/yr and has a storage capability of 10 hours (2-tank direct molten salt), thus resulting in a capacity factor of 52%.

Dish/engine CSP systems use a collection of reflectors assembled in the shape of a parabolic dish to concentrate sunlight onto a receiver cavity at the focal point of the dish. Within the receiver, the heater head collects this solar energy and runs an engine-driven generator to produce electricity. Like heliostats, all dishes rotate along two axes to track



the sun for optimum capture of solar radiation. The three major types of engines, used at the core of dish/engine technology, are kinematic Stirling engines, free-piston Stirling engines, and Brayton turbine-alternator-based engines. Dishes have also been proposed with air receivers that feed hot air to a steam generator. Both kinematic and free-piston Stirling engines harness the thermodynamic Stirling cycle to convert solar thermal energy into electricity by using a working fluid such as hydrogen or helium. Brayton systems use turbine-alternator engines with compressed hot air to produce electricity. Dish/Stirling systems generate 3–30 kW of electricity, depending on the size of the dish and type of heat engine used. Dish/Brayton systems have been proposed at sizes up to 200 kW.

Dish/engine systems are cooled by closed-loop systems, like an automobile engine; this type of cooling, combined with the lack of a steam cycle, endow these systems with the lowest water use per megawatt-hour among all the CSP technologies.

As a modular technology, dish/engine systems are built to scale to meet the needs of each individual project site, potentially satisfying loads from kilowatts to gigawatts. This scalability makes the dish/engine technology applicable for both distributed and utility-scale generation.

The technology is still under demonstration and investment costs are still high.

Several prototypes have successfully operated over the last ten years with capacities ranging from 10 to 100 kW. Thermal storage systems for dish technology are still under development.

The cost of CSP plants and STE electricity varies significantly depending on the technology, the size of the plant, the thermal storage system, the local labour and land cost, and the level of maturity (i.e. demo, pilot, commercial) of the project. The investment and financing costs account for more than 80% of the electricity cost; once the plant has been paid for, only operating costs, which are currently about 2-3 USD cents/kWh, remain. Investment costs range from 4000 to 9000 USD/kW and large differences exist in per kWh prices worldwide. STE projects in the US have executed PPA prices of 13 USD cents/kWh, while projects in Spain were paid a FiT price of 27 Euro cents/kWh. Estela estimates LCOE in the range of 8-10 Euro cents/kWh by 2025, while the US Department of Energy's SunShot Initiative is much more aggressive: 6 USD cents/kWh by 2020.

The breakdown of the investment costs depends on several factors, including the specific technology under consideration and the presence of thermal storage. Generally the solar field is the most important cost element followed by the thermal storage and the power block.

Innovations

The first commercial CSP project called SEGS (Solar Electric Generating Systems) was carried out in the 1980s in California, based on a synthetic oil as heat transfer fluid and without thermal storage system.

Since the 2000s several innovations are modifying CSP technology. The research and development effort aims at increasing economic viability by reducing investment and operating costs and increasing productivity by improving plant efficiency. Better performances can be achieved with higher temperatures for working fluids, scale factors, new materials, more efficient manufacturing processes and assembly activities on site.

The thermal energy storage improves the operational efficiency balancing short-term variations of the electric load or sudden cloud covers and mostly increases the dispatchability of the produced electric power and enhances the electric network stability.

The optimal size of storage depends on the role the plants supposed to play. Very large storage involves greater annual energy production and lower cost of energy (LCOE), but more investment cost because of the larger solar field and the storage system. The efficiency of the storage medium be very high: up to 98%.

We can distinguish three categories of storage systems that can be used in solar thermal power plants, but each category is at a different stage of maturity: Sensible heat storage systems, Latent heat storage systems, and Thermochemical storage systems.

Sensible heat storage systems are used in most state-of-the-art solar thermal power plants with "two-tank indirect molten salt storage" (two tanks with molten salts at different temperature levels). The development of new storage media with improved thermal stability will allow higher temperatures to be attained. Higher temperatures enable increased energy density to be achieved within the TES and lower the specific investment costs for the system. Improvements to TES systems would have the potential to reduce the investment cost and to improve efficiency.

Latent heat storage has not been implemented in commercial solar thermal power plants yet, but there are several research activities ongo-

ing to support the introduction and use of phase changing materials in TES technologies. The use of latent heat storage offers new possibilities for direct steam generation helping to achieve cost competitiveness with sensible heat technologies.
Since 2010, thermal storage has been used in 40% of Spanish plants, providing an average of five to ten hours storage, depending on the DNI.


Fig. 2 Test facility at the ENEA Casaccia Research Centre

ENEA's contribution

Since 2001, the Italian Agency ENEA developed an innovative CSP technology using parabolic trough collectors based on molten salt mixture as heat transfer fluid and heat storage media. Compared to diathermic oil, this innovation results in a higher thermodynamic conversion efficiency, elimination of the heat exchanger between the solar field and the thermal storage system, and lower storage tanks volume.
The use of molten salt as heat transfer fluid required a series of technological developments of key plant components, such as collectors, receivers and thermal storage systems. These innovative components have been developed and patented by ENEA, after being tested under operating conditions at the ENEA PCS (Prova Collettori Solari – solar collector testing) facility (Figure 2).
Of strategical importance, in the effort of innovation undertaken by ENEA, are the receiver tubes able to work at 550 °C thanks to a special coating developed to maximize the absorption of solar energy and minimize the heat losses by radiation. The latter are produced, using ENEA licenses, by the Archimede Solar Energy (ASE), a subsidiary of Angelantoni Industry Group.
The first industrial plant powered by the ENEA technology has been built by Enel in Sicily (Priolo Gargallo - Syracuse) – within the national Archimede Project – and is currently in the operational phase.
Thanks to its expertise, ENEA is the national reference centre for the concentrated solar thermal technology. The Agency has the ownership of several patents and exclusive competences, and collaborates with several companies within several national and international initiatives. Indeed, Italy has taken a leading role in the field of molten salt parabolic trough technology, industrial firms and research centres have created a fully integrated supply chain in the concentrated solar thermal technologies.
The main research areas where ENEA is presently involved are heat transfer fluids, innovative plant components, small- and medium-scale systems, thermal storage, new generation towers, parabolic dishes.
ENEA is studying novel salt mixtures and gas (CO_2) as heat thermal fluid, innovative collectors and tube receivers, Fresnel systems based on oil or salts as heat transfer fluid coupled with organic Rankine cycle (ORC) to produce electricity and heat, thermal storage systems based on solid (modified concrete) or phase changing materials, use of molten metals as very high temperature heat transfer and storage fluids and parabolic dishes combined with micro gas turbines. ENEA is also carrying out the development of a thermal storage system based on one thermocline tank with steam generator integrated inside the tank.
Relating to parabolic dishes, ENEA is carrying out the project OMSOP, funded by the European Commission, at Casaccia Research Centre, with the aim to develop and demonstrate technical solutions for the integration of the dish technology with the micro gas turbines to produce electricity from solar source in a small scale capacity range (5-30 kW_e). The test facility is based on a 12 m diameter parabolic dish concentrator, with 90 m^2 reflecting surface and a 5 kW electric micro gas turbines. Figure 3 shows the concentrator and the frame to support the micro gas turbine to be installed.

Next developments

As a consequence of wide efforts in research and demonstration, recently CSP technology has become more attractive to investors, presently through public incentives, but in a middle-long term perspective, also in free market condition. The IEA Solar Thermal Electricity Roadmap (2014 edition) suggests that by 2020 CSP deployment is expected to be sustained by policy incentives and emissions trading. From 2020 to 2030, CSP could become competitive with conventional base-load power due to cost reductions and the increasing prices of CO_2 and fossil fuels. Incentives to CSP will gradually disappear, and high voltage direct current (HVDC) transmission lines will reach a global extension of some 3000 km. The global installed capacity would reach 261 GW, by 2030 and 982 GW by 2050, providing about 11% the global electricity with an average capacity factor of 50%. The United States, Africa, China, India and the Middle East would be the largest producers and exporters, while Europe would be the largest importer from the Middle East-North Africa Region via HVDC transmission lines. In the long term, low-cost CSP electricity would compensate for the additional costs of electricity transmission.

For the next future, the CSP lines of development differ between large and small-medium facilities. The first ones, mainly power generating systems, would archive better performance increasing the solar energy caption and absorption efficiency, rising the operating temperature, using new thermal carrying fluids and improving the component reliability to reduce operating cost. The medium-small facilities, mainly multi-generating systems, would achieve a reduction of component costs through improvements of manufacturing processes, products standardization and utilization of new cheaper materials.

Another important CSP application area is the "solar chemistry" that mostly includes the production of solar fuels. A solar fuel is any chemical compound that can be reacted with oxygen to release energy, which has first been formed in part or in full by input of energy from solar radiation. There are a range of approaches for achieving this solar-to-chemical energy transformation. However, this case is primarily concerned with technologies that use concentrated solar radiation to store solar energy in a chemical form as a fuel via high temperature thermochemical reactions. Examples are conventional liquid hydrocarbons, alcohols and hydrogen, which can be oxidized by combustion to drive a heat cycle or to power an electric motor in a fuel cell.

Solar hybrid fuels combine solar energy with a carbonaceous fuel, such as natural gas or coal, to form a product that embodies both renewable and fossil energy. This is done by using concentrated, high temperature solar energy to provide the heat to drive endothermic chemical reactions that convert the fossil fuel into intermediate and final products, such as liquid transport fuels. In the longer term, however, there will be a need to develop technologies based on processes that are completely independent of any fossil fuel resources . In this context, the use of metal oxide redox cycles for water and carbon dioxide splitting is one promising route based on developments to date and the current scale of R&D devoted to this option. In fact, much attention is focused on the solar production of hydrogen and carbon monoxide, which form a synthesis gas (syngas) that can be further processed to liquid fuels such as methanol, diesel, and jet fuel.

Although hydrogen is a potentially clean alternative to fossil fuels – es-

Fig. 3 Parabolic dish receiver at the ENEA Casaccia Research Centre

pecially for transport uses – currently more than 90% of hydrogen is produced using process heat from fossil fuels, mainly natural gas. Generating hydrogen merely from water and solar energy would result in a completely clean fuel with no hazardous wastes or climate-changing by-products. This is the vision outlined in the European Commission's 'European hydrogen and fuel cell roadmap', which runs to 2050.

Another focus presently lies on the conversion of carbon dioxide into sustainable hydrocarbons. Like the thermochemical splitting of water into hydrogen and oxygen, carbon dioxide can be split into carbon monoxide and oxygen. Synthesis gas generated in this way can be further processed via conventional processes – e.g. Fischer-Tropsch synthesis – to liquid fuels, which will be indispensable for the following decades, especially for applications like air transportation.

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STEM® (Solar Thermo Electric Magaldi): The first industrial module in operation in Sicily

On June 30, 2016, the first STEM® (Solar Thermo Electric Magaldi) industrial model plant started operations in San Filippo del Mela (Sicily). This Concentrating Solar Power system with Thermal Energy Storage represents a "disruptive" technology because it's able to collect solar energy – through a solar field made of heliostats – and convert it into thermal energy to be stored and extracted when desired. Installed in the Integrated Energy Pole of the A2A Group – the largest Italian multi-utility in the energy sector – this plant is the first one worldwide using sand as Thermal Energy Storage

DOI 10.12910/EAI2017-033

by **Letizia Magaldi**, *Magaldi Group*

On June 30, 2016, the first STEM® (Solar Thermo Electric Magaldi) market size, first of a kind, model plant was in operation in San Filippo del Mela (Sicily).

Installed in the Integrated Energy Pole of the A2A Group – the largest Italian multi-utility in the energy sector – this disruptive CSP (Concentrating Solar Power) technology is one of a kind worldwide using fluidized bed sand as Thermal Energy Storage.

Nowadays various tests are being performed with very positive results.

STEM® technology has been developed and patented by Magaldi Group in cooperation with Prof. Piero Salatino of Federico II University of Naples and a prestigious institute of the National Research Council headed by Riccardo Chirone.

Founded in 1895, Magaldi Group is a world's leading specialist in dependable and environmentally-friendly high temperature material handling systems, pioneering solutions for demanding problems in solid-fuel Power Plants, Metallurgical & Mining companies, Waste to Energy plants.

Over the years, Magaldi has developed a broad range of patented technologies capable of ensuring such benefits as high dependability, longer service life, negligible maintenance, water and energy savings, like in the case of STEM® technology.

This new CSP system with TES (Thermal Energy Storage) is able to collect solar energy – through a heliostat solar field – and convert it into thermal energy to be stored and extracted whenever needed.

STEM® is based on modular steam generator units (SGU) for power production and thermal energy storage. Several modules can be combined together to produce the superheated steam flow rate (at around 500 °C), to be used to generate electricity or as process heat.
Solar radiation captured by heliostats field is concentrated on a secondary reflector (beam down) and subsequently focused into a receiver, positioned at ground level. The receiver is based on a fluidized bed technology: 270 tons of fluidized sand, at an operating temperature of 550-650 °C, are used to effectively transfer and store the solar thermal energy. Up to 8.2 MWh thermal energy can be stored per module, thus allowing the release of the required energy at night, or in the absence of sun radiation. Different configurations of STEM® can be applied, according to the Customer's need.
STEM® is an ideal system to be combined with existing or dedicated PV plants to grant continuity of green power production during night time. During the day, electric power could also be directly produced from sunlight with the PV plant, which also feeds the STEM® auxiliaries, allowing solar energy to be effectively stored in the fluidized bed receiver.
The fluidized bed receiver, in this way, works as TES of solar power, that can be used during the night for steam or power generation.
STEM® uses and applications may be many and different, making it an ideal solution for tomorrow's distributed energy needs, Distributed Energy Resources (DER) and Distributed Energy Storage Systems (DESS), being able to provide the user with thermal energy and steam when needed, for civil (energy, heat generation and storage), agricultural (steam, clean water through desalinization) and industrial uses such as: EOR (Enhanced Oil Recovery) – Refining for Hydrocarbon industry, Mining etc.
STEM® can be used to immediately provide thermal power generated energy to fringe and off the grid communities, to satisfy their needs, without depending on costly and large distribution lines and networks. It can therefore represent a quick solution to foster local development in rural communities or areas not reached by the grid like most

of Africa, thus providing relief to local people suffering lack of access to clean water and energy, helping to prevent them from forcedly leaving their homes..

Finally, whatever STEM® is applied to, it is an efficient way to reduce carbon footprint and a sure path to a cleaner world.

Moreover, the absolute lack of poisonous emissions into the environment (both in case of normal operation and failures) as well as the non-use of cooling water and any chemicals, makes STEM® technology the best way to produce and store green energy in remote zones.

Even from the standpoint of the landscape, STEM® confirms its commitment to the environment. In fact, compared to traditional Power Tower systems, STEM® does not have a huge visual impact since its highest structure does not exceed 22 m height whereas other CSP tower systems reach over 100 m.

STEM® key strengths:

- *Dependability*: The simple operational process and the modular configuration give STEM® a competitive advantage over other CSP technologies. Even if one module is under maintenance, the other modules guarantee continuity to the production of steam.
- *Flexibility*: Fluidized bed technology using sand as storage medium and the possibility to connect the modules in parallel or in series enable the system to generate electricity according to the load demand.
- *Modularity*: The base modules can be combined together to meet

the required power demand. It is possible to add modules at a later stage, in case demand increases.

- *Hybridization*: STEM® technology can be integrated with both renewable and fossil fuel plants, to guarantee a continuous operation, day and night, year-round. The receiver is designed to also allow the combustion of low heating value fuels, such as biogas.
- *Cogeneration*: High temperature steam generated can be used for district heating and cooling, water desalinization, greenhouses.
- *Environmental friendliness:* STEM® technology only uses absolute eco-friendly materials, such as glass for heliostats, steel for structures and sand for thermal storage so that, even in case of decommissioning or at the end of its working life, all materials are completely recyclable.
- *Long service life*: STEM® system is almost static and it is designed to be operational for decades. Batteries, on the other hand, need to be replaced after a certain number of cycles.
- *Ideal solution for remote areas*: STEM® operates locally on demand without the need to build large power plants nor expensive distribution grids.

For further information,
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The ENEA solar compass: How to catch more Sun by using the Sun

The ENEA solar compass is 100 times more precise than magnetic compasses. It is an innovative, useful and cost-effective tool in several fields: concentrating solar power plants, environmental survey, civil engineering, radar installation, accurate measurements of the magnetic declination, remote control of robot navigation, primary standard for calibration of other compasses, reference compass for transportation means, easy installation of domestic solar devices, and educational tool

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by **Francesco Flora***, *ENEA*

Mankind has used the Sun for time indication and orienteering since prehistory. Even many animals are able to find the right orientation from the Sun taking into account the time of the day by using their internal clock. Over the last two centuries, rather complex instruments have been developed to improve the accuracy of the orientation measurement by means of the Sun like, for example, Burt's solar compass [1]. Such instruments, whose accuracy is definitely higher than that of magnetic compasses, have the advantage of giving the true, rather than the magnetic, North direction; also, they are insensitive to magnetic perturbations and exploitable everywhere in the world (even close to the Poles).
Indeed, any portable sundial becomes a solar compass if used in reverse mode: if we already have a precise clock, we can turn the sundial until the time indicated by the Sun coincides with the clock (if the sundial indicates only the local true solar time, the clock time must be corrected by the equation of time, i.e. by the difference between solar time

* Co-authors: Sarah Bollanti, Domenico De Meis, Paolo Di Lazzaro, Antonio Fastelli, Gian Piero Gallerano, Luca Mezi, Daniele Murra, Amalia Torre, Davide Vicca

Fig. 1 Reconstruction of an old solar compass

and mean time). Then, the meridian line of the sundial (i.e., the line indicating twelve o'clock) will lie along the true North-South direction with a much better accuracy than that of magnetic compasses.
A typical portable sundial used as solar compass for navigation in the XVI century, according to a modern reconstruction, is shown in Fig. 1.

The ENEA solar compass

This old instrument has recently come back to use, since modern technologies allow to make it compact and automatic; about one patent per year has been released in the world as modern solar compass in recent years. Among them, the patent relative to the compass developed at ENEA released in 2014 [2]; this is shown in Fig. 2 mounted on a commercial theodolite.
The ENEA electronic solar compass is composed of an electro-optic sensor that detects the position of the Sun, a GPS device that provides the Greenwich time and the geographic coordinates of the compass, an optical pointer, a goniometer for measuring angles and a microprocessor, which elaborates data and provides the angle of observation with respect to the true North in real time. An innovative algorithm based on Kepler's laws allows to determine the Sun ephemeris and the North-South direction by knowing the local time and its geographic coordinates.
This compass is inspired to the sundials in churches, where the exploitation of the camera-obscura effect allows to reach the best accuracy achievable by a sundial (few seconds): in churches sundials, a small hole on the roof generates the 2D image of the Sun on the floor, as it happens, for instance, in the church of Santa Maria degli Angeli in Rome; in the ENEA compass, the hole is replaced by a very thin slit (Fig. 3a) while the floor is replaced by a small CMOS image detector, where the 1D Sun image is collected (Fig. 3b).
The main advantages of the ENEA compass, compared to others, are its very good accuracy and reliability, low cost, small size and weight, short measurement time (few seconds), easy operation and its applicability everywhere in the world, since it does not depend on the Earth's magnetic field.
The position on the CMOS of the vertical bright line shown in Fig. 3b (the 1D image of the Sun) gives the orientation of the compass with respect to the Sun.
At the same time, a GPS provides both local geographic coordinates and accurate time setting to the microprocessor, which calculates the Sun's azimuth angle[3]. The sum of this angle and that between the compass and the Sun directly gives the azimuth angle of the compass.
The ENEA electronic solar compass is compact, completely automatic, cheap, and reaches an accuracy better than 1 arcmin [4]. The latter is one of the best currently available values, comparable to those achievable by means of much more expensive and sophisticated devices, like coupled GPS systems (see for ex-

Fig. 2 The ENEA electronic solar compass mounted on a theodolite

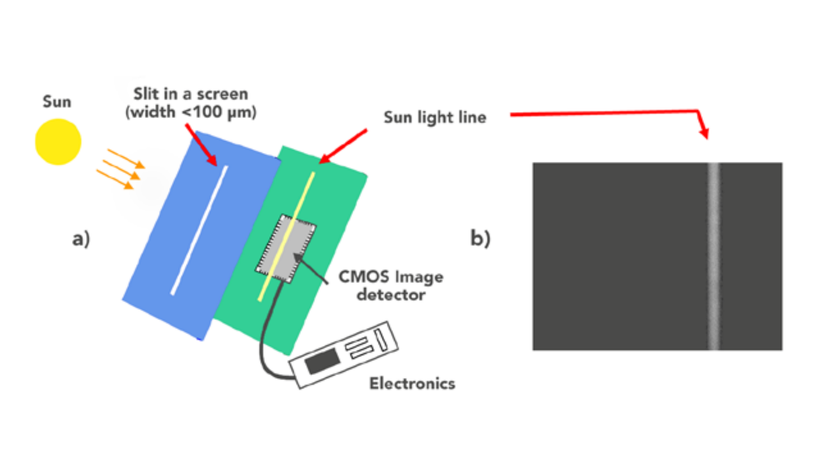

Fig. 3 Schematic of the Sun detector of the ENEA compass (a): the bright line projected on the CMOS detector is a 1D image of the Sun (b)

ample U.S. patent 5,617,317A, 1997) or gyrocompasses. Furthermore, the ENEA compass provides the orientation in a few seconds, a time extremely shorter than that necessary for gyrocompasses.
Even when the Sun is partially obscured (for example by clouds or trees) still the compass is significantly more precise than magnetic ones, as demonstrated in [5] with measurements during a solar eclipse.

Applications of the solar compass

The domains of application of the ENEA compass are concentrating solar power (CSP) installation and alignment, environmental survey (by applying the compass to survey instruments like theodolites, total stations or laser scanners), accurate measurements of orientation at low cost during the construction of buildings and roads, directional control for radar installation, accurate measurements of the magnetic declination, directional controls for tunnel construction, remote control of robot navigation (not only on the Earth, but also on all the planets of the solar system[6]), use as primary standard for calibration of other compasses, reference compass for transportation means like boats, airplanes, etc., cultural dissemination and easy installation of domestic CSP devices for smart cities and community energy network, educational tool in schools.
As far as the "solar power installation and alignment" is concerned, we should consider that, in line with the actual state of the art, most of the thermodynamic solar power plants based on CSP have a central control unit, where a single computer drives the orientation motion of all the mirrors of the installation. For example, in a thermodynamic solar installation based on linear concentration by parabolic trough mirrors, the rotation axes of all the mirrors must be parallel to each other and oriented, for instance, along the South-North direction with an accuracy better than 0.1°. If any of them is not correctly installed, its efficiency will be well below that expected by the original design.
The solar compass can get rid of such inconvenient: each mirror can be driven by a solar compass mounted on the top of one of the towers which hold the mirror itself . Each compass can then perform two functions: periodic measurements of the orientation of the single mirror rotation axis, and consequent optimized guiding of the mirror to orient it correctly towards the Sun. In this way the central unit is avoided, the parabolic mirrors do not need to be rigorously parallel to each other and the single mirror movement is completely independent of the others. The whole solar plant efficiency is increased: **"more Sun" is captured**.
At the present moment, ENEA is cooperating with the Italian enterprise "D.D. Costruzioni Meccaniche Srl" for the development and test of a Sun compass specifically designed for this application, as shown in Fig. 4. The assembling of the compass is already completed; it will be tested on the ENEA-Casaccia CSP test-bed installation by next summer 2017.
The apparatus shown in Fig. 4 is the latest prototype compass version; it is fully automatic, all-in-one design (sun sensor and electronics are in the same box), controlled through an Ethernet cable and by a touch-

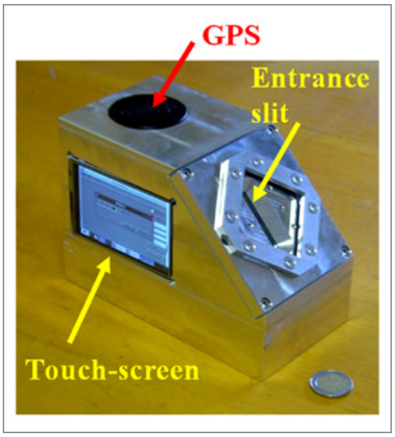

Fig. 4 The solar compass designed for parabolic trough mirror driving

screen, with an internal rechargeable battery.
In other cases, like for the more recent CSP installations based on Dish mirrors, the ENEA solar compass can, day by day, automatically determine all the mechanical defects of the mirror mechanics (misalignment of the two rotation axes, non-verticality of the azimuthal axis, etc.) and can compensate for such defects while driving the mirror motors.
Concerning the application to survey instruments, preliminary contacts with the Italian Institute for Geophysics (INGV) are now in progress regarding geo-magnetism measurements.
At present, the compass team is working for an extension to the GHz range of the acceptance spectrum, in order to make the compass working even during cloudy days.

Benefit for developing Countries and education of young generation

The solar compass is one of the results of ENEA's integrated approach to the development of innovative technologies for power generation and use of renewable energy. It has many domains of application and can be very useful especially in developing Countries, since alternative accurate orientation instruments, like total stations, are much more expensive and need reference targets (having well-known geographical coordinates) that in such Countries might be absent.
It has also been conceived as an educational tool for the young generation and at school.
The algorithm of the solar compass is so manageable that it could be downloaded as an "App" in any smartphone and even any child could learn how to make a solar compass by himself and play with it.
The App for smart-phones can be designed to evaluate the Sun position and the azimuth of the smart-phone with a precision better than that of magnetic compasses.
Most young people not only do not know what is the Sun orientation (the so called Sun azimuth angle) at different hours of the day, but they are not even sure if the Sun rises at East or West direction. The solar compass could help to learn more about the Sun, exploiting its possible uses and benefits for mankind.

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Divertor Test Tokamak: An Italian proposal to pave the path to Nuclear Fusion resource

Nuclear Fusion, once realized, would have the advantages to ensure sustainability and security of supply, no production of greenhouse gases, intrinsic safety; environmentally responsible. Italy plays an acknowledged role in international nuclear fusion research, strengthened in the years thanks to educational and training actions of universities and research institutions as well as to a fruitful involvement of the national industries. The proposal for the realization of a Divertor Tokamak Test Facility in Italy has been brought forward backed by the Italian Fusion scientific and technological community in the field of EU Fusion Program

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by **Flavio Crisanti**, **Lori Gabellieri** *and* **Angelo Antonio Tuccillo**, *ENEA*

Energy demand is expected to more than double by 2050 as the combined effect of the increases of population and energy consumption per capita in developing countries. Energy sources that can prove their long-term sustainability and security of supply must replace fossil fuels. The solution to the energy problem can only come by a portfolio of options that includes improvements in energy efficiency and renewable energy, nuclear fission and carbon capture and sequestration. The alternative of Nuclear Fusion, once realized, would have the advantages to ensure sustainability and security of supply (fuels are widely available and virtually unlimited), no production of greenhouse gases, intrinsic safety (as no chain-reaction is possible); environmentally responsible: no generation of radioactive waste and – with a proper choice of materials for the reaction chamber – the produced radioactivity would decay in a few tens of years. With the strong impulse given by an energy policy driven by the reduction of CO_2 emissions, fusion could realize its first demonstrative plant (DEMO) in the second half of this century and give a strong contribution for the base power load towards the beginning of the new century.
Nuclear fusion is the process that powers the sun and the stars, making life on Earth possible. It is named "fusion" because the energy is produced by combining light nuclei, such as hydrogen isotopes, at extremely high temperatures. In this process part of the mass of the reactants is converted into kinetic energy of the reaction products (helium and a neutron for the hydrogen isotopes deuterium-tritium reaction), which in turn can be used to produce electric energy in a standard steam turbine cycle.

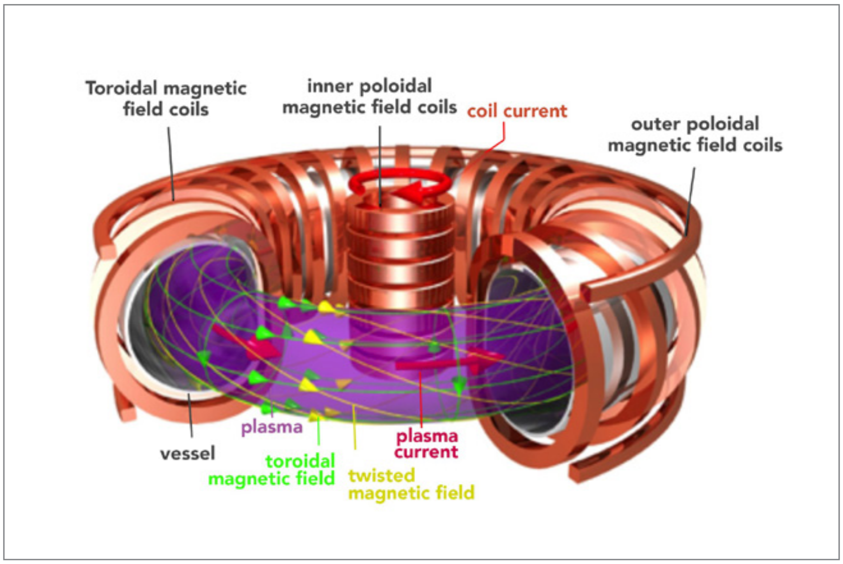
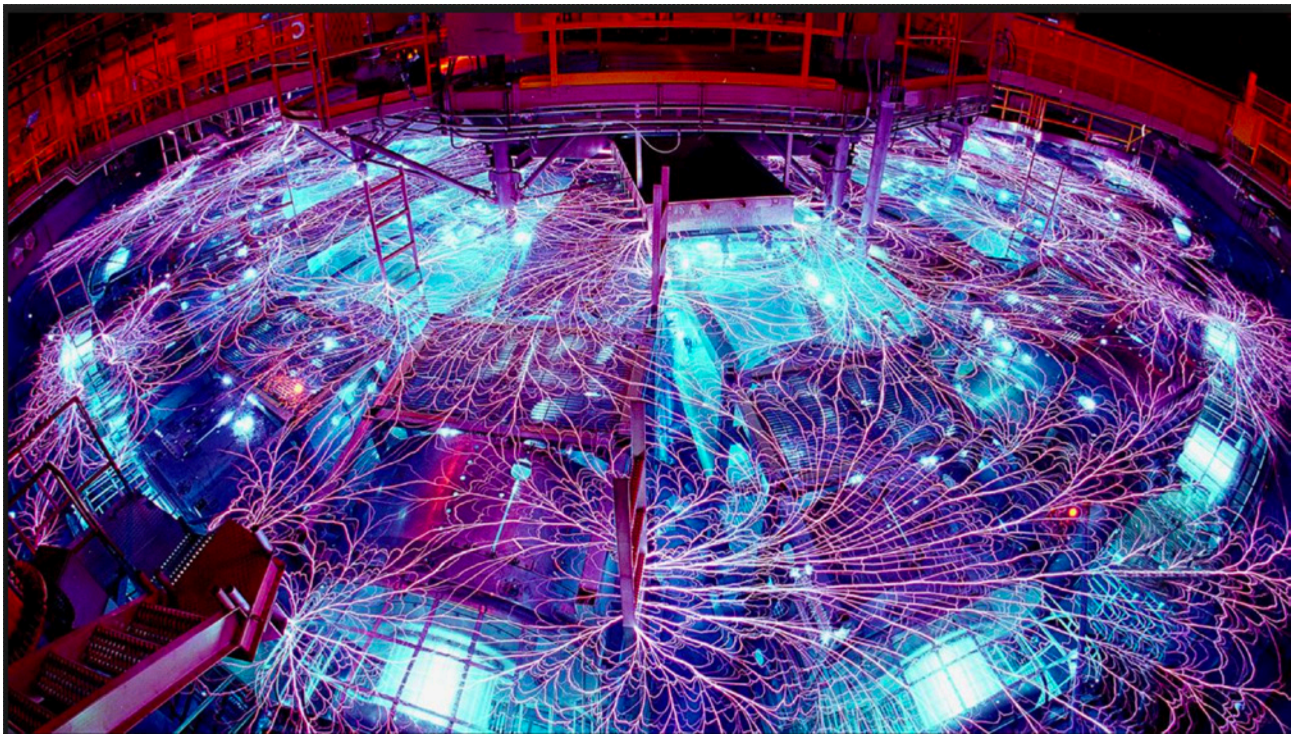


Fig. 1 Schematic view of magnetic confinement in a Tokamak

At the extremely high temperature needed to achieve fusion on Earth, the fuel is in the plasma state, a particular gas where its components are ionized, i.e. composed by ions and electrons. In the magnetic confinement approach (alternative to the inertial one where fusion takes place before fuel can expand and touch the walls) the fusion fuel is kept "detached" from the wall of the reactor device, among which the "Tokamak" configuration [1.1] has achieved the best performance (Figure 1).
At the edge of the plasma a thin (few centimeters) region of open field lines is created (the SOL) through which charged particles and heat flowing out of the plasma core are guided into the so-called divertor, where the plasma impinges on material surfaces (the divertor target plates). This divertor region is the place where the largest part of the power contained in the vacuum vessel must be exhausted. Since the heat flux flowing along the magnetic field lines in the SOL region of a reactor is expected to be even higher than that on the sun's surface, the *"power exhaust"* problem is definitely one of the most challenging in view of the fusion power achievement.
The EU Fusion Program coordinates the activity of 29 countries, with a common vision, highlighted in a "Roadmap" [1.2] aiming at the generation of electrical power with a Demonstration Fusion Power Plant (DEMO) by 2050. In its path, EU roadmap foresees two important milestones:

- ITER [1.3], the international tokamak experiment presently under construction in the south of France (Cadarache), see Figure 2, which should solve the remaining open physics issues before moving to the realization of the above mentioned DEMO,
- an R&D activity, articulated in 8 Missions, to tackle the main challenges in achieving Fusion reactor accomplishment goal.

In particular a dedicated Mission (M.2) has been devoted to the pow-



er exhaust issue, identified as a potential show-stopper on the fusion roadmap. Part of the terms of reference for the Divertor Test Tokamak (DTT) Project are articulated within Roadmap Mission 2: "Heat-exhaust systems".
An important constraint in the design of the DTT facility is the necessity to operate in a plasma physics regime as close as possible to a reactor one; this fact is realizable by operating with edge and bulk parameters [31.4] adequately scaled to reproduce as close as possible ITER/DEMO like conditions.

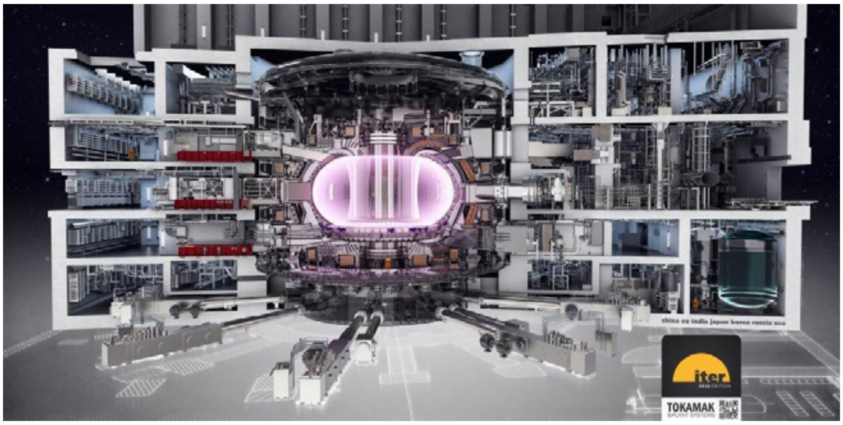


Fig. 2 Artistic view of ITER, under construction at Cadarache in the South of France

Italy plays an acknowledged role in international nuclear fusion research, strengthened in the years thanks to educational and training actions of universities and research institutions as well as to a fruitful involvement of the national industries, paying attention to innovation and giving rise to a virtuous circle that enriches the country. Italian fusion research is carried out under the aegis of MISE (Ministero dello Sviluppo Economico - Ministry of Economic Development) and MIUR (Ministero dell'Istruzione, Università e Ricerca - Ministry of Education, University and Research) in several laboratories: ENEA in Frascati, Consorzio RFX in Padua, Istituto di Fisica del Plasma del CNR in Milan, Consorzio CREATE in Naples – which coordinates the activities of several universities in Southern Italy – INFN with its labs in Legnaro, together with the important contributions of a number of other Italian universities ranging from Politecnico of Torino and Milano to University of Padua down to Catania and Cagliari passing from the three universities of Rome. These groups have been working together for years under the umbrella of EURATOM-ENEA Association in the framework of EFDA (European Fusion Development Agreement), and from 2014 of the EUROfusion Consortium agreement.

There are significant results achieved at the Italian labs. In Frascati, FTU held the world record of the fusion performance parameter (triple product) for years and now is a leader in the study of new first wall materials: Liquid Metals. FTU is indeed operating in presence of liquid Lithium and Tin. In Padua RFX-mod owns the unique capability to explore the Reversed Field Pinch configuration at plasma currents up to 2MA and it is equipped with a sophisticated magnetic feedback system. Italian researchers also gave a significant contribution to the design and operation of JET and are significantly contributing to the design and construction of ITER. Italy is also building in Padua the facility for full-scale testing of ITER Neutral Beam Injectors. Italian researchers, meanwhile, play a key role in the fusion roadmap, leading several Work Packages in the Horizon 2020 Workprogramme. Eventually, along the years a strong cooperation/integration has been realized and consolidated between the research system and the Italian national industry. This cooperation has allowed the national industry to play a major role in the realization of the international experiment ITER [1.3]. *So far, about 1 billion of procurement contracts have been awarded to the Italian industries for a fraction of about 56%, against an Italian contribution to the project lower than 10%.* But the most important point to be underlined is that, in several cases, this participation has allowed our industries to further improve their high level technological skills and develop new ones that have been reused out of fusion to conquer important market sectors, even during the recent, very serious, economic crisis time.

Taking into account the Italian role in nuclear fusion research, the proposal for the realization of a DTT facility in Italy has been brought forward backed by the Italian Fusion scientific and technological community. This community boasts a broad expertise covering all field involved in Fusion, from Plasma Theory to Plasma Engineering, from Nuclear Engineering to Remote Handling, from Superconductor to High Power Heating Systems and Power Supply.

The DTT proposal is among the projects submitted to Juncker's plan (EFSI: European Fund for Strategic Investments) with a budget of 500 million Euro.

The "Construction of a Divertor Tokamak Test Facility for fusion energy research", DTT proposal, is in the list "Knowledge, SMEs and the digital economy" presented by ENEA and Italian Ministry of Economic Development.

In March 2015 the EUROfusion General Assembly welcomed the opportunity of gaining additional resources for the DTT, suggesting that the conceptual activities, the definition of the objectives and the design

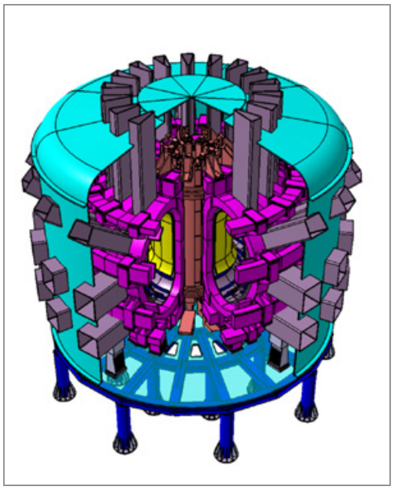


Fig. 3 Sectional view of DTT tokamak basic machine

were carried out in a truly European framework with Work Packages DTT1 and DTT2.

Recently (April 2017) the Industry Commission of the Italian Parliament has approved a motion committing the Government to fund the project.

An internationalization workshop meeting of the proposal is being called by EUROfusion and is in advanced phase of preparation to be held in Frascati June 19-20, 2017.

The present DTT proposal [41.5] has been elaborated by an International European Team of experts. Its contents has been independently revised and recommended by Chinese experts. This joint work demonstrates the possibility to set up a facility able to bridge the power handling gaps between the present day devices, ITER and DEMO. Letters of interest have been sent by the Responsible of Fusion Programme of the China Academy of Science and by the Corean President of the National Fusion Research Institute declaring they willingness to participate to the Italian DTT proposal considering in

kind contributions.
DTT machine has been designed with a major plasma radius of 2.15 m to compromise wit budget constrain, but still guaranteeing the necessary flexibility in the divertor region to allow testing different magnetic topologies and different divertor geometries and/or materials (including liquid metals). The relatively high toroidal field (B_T=6T) will give the possibility to achieve plasma parameters not far from the DEMO ones,. The plasma parameters achievable in such a machine satisfy the expected design goal and have been benchmarked in several ways, by using the knowledge provided by the present ongoing experiments and, of course, verified with the more sophisticated modelling tools available, where all the main physics aspects are included.

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Bioenergy, biorefineries and green chemistry: ENEA projects to advance a more sustainable economy

With the widespread use of biomass for energy purposes, Italy is one of the leading countries engaged to exploit this potential renewable source for the production of bio-based products including chemicals, polymers, materials, feed and bioenergy, pursuing a cascading approach (biorefinery).
It is true that substantial breakthrough have been achieved but the fact remains that R&D efforts are still necessary to address both technological and non-technological barriers. Development and demonstration of qualified innovative processes, technologies and components for the generation of both electric and thermal power in small-sized plants and the production of second-generation biofuels and sustainable biobased products, are the main challenges that needs to be addressed. In the above context, ENEA, in cooperation with both national and international stakeholders, has a number of R&D activities and a strategic projects portfolio. The focal point of ENEA's activities as well as brief description of some prototype technologies, are described in the present communication

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by **Giacobbe Braccio**, **Giacinto Cornacchia**, **Isabella De Bari and Vito Pignatelli**, *ENEA*

Biogas production from waste materials is one of the main research topics. Initiatives underway are aimed at the production and upgrade of biogas for electric power generation or for the grid. Innovative technologies are tested for the energetic valorisation of the digestate.
R&TD on second-generation biofuels is focused on both thermochemical and biochemical conversion processes of lignocellulosic materials. More precisely, fermentation of carbohydrates into bioethanol, production of hydrogen through fermentation of humid biomass and biofuels from microalgae cultures are some of the main activities. An important research infrastructure is available at ENEA Trisaia Research Centre for the biomass gasification to carbon monoxide and hydrogen, which represents a versatile platform for the production of energy and liquid biofuels, for instance, through the Fischer-Tropsch process.
Production of second-generation bioethanol to be used in the transport sector using a number of feedstocks, namely agroforestry biomass, poliannual and grass biomass crops, has been the focus in a number of R&D programmes. The process comprises the biomass pretreatment, the enzymatic hydrolysis, and fermentation, and finally the alcohol separation. Biomass pre-treatment is carried out with saturated steam at moderate temperatures (200 °C, approximately) enabling a deep biomass destructuration which facilitates the separation of its main components (cellulose, hemicellulose, lignin).
R&TD activities on microalgae and other photosynthetic micro-organisms for the production of energy and non-energy products through bench scale optimization and final testing of pilot plants.
Also, the ENEA laboratories include a Genomics and Proteomics platform supporting the discovery of novel genes involved in the biological biomass degradation and in the biosynthesis of value-added molecules.

Technologies and Processes for Biorefinery and Green Chemistry

A number of initiatives are underway in Europe to promote the development of a bio-based economy. Increasing the share of advanced biofuels in the transport sector and finding new bio-based products derived from renewable natural resources are only some of them.
As an example, a number of chemicals and advanced biofuels can be produced from sugars derived from lignocellulosic biomass using a *biorefinery approach*. Such approach consists in the maximum exploitation of the biomass barrel aimed at increasing the conversion efficiency. ENEA activities support the development of new integrated biorefinery models through the implementation of cutting-edge processes and technologies for the production and conversion of some platform molecules from the biomass conversion, namely sugars, lignin, and oils. Already in the early 1990s, ENEA was pioneer in the evaluation of sustainable crops for industrial applications and test fields were planted with poliannual species at ENEA Trisaia Research Centre. The biomass productivities were monitored continuously over the years.
More recently, ENEA has strengthened some alliances with industrial stakeholders, including Biochemetex and Novamont, with significant investments in the construction of innovative biorefineries fed with poliannual crops. In particular, Giant Reed (Arundo donax) was selected as raw material for the BioChemtex Demo Plant in Crescentino (Vercelli, Italy) and tailor-made processes were developed under PRIT and BIOLYFE projects for the production of second-generation bioethanol. Common Cardoon (Cynara cardunculus) was selected by Novamont® as raw material for The Matrica Biorefinery in Porto Torres (Sardinia), and the development of a cardoon-based biorefinery was part of strategic projects in the Italian Cluster of the Green Chemistry (BIT3G, REBIOCHEM).
Amongst various biorefineries scheme, sugars platform involves the breakdown of raw materials into sugars, which can be fermented, dehydrated or hydrogenated to produce a spectrum of chemicals. R&TD activities in cooperation with industries and research organizations are underway on the three main steps of the biomass conversion and include: i) biomass pre-treatment/fractionation to facilitate the enzymatic digestion; ii) hydrolysis at high solids content (the so-called high gravity hydrolysis); and iii) sugars upgrade and conversion to a number of bio-based products, mainly through fermentation (e.g. bioethanol, microbial lipids, lactic acid).
Pretreatment and fractionation through *Steam Explosion* can be considered as a flexible process scheme since it uses saturated steam to produce high degrees of biomass destructuration. The use of small amounts of additives could catalyze the process at mild conditions. The type of additive could determine a different fractionation scheme. At the ENEA Trisaia Research Centre,

the pilot station for biomass fractionation consists of three units of compatible size. The digester is able to process 300 kg/h biomass in the continuous mode. This technology is suitable to treat different biomass. The cellulose reach stream could reach purity of 80% and a lignin stream, containing less than 2% sugars, can be separated.
The reliability of a local biomass supply is a key element for biorefineries development. It is worth to note that a national GIS-based database and National Atlas of Biomass was created by ENEA enabling a detailed assessment of the distribution and type of biomass at province level (http://www.atlantebiomasse.enea.it/). In addition, ENEA carries out analysis on the local biomass potential for instance in abandoned lands by applying an integrated evaluation of the agro-climatic vocation. The full development of biorefineries in the future will imply both technological and non-technological challenges. One main objective of the future research in the conversion of lignocellulosic materials will regard the exploitation of lignin, currently considered as a side stream and used for the production of heat and electricity to make biorefinery self-sufficient. The question is: how does the biorefinery energy balance look if part of the lignin is used to produce bioaromatics/biochemicals?

Thermo-chemical Processes for the Exploitation of Biomass, Residues and Wastes

Research and development activities on thermochemical conversion processes are based on gasification and pyrolysis and, thus, support the National and European industrial system to scout and focus on advanced new technologies. In relation to the exploitation of biomass, activities are mainly focused on the development of gasification processes for the production of gaseous energy carriers of higher value, available for direct application in CHP production or, after proper cleaning and conditioning, as a gas of synthesis to produce derived fuels (e.g. hydrogen, SNG, Fischer-Tropsch liquids, methanol, DME). From the produced gas, chemicals can also be synthesized.
R&D activities are mainly focused on the development of small to medium size technologies for power production using low value feedstocks. Five pilot-scale gasification plants, based on different reactor design (fixed bed, fluidized bed and staged gasifiers), effective gas cleaning and conditioning unit and size ranging from 120 kW_{th} to 1000 kWth, are available at the ENEA Trisaia Research Centre.
Recently, an updraft fixed bed gasification plant, based on 150 kWth reactor with steam/air gasifying agent, operates with feedstock of high biogenic fraction and a generating producer gas of LHV 5-6 MJ/Nm^3dry is implemented. The plant is equipped with a wet purification system operated with biodiesel. The produced gas was considered to generate a gaseous stream with a high H_2/CO ratio (> 2), to be used in the synthesis of biofuels (e.g. methanol) [10], or to produce hydrogen of fuel cell grade. To this aim, after the biodiesel scrubbing, the gas stream is addressed to a section for gas upgrading and CO_2 removal.
As shown in Figure 1, a 500 kW_{th} staged pilot plant is based on a three stages gasification process carried out in different units.
The process starts with the pyrolysis of the supplied biomass. The pyrolysis gas is conveyed to a partial oxidation reactor where tars are mostly cracked and converted into lighter gases. Pyrolysis char is fed to an open core downdraft reactor, with air/steam primary and secondary lines. The char bed also acts as an active carbon filter for raw product gas. Overall, the ultimate results are a producer gas with a very low tar level content and the possibility of using a wide range of biomass feedstocks (including low value residues, e.g. AD sludge) as solid fuels.
Innovative thermal processes for treatment of residues and wastes were developed in order to recover carbon fibres and energy from end-of-life composites, produce activated carbon and energy from scrap tires and waste biomass, produce high added value technical ceramics and energy from scrap tires and waste glass, convert chemical energy of non-recyclable waste (refuse derived fuel, automotive shredder residues, manure, sewage sludge, waste plastics) in more flexible energetic vectors such as char, bio-oil, and syngas. Preliminary tests conducted on bench scale continuous rotary kiln with mass rate of about 1 kg/h provided useful information for the scale-up of pyrolysis/gasification process of tires, sewage sludge, ASR, and digestate.
A pilot scale rotary kiln system to process automotive shredder residues and waste biomass at a maximum mass rate of 10 kg/h and equipped with a gravity settler to collect char has been built. The raw gas is purified by the gas treatment system composed of an spray tower, panel filter and a scrubber working with alkaline solution. Also, a rotary kiln plant, with treatment capacity of 30 kg/h, was built up with an indus-

Fig. 1 Three stages gasification pilot plant

trial partner SICAV Srl. It is a 4 meters long rotating drum reactor with internal diameter of 0.4 m. The main purpose of this plant was to develop and optimize a thermochemical process to convert waste/biomass to solid products with high added value "Activated carbon" and synthesis gas. A "batch" fixed bed pyrolysis plant with reactor capacity of 5 m^3 has also been realized to recover carbon fibres from scraps and composite waste materials (Figure 2). The ENEA-patented process allows the recovery of the carbon fibres that still retain 90% of the mechanical properties of virgin fibres. Moreover, the recovery cost is about 20% lower than the commercial cost. The patented process was validated in the continuous rotary kiln (Figure 2). Moreover it was sold to a SME that is building up an industrial plant for the recovery of carbon fibres by ENEA patent.

A fluidized bed gasifier was built to treat refuse derived fuel with a mass rate of 10 kg/h. It has a raw gas cleaning section and catalytic modules of steam reforming and water gas shift for hydrogen enrichment. A technological integrated platform was realized to dispose waste tires, to produce high added value material, such as nanometric silicon carbide, to recovery power.

Biomass and Biotechnology for Energy

Development of efficient biomass conversion processes and innovative technologies for the conversion of different biomass (including no-food crops and microalgae) into biofuels and chemicals by means of biological processes are the main goals of R&D activities on Biomass and Biotechnology for Energy. Activities are mainly focused on the selection and use of microbial pools for the production of second-generation biofuels, applying the biorefinery concept and microbial ecology approach for sustainable energy production.

Research activities are mainly focused on the enhancement of biogas production from lignocellulosic wastes by a biological co-treatment and its scale-up, development of two-stage anaerobic digestion processes for hydrogen and methane production from organic wastes, ethanol and hydrogen production from raw glycerol arising from biodiesel industry by anaerobic fermentation with mixed bacteria cultures and experimental cultivation of microalgae to produce biofuels and/or high-value products for chemicals. Such goals are pursued through selection of functional consortia by means of bio-augmentation, acclimatization and enrichment and the statistical optimization, in order to increase their productivity and stability for a further scale-up and industrial exploitation.

Lignocellulosic substrates represent the main potential energetic stock among organic wastes. When lignocellulosic wastes are used as sole substrate, the hydrolysis step represents the bottleneck of the whole process; if they are used in co-digestion with other substrates, they become the limiting factor of the process efficiency. Recently, biological treatments of lignocellulosic wastes are gaining more attention thanks to the low energy requests, mild operational conditions, and low production of toxic and unwanted by-products.

An innovative approach (based on

Fig. 2 Pyrolysis fixed bed plant

the development of microbial processes for hydrolysis of lignocellulosic materials by Anaerobic Ruminal Fungi - ARF) through Anaerobic Digestion (AD) of lignocellulosic biomass was tested at ENEA in two different series of experiments, where the second experiment was a scale-up (10x) of the best results obtained in the first one. A mathematical model to predict methane production was calibrated on the first experiment while data from the scale-up experiment were used to validate it.

The bio-augmentation approach is innovative because the breakdown of lignocellulosic biomass promoted by ARF is not performed upstream, as imposed by typical pre-treatments, but it is totally integrated and concurrent within the AD process. The obtained results enlighten interesting perspectives for the application of bio-augmentation in the AD process, providing a co-treatment of lignocellulosic wastes. Moreover, the microbial bio-augmentation leads to even better results in a greater process scale. This aspect is under investigation with increasing process scale.

Several research activities have been and are presently carried out on the development of advanced anaerobic digestion processes, aimed at increasing energy production from organic wastes (manure, crude glycerol, cheese whey) through a two-stage fermenter, made of two separate reactors, the first producing hydrogen and the second one methane. Anaerobic digestion of ricotta cheese whey (RCW) has been extensively studied at ENEA. The results of these research show that the two-phase reactor configuration improves the energy efficiency of the process in terms of total energy production and methane quality. The two-stage process has been patented (ENEA-CRA Patent number PCT/IB2014/059942), leading to the construction of a pilot plant with a size of a first stage reactor of 0.3 m^3 volume and a second stage reactor of 3 m^3 at the Monterotondo (Roma) Research Centre of CREA (Figure 3), and some full-scale plants are currently in advanced stages of construction.

Furthermore, ENEA has developed a technology making use of raw glycerol - by-product of the industrial biodiesel production - by way of innovative anaerobic fermentation processes to obtain bioethanol, hydrogen or synthesis intermediates (lactic and succinic acid, 1-3 propanediol) for chemical industry. Enrichment of activated sewage sludge allowed to select a suitable microbial culture able to grow on crude glycerol as the only carbon source, using this simple medium without any extra-nutrient supplements.

The process developed at ENEA laboratories has been patented (Patent No. RM2011A000480). It is to be noted that in the framework of European R/S project "GRAIL", trials on both lab-scale fermenters and pilot plant are in progress. Next step of the research will involve the development of a continuous process, both at lab as well as pilot plant scale. Preliminary tests for the scale-up of the process have been carried out on a pilot bioreactor of 50 L at the ENEA Trisaia Research Centre (Figure 4) and appears to be quite promising for beginning the continuous fermentation.

Cultivation of microalgae to produce biofuels, food products with high nutritional power and/or high-value products for chemical industry are in progress at the ENEA Casaccia Research Centre.

The main target of these research is the realization of innovative, simplified and low-cost systems for microalgal cultures, both at laboratory scale (PET used bottles), as well as outdoors.

A brief of activities, already completed or in progress, is given below:

Fig. 3 Two-stage anaerobic digestion pilot plant at CREA Research Centre in Monterotondo

Fig. 4 Pilot fermenter at ENEA Trisaia Research Centre

- Bioenergy: use of liquid digestate as fertilizer for microalgae crops to be used for biogas production;
- Green chemistry: *Botryococcus braunii* and *Dunaliella salina* production experiments for enhancing their content in oleic acid and dienes;
- Production of nutraceuticals: production of *Artrhrospira platensis* (spirulina) to be used as a food supplement or as a source of natural dyes (phycocyanin) for food, cosmetics and chemical analysis;
- Restoration of cultural heritage: screening and evaluation of micro- and macro-algae for the production of polysaccharides extracts to be applied on paper works (manuscripts, books, drawings) deteriorated or at risk of deterioration.

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SINERGIA and AGRICARE: two European projects on energy efficiency in the agrifood and agriculture sector

Advantages coming from technological competences are a specific feature of the competitive processes of the industrialised world, since the development potential of advanced Countries depends on their ability to continuously innovate production systems

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In the Mediterranean in the agrifood and agriculture sector companies, often small and medium-sized (SMEs), still spend few resources on improving energy efficiency and innovation, which is, instead, a crucial factor for their competitiveness. Consequently, the energy costs associated with the various operations (e.g. soil tillage, sowing, harvesting but also pasteurization, drying, cooling, heating) may be very significant. It is, therefore, necessary for SMEs to implement actions aimed at improving energy efficiency (e.g. adopting innovative cultivation techniques, replacing old machinery, changing technologies) and introducing energy self-production from renewable sources.

In this context the link between scientific research and the world of production has been strengthened with an increasingly central role in the transfer of technology from knowledge-based institutions (universities and public research centers) to those which use it economically (enterprises). The technological transfer enables the introduction of important innovation processes in the SME system, including the improvement of energy efficiency, which is one of the main objectives of two European projects: SINERGIA for the agrifood and AGRICARE for the agriculture sector.

SINERGIA, "Increasing energy performance by transfer of innovation to agri-food SMEs in the Mediterranean Area", is a European project cofinanced by the MED Programme, an EU transnational cooperation programme of the EU Cohesion Policy with the objective to strengthen

the competitiveness, employment and sustainable development of the Mediterranean area.
The general aim of SINERGIA was to promote technology transfer to SMEs in the agrifood industry in order to:

- identify innovative processes to address energy efficiency patterns in the productive chain;
- guarantee a wide replication of the technological solutions for energy saving and CO_2 reduction in the involved MED regions;
- strengthen the competitiveness of the agrifood industry in the Euro-Mediterranean and global markets.

In seven specific MED pilot regions across different agrifood pilot sectors SINERGIA Partnership has performed the following activities:

- capitalization of the most important MED and Research projects tackling the innovation in the agrifood sector and zooming the critical factors related to energy efficiency in the agrifood industry, in order to steering enterprises towards adequate and innovative solutions;
- identification of innovative solutions and benchmarks also through the realization of energy assessments on a pool of 50 SMEs;
- at local/productive cluster dimension, multiplication of the SINERGIA energy efficiency cooperative model to a broader range of SMEs and stakeholders through the empowerment of existing eco-innovation help-desks in each project region as well as through the promotion of public and private agreements.

Then the project, which tackles the energy challenges, has developed some user-friendly instruments to increase SMEs' awareness on the best tailored actions to introduce innovation in energy efficiency processes, from monitoring to selection of the most fitting technologies to the energy managers' coaching across the whole investment life cycle:

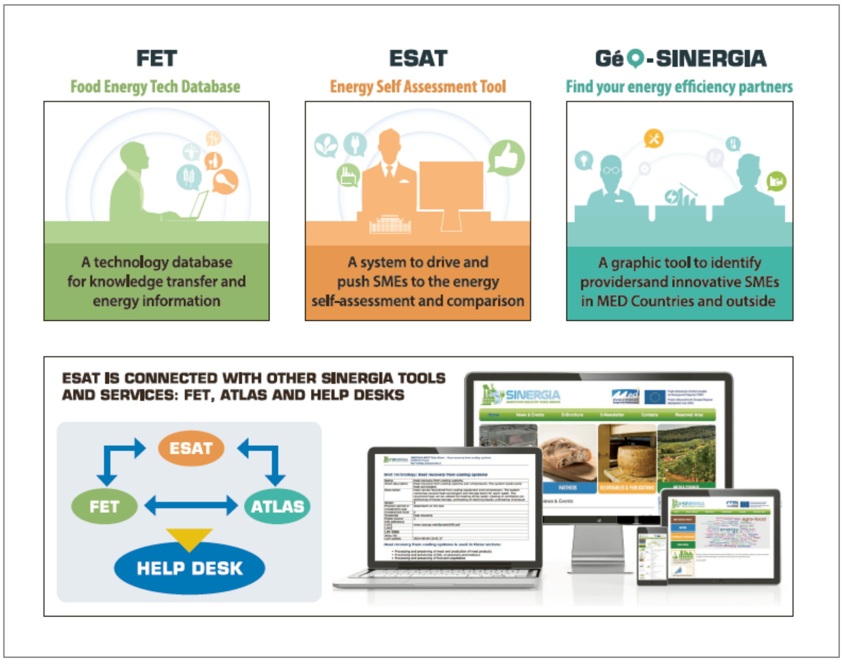
- a decision support system, named Energy Self-Assessment Tool (ESAT), which offers a set of energy performance reference values for the selected agrifood divisions and technologies, helps enterprises to pre-evaluate the potential benefits, and maps out the innovation hubs and the available local RES and E-services. It basically encourages agrifood companies to wisely approach their own energy performance problems and deal with the EU directive on energy efficiency, which promotes the energy diagnosis in the EU SMEs.
- a reliable, scientific-based and independent database, Food Energy Techs – FET, which helps the interested food & drink companies to get a first screen of the possible company-based interventions and to focus the best available technologies in the fields of energy efficiency and renewable energy production, that best fit with the numerous and different agrifood sectors.

Additionally SINERGIA has profiled a common vision and a set of future initiatives and recommendations addressed to both agrifood Federations and Governance bodies to help the Mediterranean SMEs to meet the current challenges in the fields of energy efficiency and green energy production - embedding a wider concept of sustainability and environmental footprint - in line with the EU2020 Strategy, in particular the climate/energy package objectives and Roadmap to a Resource Efficient Europe.
SINERGIA recommendations highlight that making agrifood compa-

nies – particularly SMEs – aware about their potential energy efficiency upgrade is definitely the first step to address the problem. Helping them to run an initial self-diagnosis of their energy consumption is the way to convince them to investigate market and organizational solutions to deal with energy innovation. It is also a propaedeutic step to identify suitable low-carbon technologies fitting with their own industrial processes. The access to good quality and scientific-based innovative ideas to improve the environmental performances of the food & drink industry is one of the main challenges to stimulate the green innovation of this sector. Among the various source of information and telecommunication technologies available today, the internet is certainly the most innovative and useful one. However enterprises, especially small- and medium-sized, must be supported in order to fully exploit the advantages offered by this heterogeneous, numerous and complex information instrument. SMEs do not often have a sufficient capacity to understand what technology options could best fit with their own production patterns and to calculate the cost/benefits of the investment in the full life cycle. Key elements to meet new SMEs' requests for information are the various tools available online to enable two-way information flows, starting from the simplest to the more evolved, that attract companies, making it possible to obtain useful information about the opportunity of new energy technologies. Therefore, using organized and structured tools allows SMEs to achieve a high level of innovation but this process should be guided by technology intermediates and skilled specialists to better fulfil companies' expectations.

Agrifood associations are invited to enhance their efforts to provide their members with a vision over future market trends and new services, with the goal of promoting the large scale introduction of eco-innovation model analysis in the agrifood sector and stimulating targeted investment to green the food & drink industrial supply chain.

The European Regional Development Fund, which roughly represents one/third of the European Union's budget in the period 2014-2020, represents in terms of budget, investment schemes and accessibility an important financial instrument to support European companies towards low-carbon production phases and in greening the supply chain. Agrifood federations should provide policymakers with result-based recommendations to invest resources to support agrifood companies in improving their energy efficiency standards and promoting synergies among agrifood cluster and local administration on energy policies. EU Funds could support investments with positive impacts for the whole agrifood local systems and could stimulate replication mechanisms. The ownership and circulation of a successful case study become a crucial factor to stimulate worthy projects specifically addressed to the agrifood system and make the best cost/benefit use of the dedicated Structural Funds. Agrifood industrial associations should help their members to deal with the bureaucratic procedures to access the financing and - in short - catch the opportunities offered by the European Union, possibly through specific consultancy services.



SINERGIA Project dissemination tools kit by Marco D'Andrea, ENEA






Furthermore agrifood federations, R&D centers and public administrations are called to profile fresh schemes to get research out of laboratories, meet the real companies' demand for innovation and get subsidies to introduce eco-innovation technologies for energy efficiency and RES in the Mediterranean agrifood sector. Services and applications delivered by the close-to-market research need customization and adaptation when applied to different market sectors, whilst tailored-made strategies to penetrate the agrifood organization structures are demanding to be concretely used by SMEs. Special attention must be devoted to diffuse, across stakeholders, mature technologies and organization models that are currently existing on the market but that suffer no technological barriers (knowledge and ways of application, costs, understanding of the whole investment life cycle costs, etc...). The creation of public and private partnerships for the green innovation of the agrifood sector, both at territorial and European level, becomes a matter of competitiveness.

In fact agrifood is one of the main economic pillars in the Mediterranean area and is recognized in most of the Regions as Smart Specialization Strategy (S3), with a goal that is to boost regional innovation and growth by enabling regions to focus on their strengths. The introduction of the eco-innovation model analysis in the agrifood sector, both to reduce the environmental stress factors in the supply chain and to support the competitiveness of the agrifood SMEs, is part the roadmap. This requires a convergence of the education and business regional strategies:

- the specialization of the educational systems, from the technical colleges to universities, to meet the demand of new green skills and green jobs shall be pursued by encouraging new forms of public and private collaboration on the labour market;
- the enrichment of the vocational training with topics for the development of skills on eco-innovation, the innovation management and the sustainability issues.

Initiatives among agrifood federations, high education and R&D and specialized market/skills intelligence organizations – also at transnational level by using the available Growth and Jobs EU Funds – should be launched to increase the professional abilities in energy diagnosis and green energy projecting in agrifood enterprises, also by extending the concept of sustainability to the global environmental footprint.

LIFE+ AGRICARE, "Introducing innovative precision farming techniques", is a project coordinated by Veneto Region's Agency for innova-

MED PROGRAMME

The MED Programme is an EU transnational cooperation programme among the "Territorial Cooperation objective" of the EU Cohesion Policy. Partners from 13 countries including the whole Northern Mediterranean seacoast are working together to strengthen the competitiveness, employment and sustainable development of this area. The transnational setup allows the programme to tackle territorial challenges beyond national boundaries, such as environmental risk management, international business or transport corridors. So far, 144 projects have been programmed, co-funded by the European Regional Development Fund (ERDF) up to a rate of 85%. The Programme objectives are to improve the area's competitiveness in a way that guarantees growth and employment for the next generations and to promote territorial cohesion and environmental protection, according to the logic of sustainable development.

tion in the primay sector, in collaboration of Maschio Gaspardo SpA, Department of Land, Environment, Agriculture and Forestry of Padua University and Agroindustry Division of ENEA, and is co-funded by LIFE+ Programme with a duration of three years from June 2014 to May 2017.
The overall objective of the project is to demonstrate how the application of advanced techniques in precision farming (Variable Rate Application and assisted steerings systems), combined with different types of no-till farming, can play an important role in terms of greenhouse gases (GHG) reduction, and energy saving.
The project regards four different rotated crops (winter-wheat, canola, maize, soybean) and four different soil management techniques: conventional, minimum tillage, strip tillage and no-tillage at the pilot farm Vallevecchia managed by Veneto Region's Agency for innovation in the primay sector (Venice, IT). The testing regards 16 parcels (1.5 hectare each) of department 12 in the pilot farm Vallevecchia subject to winter-wheat, canola, maize, soybean rotation. Harvest, in all scenarios, is done by combines equipped with yield map systems.
The specific objectives of the project are to:

- Verify and demonstrate the effective potential of the precision farming techniques in terms of energy saving and greenhouse gas reduction.
- Analyze the efficiency of the machines used, enhanced by electronic precision farming devices which reduce CO_2 emissions.
- Examine the suitable scenarios for the diffusion of such techniques in different Italian agricultural contexts.
- Assess the threshold of economic convenience and environmental benefits.
- Assess, through analytical models based on "ground, plant, climate" data and Life Cycle Assessment (LCA), the long term effects of the experimented technologies introduced.
- Diffuse what examined and proven by tests, not only in the pilote site, to encourage the diffusion of such technologies and techniques.

In addition to the tests performed in the pilot farm, the project foresees a self-assessment Web application with related guidelines to calculate the convenience to introduce new technologies and different soil management in fields, while significantly reducing the GHG emissions and the energy consumption.

Vallevecchia pilot farm


ZEBRA strip tiller by Maschio Gaspardo, working at Vallevecchia pilot farm

This free web application, developed by ENEA and placed on the project website, will guide farmers through some defined steps to fill information about their farm crops and cultivation techniques and will provide them with a calculation of their own energy consumption as well economic balance.

Another important project result is represented by the analysis of energy and environmental benefits, direct and indirect, resulting from the integrated use of precision farming equipment and the soil management techniques of no-till farming (conservative farming). It was carried out to assess potentially generable carbon credits from the introduction of such techniques to farms and to compare financial incentive schemes for the reduction of agriculture carbon emissions in Italy and Europe.

The analysis of energy and environmental benefits were carried out in particular to:

1. test and demonstrate the benefits associated with the introduction of the latest prototypes of conservative farming machines, integrated with precision technologies, compared with similar traditional tests;
2. assess the environmental benefits associated with different methods of soil management for the 4 different crops (winter-wheat, canola, maize, soybean), with or without precision farming;
3. compare energy consumption and potential environmental impacts for different soil management systems on the basis of chosen crops: winter-wheat, canola, maize, soybean including cover crops, where provided.

The evaluations were made separately for each method of soil management techniques. Then a first data collection and systematization were carried out by the implementation of a shared collection and management data protocol for each operation.

The analysis allowed to calculate the following indicators: Gross Energy Requirement (GER), and Energy Efficiency. GER is defined as the amount of energy required for the production of a specific product and includes all crop cultivation

LIFE+ PROGRAMME

The LIFE programme is the EU's funding instrument for the environment and climate action. The general objective of LIFE is to contribute to the implementation, updating, and development of EU environmental and climate policy and legislation by co-financing projects with European added value.

The 'Environment' strand of the new programme covers three priority areas: environment and resource efficiency; nature and biodiversity; and environmental governance and information. The 'Climate Action' strand covers climate change mitigation; climate change adaptation; and climate governance and information. One of the main energy-related policy drivers in the EU is the reduction of greenhouse gases (GHG) at their sources. LIFE climate change and energy projects reflect this priority: exploring innovative ways of implementing mitigation or adaptation measures to reduce GHG; and targeting energy production and distribution, renewable energy technologies and energy-efficiencies in areas such as industry, services, buildings, transportation, lighting and equipment.

operations and also machines and technical inputs applied. Energy Efficiency means the amount of energetic input to produce a unit of energy output. When conservative techniques were integrated with rate variable application of inputs, energy consumes slightly decreased. For each crop, use of machines, fertilization and/or irrigation were the most energy intensive operations.
With regard to environmental and energy evaluation, results showed that direct and indirect impacts of agricultural activities varied on the basis of the different techniques used. In particular, no-tillage technique was the most interesting result in terms of energy used and, consequently, CO_2 emission.
In general, the most energy consuming crop operations were those related to soil tillage and to use of fuel consuming machines, and those relating to fertilizing, especially nitrogen fertilization. Energy-intensive operations were also those that substantially contribute to CO_2 emissions.
However an interesting outcome was that introducing new technologies and techniques could reduce the impact of agriculture on the environment, decreasing energy use and supporting accumulation of carbon in the soil.
The data validation and control process are still ongoing but
the processed data clearly indicate that the innovative techniques are less energy consuming and variable input management gives an important contribution to improve overall performance, although it is complex in its planning and implementation.
The experiences made in the framework of the SINERGIA and AGRICARE projects will be shared in the technical workshop organised with FAO on the Nexus between Food Energy Water, in the contest of a MoU for enhancing the sustainability of the food production and nutrition in developing countries.

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Energy consumption and energy efficiency in the residential sector: A joint analysis by administrative and survey data

The article analyzes the investments in energy efficiency by Italian families through a joint reading of sample data on energy consumption of households and administrative data on various incentive mechanisms in the residential sector

DDOI 10.12910/EAI2017-038

by **Alessandro Federici**, **Chiara Martini**, **Mario Nocera** *and* **Giovanni Puglisi**, *ENEA*; **Valentina Talucci** *and* **Paola Ungaro**, *Istat*

Over the past few years, the energy issue has become increasingly important in the political agenda and in the scientific debate, given its close interrelation with the economic and social systems and its impact on the environment. In particular, national policies pay great attention to energy sustainability through a number of measures, aimed at containing consumption and related emissions and at promoting innovation in renewable energy sources.

Investments in energy efficiency allow to deliver more services for the same amount of energy input, or the same services for even less energy input. In recent years, energy efficiency has increasingly been recognized as the "first fuel": a source of energy in its own right, it provides a key contribution to decarbonization objectives and is associated to a wide range of economic and social benefits. As is the case for renewable energy sources, energy efficiency strongly innovates the energy system, in a holistic way and on both the demand and the supply side.

The 20% reduction of primary energy demand[1] is a very important target of Europe's 20-20-20 targets of the "Climate and Energy Package", to be achieved through the increase in energy efficiency (Directive 2012/27/EU). The contribution of the residential sector for the achievement of this target is significant, given the importance of household consumption on total energy consumption (in 2015, more than 28% of consumption

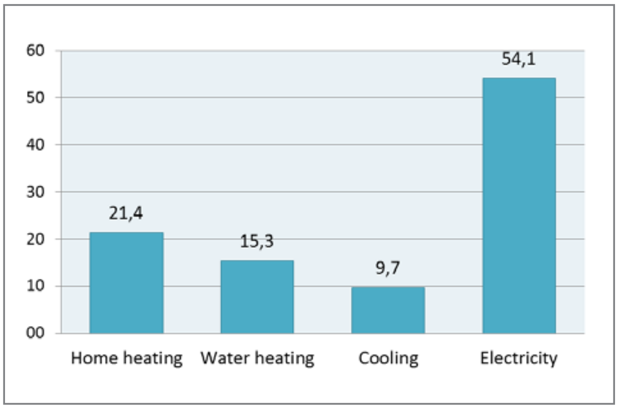

Fig. 1 Households who made investments to reduce energy consumption costs for purpose (for 100 households)

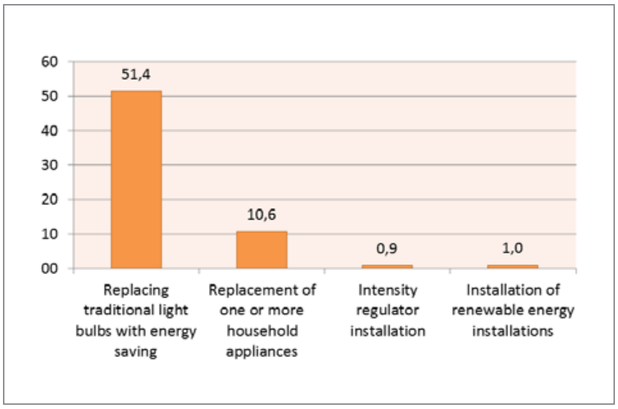

Fig. 2 Households who made investments to reduce electricity costs for purpose (for 100 households)

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The availability of information on household energy habits is essential for the promotion of solutions that contribute to reduce energy demand and to increase the efficiency of consumption, encouraging conscious behaviors by end users.
Aim of this paper is to analyze the investments in energy efficiency by Italian families through a joint reading of sample data (Istat survey on energy consumption of households) and administrative data (ENEA, MiSE and GSE databases on various incentive mechanisms in the residential sector).

Sample Data - Istat

Istat survey on energy consumption of households responds to information needs at international level, and in particular to the European Regulation on “Renewable energy statistics and final energy consumption” (no. 1099/2008). In order to expand the level of detail of information on energy consumption (art. 9), Energy Regulation has been recently amended to include the statistics on energy consumption in the residential sector in mandatory data requests (Commission Regulation (EU) no. 431/2014).
Istat data on energy consumption of households has also been widely used to feed the flow of information for monitoring two EU 20-20-20 targets: the target of 20% share of renewable sources in energy consumption (HP and biomasses consumption of the residential sector) and the target of emission reduction by 20% (biomasses consumption of residential sector).
The survey was conducted by Istat for the first time in 2013 with reference to the entire national territory – in cooperation with the Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA) and the Ministry of Economic Development (MiSE) – to estimate energy consumption of households by energy source and final destination, in accordance with EU Regulation N. 1099/2008. The main topics are: Dwelling characteristics and census of energy facilities and equipment; Space heating; Space cooling; Water heating; Lighting and electrical appliances; Energy consumption and expenditures; Invest-

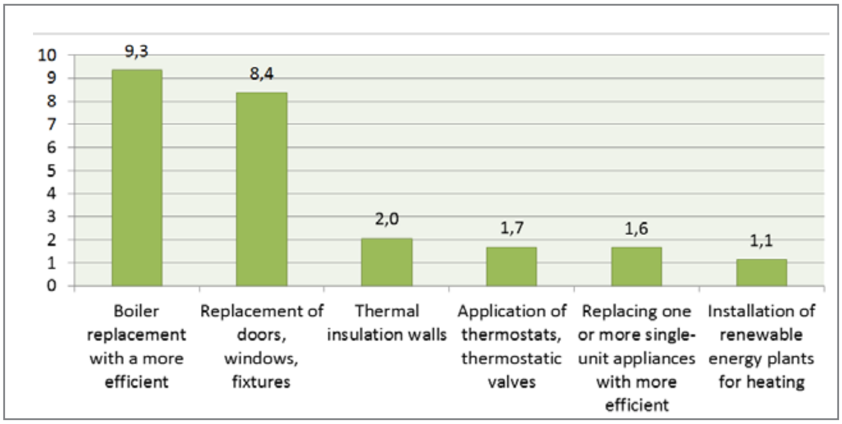

Fig. 3 Households who made investments to reduce heating costs for purpose (for 100 households)

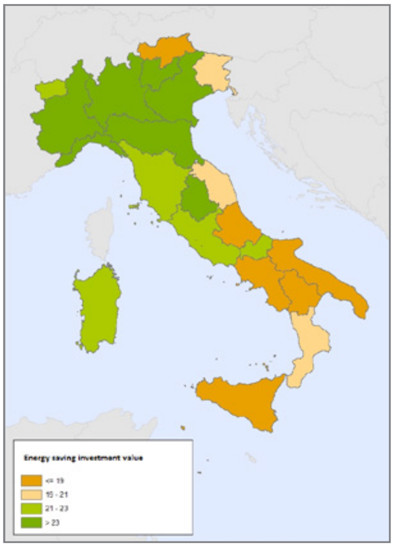

Fig. 4 Households who made investments to reduce energy costs for geographic area (synthetic indicator)

ment to increase efficiency and energy savings. The sample consists of 20,000 households, representative, at regional level, of 25,872,613 resident families.

Energy Saving Investment

Energy saving is a virtuous practice aimed at respecting and protecting the environment by the adoption of new daily behaviors which reduce at the same time fuel consumption, expenses, and related pollution. Households were asked if they had invested in money over the past five years to reduce their energy costs. In 54.1% of households, investments were made to reduce expenses for electricity (mainly due to the replacement of bulbs); in 21.4% for home heating costs; in 15% for heating water and in about 10% for conditioning.
The replacement of traditional light bulbs with energy-saving ones (51%) is the most common electricity saving investment in households, while only 10.6% replace appliances.
The costs for space heating are mainly reduced by replacing boilers with more modern and efficient devices (9.3%), but also by changing doors, windows or fixtures in order to reduce the loss of heat (8.4%). More structural (and therefore more expensive) interventions, such as thermal insulation, are still negligible.
Renewable energy systems, both for electricity and heat production (about 1%), are still uncommon.
Among the many possible investments to reduce energy costs, the most complex and costly interventions were selected and combined for the construction of a synthetic indicator for a more immediate and representative reading of the phenomenon. The selected investments are: replacement of heating devices or appliances with more efficient equipment and/or installation of renewable electricity and heat production systems and/or installation of equipment for monitoring consumption.
According to the synthetic indicator, 22% of households made investments in energy efficiency.
Compared with households resident in South, families living in central and northern Italy show a greater propensity to make investments for energy saving. The most "virtuous" regions are: Lombardy and Autonomous Province of Trento (26%), Veneto (25.3%), Emilia Romagna and Liguria (24.5%), Umbria (24.3%) and Piemonte (23.2 %). A stronger inclination to energy saving is still to be developed in Sicily (14.2%), Autonomous Province

	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
Tax deductions for energy renovation										
Overall renovation	0.006	0.014	0.010	0.004	0.003	0.003	0.003	0.003	0.006	0.052
Thermal insulation of the envelope	0.016	0.043	0.043	0.066	0.052	0.047	0.064	0.065	0.061	0.457
Efficient heating system installation	0.023	0.053	0.054	0.083	0.055	0.047	0.056	0.046	0.012	0.429
Solar shading	-	-	-	-	-	-	-	-	0.001	0.001
Multiple action	0.015	0.034	-	-	-	-	-	-	-	0.049
Total	0.060	0.144	0.107	0.153	0.110	0.097	0.123	0.113	0.080	0.988
Tax deductions for building renovation										
Efficient heating system installation and windows replacement	0.204	0.197	0.185	0.173	0.213	0.191	0.132	0.162	0.18	1.637

Table 1 Savings from tax deductions (primary energy, Mtoe/year) 2007-2015 period
Source: ENEA

Sector	White Certificates	Tax deductions*	Thermal account	Legislative Decree 192/05*	Measures in transport sector*	Other measures**	Energy saving		Achieved target (%)
							Achieved in 2016[b]	Expected by 2020	
Residential	0.59	1.56	-	0.91	-	0.02	3.09	3.67	84.2%
Services	0.13	0.02	0.003	0,05	-	-	0.19	1.23	15.4%
Industry	1.84	0.03	-	0.09	-	-	1.95	5.10	38.3%
Trasport	-	-	-	-	1.13	0.04	1.18	5.50	21.4%
Total	2.56	1.60	0.003	1.05	1.13	0.07	6.41	15.50	41.4%

Table 2 Achieved and expected savings according to Italian National Energy Strategy measures (primary energy, Mtoe/year) 2011-2016 period
Source: ENEA elaboration on data from Ministry of Economic Development, ISTAT, Gestore dei Servizi Energetici SpA, ENEA, FIAIP, GFK
* Estimates for 2016
** Saving deriving from major appliances replacement are considered in residential sector total. Savings associated to high speed railways are included in transport sector figures

of Bolzano (17.6%), Basilicata and Abruzzo (18.7%).

Administrative Data - ENEA

Tax deductions for energy renovation have been a key driver of energy efficiency improvements in the housing sector, representing the main incentive mechanism for favouring interventions in the existing building stock. Initially introduced by Law no. 296/06 (2007 Budget Law), tax deductions for energy renovation – also called Ecobonus – were extended several times by different laws. In particular, the 2017 Budget Law (Law n° 232/2016) confirmed the tax rebate scheme until the end of December 2017, and until the end of December 2021 for the renovations carried out on the common parts of residential buildings. Relative to the initial version of the scheme, the main changes are that the incentive has been extended to new interventions and the rebate rate increased from 55% to 65% (and in 2017 the Ecobonus could reach 75% for specific interventions).
In tax terms, the incentive works as a direct deduction for IRPEF (personal income tax) or IRES (corporate income tax), to be repaid in 10 years, and aimed at realising interventions to improve energy efficiency in existing buildings. According to the law, a wide range of beneficiaries can apply for the incentive: natural persons; professionals; companies and firms; and, since 2016, also social housing institutions.
In particular, possible interventions can be summarised as follows:

- Renovation of existing buildings;
- Improvement of thermal performance of building envelope (insulation, windows replacement);
- Solar shading;
- Installation of solar thermal systems for hot water;
- Replacement of heating systems (condensation boilers, heat pumps, geothermal systems, biomass boilers);
- Building automation systems.

Tax deductions for energy renovation

Total saving from energy renovation interventions in the 2007-2015 has been almost 1 Mtoe/year[2] (Table 1). In this period, around 3 million interventions were incentivised by tax deductions for energy renovation, with more than 31 billion € invested by households. A large amount of interventions concerned efficient heating system installations, including condensation

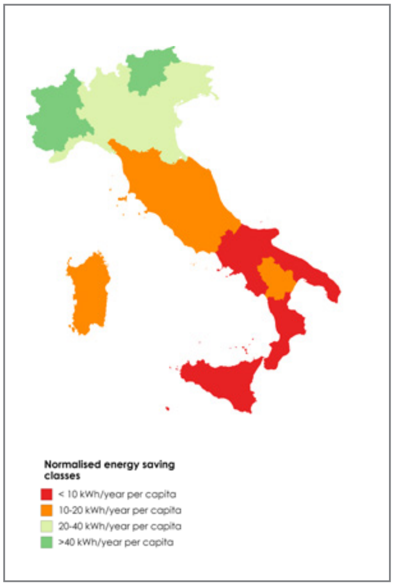

Fig. 5 Per capita energy savings (primary energy)associated to tax deductions for energy renovation in 2015 (preliminary values)
Source: ENEA

boilers, incentivised also by tax deductions for building renovation (incentive equal to 50% of the expense). In particular, a significant share of condensation boilers sold on the market, and used to replace old systems, are incentivised by this other tax rebate scheme. Using for calculation the energy saving per unit available from deductions for energy renovation, the overall value of saving achieved in 2015 associated to condensation boilers has been estimated equal to 0.88 Mtoe/year (Table 1)[3].

Compared to the energy saving objectives set in the 2014 National Energy Efficiency Action Plan, the overall cumulated saving in the period 2011-2016 represents 41% of the 2020 target, as shown in Table 2. Almost half of this value is achieved thanks to the White Certificate mechanism. At sectoral level, the residential sector has already achieved 84% of the 2020 objective.

Figure 5 shows energy savings associated to tax deductions for energy renovation in 2015, classified by geographic regions and expressed in primary energy. As other market-indicators (investment or type of intervention), energy savings clearly show great heterogeneity among regions. Differences are very significant between maximum and minimum values (with a ratio up to 1:10). In northen Italy, the best results are observed in Piemonte, Val d'Aosta and Autonomous Provinces of Trento and Bolzano: these regions have always been very sensitive to the energy efficiency issue. Central Italy shows quite homogeneity in results expressed in absolute value, even though these results are associated with different categories of interventions. Lower unitary savings are registered in southern regions, except for Basilicata, due both to climatic reasons and limited spending capacity.

Conclusions

The incomplete correspondence of information on energy efficiency from administrative and sample sources encourages a joint data analysis, in order to implement a wider and more detailed description and interpretation of Italian population's behaviors in the energy field. This analysis has shown that, overall, the contribution of households to energy efficiency is significant, also thanks to a greater participation of residents in the North, only partly due to more pressing climate-related needs. Further developments in view of a more in-depth analysis of available data will provide more insights into the causes and determinants of this phenomenon.

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[1] The target was increased to 27% for 2030 (http://ec.europa.eu/clima/policies/strategies/2030/index_it.htm)

[2] Preliminary data for 2016

[3] This value has been computed by applying the share of condensation boilers to the overall number shown in Table 1 for tax deductions for building renovation (efficient heating system installation and windows replacement)

Organic Light Emitting Diodes, OLEDs. Activities in the ENEA Laboratory of Nanomaterials and Devices

Lighting has a central role in human activities and is being recognized its importance for the health and wellbeing of human beings. Therefore, efficient light sources are mandatory for their effective use in everyday life and to reduce the electrical energy that lighting uses nowadays. The OLEDs can be one of the key responses to this demand because of their peculiar properties. ENEA NANO Laboratory is actively working on this technology, collaborating with companies to bring it to the market

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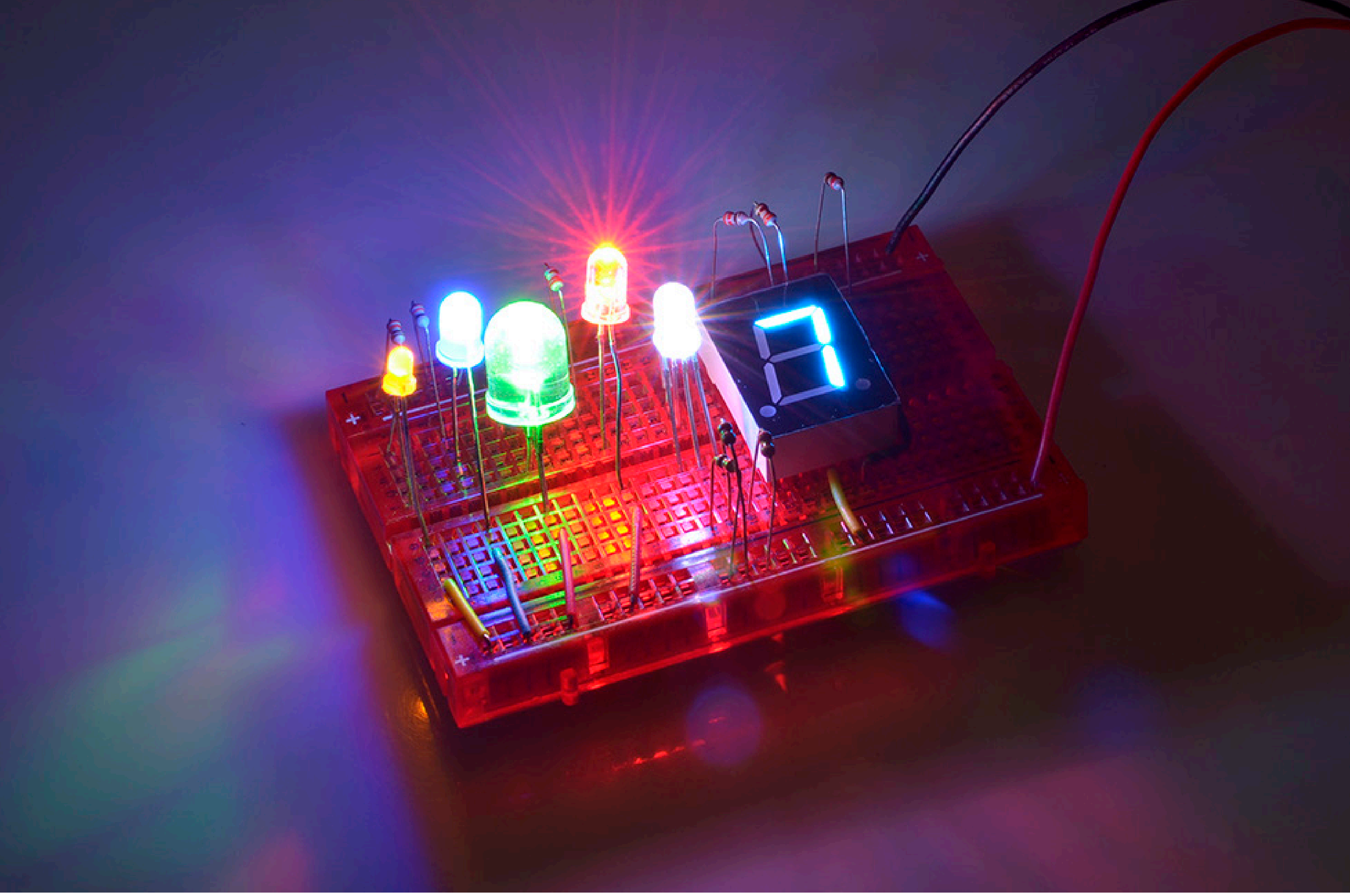
by **Maria Grazia Maglione**, **Paolo Tassini**, **Claudia Diletto** *and* **Carla Minarini**, *ENEA*

Large area, non-glare and relaxing light sources for our houses and working places. Thin, light and efficient photovoltaics cells for the building facades. Pervasive but non-invasive sensors for health, wellbeing and the environment. Flexible, long-lasting batteries. Cheap and sustainable fabrication processes with high yield and large throughput.
All of this is now possible thanks to a totally new technology, which uses organic materials and new approaches for the devices fabrication: it is the Organic and Printed Electronics (OE).

Organic and Printed Electronic

We can think it all started just 30 years ago, in 1987, when Tang and VanSlyke of KODAK company published their seminal work about a new efficient type of electroluminescent devices made by using organic materials, the OLEDs, organic light emitting diodes [1]: they demonstrated how it was possible to exploit “plastics” as active materials for electronic devices. From then, several hundreds of thousands of scientific papers have been published and continue to be published[1] by many research groups all over the world, and lots of companies are born to bring to the market new materials, new devices, new processes, new systems and new products that will be used



in every aspect of society and industry into few years [2]. Lighting, ICT, automotive and means of transportation, white goods and domotics, agri-food, biomedicine, environmental monitoring, logistics, Internet of Things, etc. are a few examples of the applications of the OE.

OLEDs, the human friendly new light source

OLEDs are made of extremely thin films of organic materials sandwiched between two contacts, named anode and cathode, respectively. Excluding the substrate on which an OLED is fabricated, the total thickness of a device is far less than one micrometre. When an electrical current flows through a device, electrons are injected into the device from the cathode and holes from the anode. These charges drift through the organic films until they arrive at a specific interface or in a specific layer, the emitting layer (EML), where they recombine generating light. The electronic properties of the EML determine the colour of the light. Apart the substrate, at least one of the two contacts, usually the anode, is transparent, so the generated light can exit the device (Figure 1). To improve the performances, research has developed devices architectures of several layers and added structures to perform different functions and generate more light and colours, increase efficacy, and extend lifetime.

The first application of OLEDs has been in flat displays: with respect to the liquid crystal displays (LCDs), OLED displays don't need backlighting, neither polarizers nor colour filters and liquid crystal cells, because an OLED pixel is a light source that can be directly driven to form the desired images. So, OLED displays can be made thinner, lighter, more efficient, faster, and have more vibrant colours and a wider angle of vision than LCDs[2]. Moreover, OLED displays fabrication processes can be simple and cheap, using low environmental impact materials, and can be prepared on flexible substrates like plastic and metal foils. In these days, OLED displays are used in many models of mobile phones, and large TV sets are presented by various companies [3].

The second application of OLEDs is for lighting: large area light sources, mainly for interiors. The

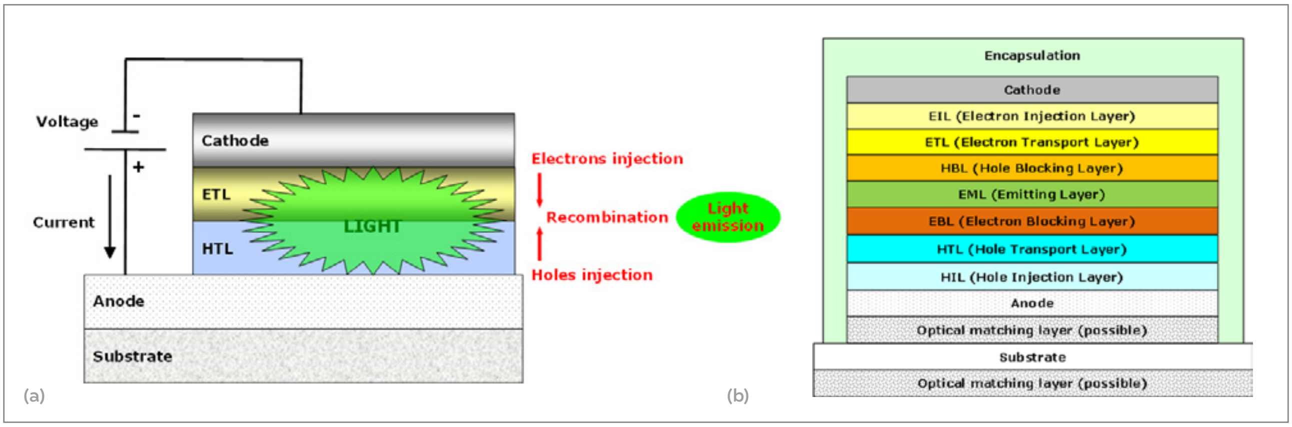


Fig. 1 (a) Basic OLED structure and working mechanism: usually the electron transport layer is also the emitting layer. (b) Example of OLED structure aimed at increasing the performances

devices of these lamps have the same advantages listed for the OLED displays, with the addiction of the potentiality to obtain emitting surfaces in the range of the square metres, and not using poisonous materials like mercury. OLED sources can be prepared of every shapes and geometries, and this possibility is further increased using flexible and foldable substrates (Figure 2). Then, the light emitted by the OLED sources can be of every colour and hues, the intensity easily adjusted, and the large area of the devices generates a non-glare light, so they can be tailored and fitted to be best used in architectural outfitting and interior design, with brightness and colour ideal for the human well-being, making OLEDs an important element for the diffusion of the so called Human Centric Lighting [3]. For the fabrication, the printing processes on continuous stripes are actively studied, similar to the ones of the publishing industry, to succeed in preparing large active surfaces at high pace on flexible substrates.

ENEA SSPT-PROMAS-NANO Laboratory

It's now well over ten years that ENEA Laboratory of Nanomaterials and Devices (SSPT-PROMAS-NANO), in the ENEA Research Centre Portici, has studied organic devices, their processing and applications. NANO is organized as a full lab-scale processing line for simulation, design, fabrication and test of materials, devices and systems for organic and printed electronics. Research themes cover OLEDs (organic light emitting diodes), OPV (organic photovoltaics), transistors and RFIDs (radio frequency identification devices), sensors, materials, processes for layers deposition and patterning, as well as the recovery and reuse of valuable materials at the end-of-life of the devices, and the applications of this technology.
In particular, activities on OLEDs are focused on: the improvement of the devices performances and efficiency, using strongly emitting materials, and applying innovative devices architectures; the increase in the active area with good uniformity of the generated light; the study of materials with a reduced use of critical raw

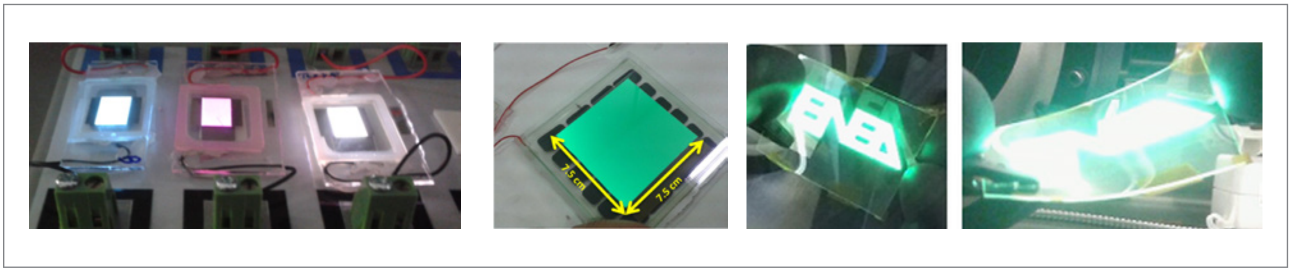


Fig. 2 ENEA NANO OLEDs: (a) on glass, area 1 cm^2 and about 55 cm^2; (b) on plastic

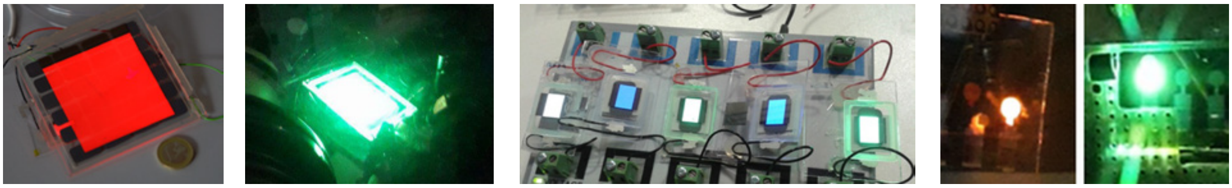


Fig. 3 Other ENEA NANO OLEDs of various shapes, dimensions and colours

materials, mainly for the anode; the use of effective and sustainable processes, like ultra-high vacuum deposition techniques, deposition from solution and printing; the increase of the devices lifetime, studying the degradation mechanisms of their materials to prevent them, applying an ENEA NANO patented encapsulation layout, and studying new barrier materials to seal the devices prepared on both rigid and flexible substrates; the study of innovative bio-based and bio-compatible materials; and to obtain useful devices characteristics for energy efficient applications in human centric lighting, in the biomedical sector, etc..

ENEA NANO can fabricate and characterize OLED light sources emitting at any wavelengths of the visible spectrum, with various geometries and dimensions (ranging from a few square millimetres up to tens of square centimetres), both on flexible and rigid substrates. Moreover, OLEDs are studied having a broad emission spectrum to achieve an overall white emission of different colour temperatures (warm or cold white). These sources have a lifetime of several thousands of hours, a low turn on voltage and reach a luminance above 50000 cd/m^2 at 10 V (Figure 2, Figure 3).

The ENEA NANO competence covers a wide range of topics:

- thin-film deposition of organic and inorganic materials through high vacuum techniques and from solution (thermal evaporation,

sputtering, spin-coating, printing);
- development of innovative organic and hybrid conductive transparent materials;
- structural, morphological, optical and electrical materials characterizations;
- design of devices architectures and layouts, and in-house preparation of photolithographic masks;
- devices fabrication and encapsulation;
- electrical and electro-optical characterizations of devices;
- devices lifetime improvement and ageing studies.

ENEA NANO leads or participates in several funded research projects studying OLEDs:

- Public Private Laboratory TRIPODE, for large area OLEDs and development of encapsulation methods;
- ALADIN Project, dealing with OLEDs for lighting systems and small smart signage systems;
- RELIGHT (Research For Light) Project for the improvement of OLEDs performances and lifetime, and their application in a diagnostic medical system.

ENEA NANO is member of international organizations like the Organic and Printed Electronics Association (OE-A) and of the Emerging Lighting, Electronics and Displays working group of the Photonics21 European technological platform. NANO also collaborates with different Italian companies working on lighting and encapsulation (Beghelli, Vimar, Electrolux, BTicino, Saes Getters, etc.), and universities.

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[1] Over 3 million of matches can be found in Google Scholar, searching for "organic electronics"

[2] LCDs began to be produced several years before than OLED displays, so many improvements have been applied in their fabrication, increasing their performances and decreasing the market prices, that's why LCDs displays are now cheaper than OLED ones

[3] OLED displays are often indicated as AMOLED, for active matrix organic light emitting display, as they are made of specific electronic circuits (the active matrix), fabricated side-by-side each pixel, that generate the required levels of current to power on the OLED pixels at the desired light intensity and colour

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High specific power batteries for racing applications: The HI-ZEV vehicles

Within the “Industria 2015” Italian framework program, the HI-ZEV project has the aim to develop two high performance vehicles: the first one full electric, the second one hybrid. This paper deals with the electric energy storage (EES) design and testing of such vehicles. Different applications mean different storage: the hybrid battery storage has been designed to be able to supply the maximum power of the electric motor, without requirements in terms of energy, while the electric has the energy (and range) as main requirement

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The object of the HI-ZEV Project is the implementation of two vehicles with high performance and low environmental impact. One vehicle will be a pure electric vehicle (Zero Emission Vehicle, targeted to the United Arab Emirates market), the other one a plug-in hybrid, targeted to EU and USA market).

The final design of the hybrid prototype is a 4x4 sport car powered with an internal combustion engine (maximum power: 300 kW) at rear axle and an electric motor with a maximum power of 150 kW at front axle. It is equipped with a 400 V, 15 Ah storage system with high maximum discharge currents (up to 35 times the nominal current). The electric prototype has the same chassis, equipped with the same electric engine at front axle, but with 2 electric motors at rear axle with 100 kW each instead of the internal combustion engine (ICE) and 24 kWh of energy on-board (two batteries of 12 kWh for each axle).

Even though both vehicles have the same chassis and the same powertrain for the front axle, the energy storages have completely different requirements to be met. High specific power is the main requirement for the hybrid vehicle: it must supply all the motor power (150 kW plus losses) but there are not many requirements for energy (about 30 km in electric mode) so low energy storage can be installed on board. The electric vehicle, instead, must supply the same motor power (for example

the battery of the front axle), but the requirements in terms of energy are more important: as a result, the storages of the vehicles are totally different: 6 kWh OCCL Li-Ion batteries for the hybrid version and two 12 kWh KOKAM Li-NMC batteries for the electric one.
Since performance, cost and durability of the electric energy storage (EES) are critical for the overall feasibility, such demanding performance requires a very careful design, especially with respect to the thermal management of the Li-Io cells, very sensitive to high temperatures, also for safety reasons. Therefore a model of the storage system has been developed, simulating each module like an electric generator with more RC circuits in series. To take account of the heat transfer, a forced convection model has been used too, with the air speed proportional to the vehicle speed.
The paper reports the choice, design and preliminary testing of the EES of both vehicles; for the hybrid vehicle, the critical issue is the power response and thermal management: smaller storage systems (compared to electrics vehicles) are chosen in order to control the vehicle weight so high power request could create problems to control the module temperature. The temperature is critical also for the electric vehicle: high power has proportional losses, and forced convection is the choice for this battery.

The vehicle lay-out

The vehicle is thought of as a high-performance sports car with all-wheel drive, two seaters and careful aerodynamics. The vehicle management system has a supervisor who manages the operation of the subsystems traction& electric energy storage, and deals with the integration of torque and power.
The hybrid vehicle design was developed by studying different configurations. The schematics about arrangement of the engine are different, each with very specific characteristics [1-2].
Since the goal of the project was to have a maximum of similarity for the "pure electric" and the hybrid version, a different configuration, a "split" hybrid (Figure 1) was chosen. A split hybrid is a four-wheel traction vehicle with two independent traction systems, a conventional (based on an internal combustion engine) and an electric one. The front axle has an electric traction and the rear has a classical thermal engine configuration. The "pure electric" configuration differs in having both axes electrified.
This configuration makes mechanical installation simpler, while the handling of the torque must be careful, to avoid unpleasant effects in accelerating during cornering.
The hybrid electrical traction system consists of a 150 kW motor controlled by an inverter which also shares the liquid cooling system. The PTM coordinates messages between INV and BMS and has an important role in checking the battery status and regulates the power availability of the inverter. The cooperation strategy of the two axes is defined by a parallel-hybrid state-control, with special features in thrusting and braking. The battery modules are arranged on both sides of the vehicle, near the driver's seat, and are air-cooled.
The vehicle also has an electric parking brake installed, an electro-actuated gearbox and clutch, an electric power assisted steering and other systems that manage data logging and displaying.
The electric vehicle is a 4-wheel-drive with the chassis of the hybrid one, the same front axle, but with 2 YASA 100 kW at rear. There are two batteries (equal), each one is connected to an axle powertrain (Figure 2).
The maximum power is then 350 kW with a weight of about 1300 kg.
The Table 1 summarizes the specifications of both vehicles. A num-

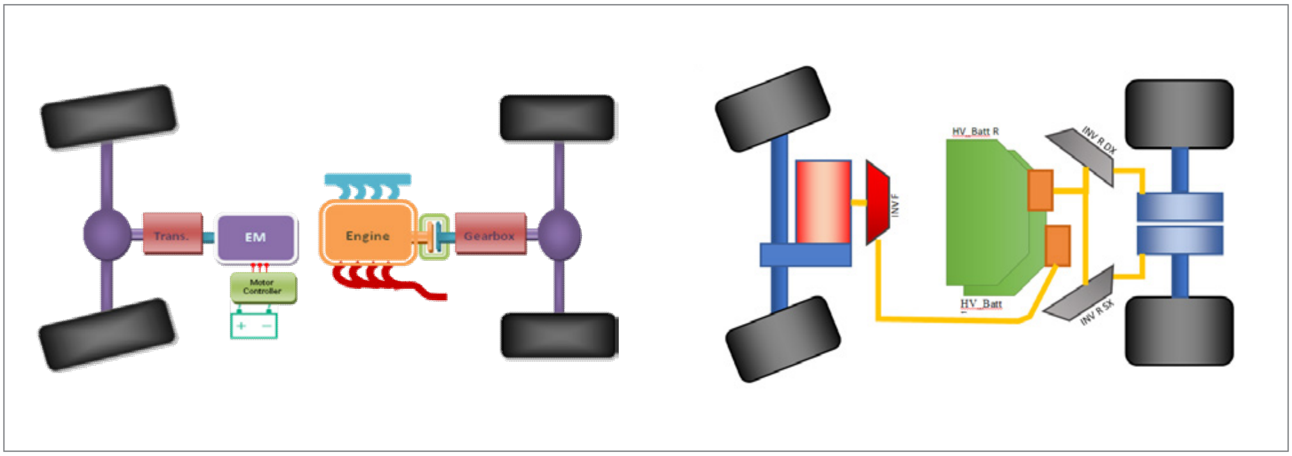

Fig. 1 and 2 Hizev hybrid layout (left) and Hizev electric layout (right)

ber of data are reserved because the design is covered by an intellectual property by the consortium owner of the project.

Different choices for the electric energy storage (EES)

Designing a vehicle all the interesting parameters need to be fixed: then the designer has to choose the ones to be used like input data, the remaining ones will be the output of a verifying session. This type of approach is correct for all electric or thermal vehicles; for example, by fixing the mass and the requested acceleration it is possible to calculate the engine output power. Then it is possible to carry on the design, compute speed, evaluate consumptions and emissions level and, finally, verify vehicle performances, put in the pre-established (design) cycles into the model [3].
For a hybrid vehicle, the designer has one more degree of freedom because it is possible to choose the way to share the (required) total power between the electric motor(s) and the thermal engine.
Moving on the extremes of the operative range, the designer can start from the diesel-electric propulsion, often used in railway and naval fields, in which the batteries have an auxiliary rule because the electric motors are fed by the motor-generator, to the "range extender" hybrids, in which the generator is very small and it is used only to recharge the batteries, that are dimensioned to power by the traction motor(s) (P) alone for the requested "pure electric" range (E).
The choice of these design parameters leads the project development to the next step. In fact, the pulse discharge power (Ppeak) and the total available energy (E), are the input to correctly design the vehicle storage system [4].
In our case, the vehicle specifications are shown in Table 2.
A P/E ratio can be calculated for any kind of storage device by dividing its specific power (W/kg) by its specific energy (Wh/kg). For instance, available traction batteries have a P/E ratio between 1 and 4, that is good for pure EV but far too low for hybrid applications.
High power Li-Io batteries offer more adequate P/E ratios, approx. 10 W/Wh, with specific power and energy of about 1000 W/kg and 100 Wh/kg. SCs benefit from higher P/E ratios exceeding 100 W/Wh since the specific power is very high, up to 1000 W/kg, and the specific energy is less than 5 Wh/kg [5].
Conceptually speaking, a storage system having the P/E ratio required by the typical mission of the considered hybrid vehicle, would have all the power needed for the cycle power peaks without storing more energy than necessary.
The normal Li-Ion cells or SC are not compliant with these characteristics. So the EES has to be composed by ultra-high power Li-Io cells, i.e. Demon OCCL.
On the basis of the previous hypotheses high-performance Li-Ion modules have been adopted, the Demon OCCL (Oxygen – Cobalt – Carbon – Li-Po) Nanotechnology with a capacity of 5 Ah.
The characteristics of such modules are compliant with the maximum power that the electric motor must supply: 70C of maximum continuous discharge current (70 times the nominal capacity, 350 A) and 5C of charge current (25 A). Every mod-

	HIZEV Hybrid	HIZEV Electric
Wheelbase	2700 mm	
Mean track	1716 mm	
Weight	1118 kg	
Front suspension	Double A-Arm, with pull rod link to the damper, torsion bar	
Rear suspension	Double A-Arm, with push rod link to damper, torsion bar	
Steering	Crank-pinion, with power assistance	
Brakes	ABS, carbon-ceramic ventilated discs	
Calipers	6 pistons on front, 4 pistons on rear	
Aerodynamics	Cx: 0.26; Flat bottom and rear diffuser	
Wheels	235/35 ZR 20 88Y/ 295/35 ZR 20 101Y	
Front Axle Power Unit	Brusa Electric 150 kw from 4300 rpm Rpm max 13000 rpm	Brusa Electric 150 kw from 4300 rpm Rpm max 13000 rpm
Rear Axle Power Unit	Rear: ICE:1750 cc 400 hp @ 8000 rpm (nominal)/max 8000	Rear: 2 YASA 100 kW
Storage	400V – 15Ah 6kWh	2 packs 400V –31Ah 12Wh

Table 1 Specifications of the vehicles

ule is composed by 6 cells in series with a nominal voltage of 22.2 V. The storage system is composed by 18 modules in series (nominal voltage: 399.6 V) and 3 in parallel (capacity 15 Ah), with a total energy of about 6 kWh. With such a storage system, the maximum discharge current (at the minimum allowable Voltage of 350 V) is 500 A, so every module has to supply 167 A (33 times the nominal capacity), below the maximum discharge current of the module.
A single module has been tested on a battery cycler in order to check if it can really work with such high currents without an excessive increase in temperature. Several tests have been made on a single module, discharging it with a constant current from 1 to 25C and re-charging it with a constant current up to 5C. The environment temperature has been controlled and set to 23 °C and the module is cooled with natural convection (Figure 3 left).
A battery thermal model has been developed in order to evaluate the modules temperature during some driving cycles of the vehicle, one is the ARTEMIS driving cycles, simulated to be run in electric mode, and the other is a racing driving cycle, run in hybrid mode. The module has a tester to calculate the OCV (Open Circuit Voltage) and the internal resistances (discharge and charge) as a function of the SOC (State of Charge).
In Figure 3 the comparison between the measured and the calculated voltages is reported, and there is good accordance between the two set of data, especially when the discharge is not too long (first discharge at 25 A, 10-40 s), while for longer discharges (400-600 s) there is a little underestimate of the internal resistance. To improve the accuracy also in this condition, a series of RC in the circuital model of the battery circuits could be useful, but for an in-vehicle application the steady-

	Requested	Unit
Electric motor peak power, P	150	kW
“Pure electric” range	30	km
Specific consumption	0.2	kWh/km
Needed energy storage, E	6	kWh
Power/Energy ratio	30	1/h

Table 2 Electric subsystem specification

state conditions are not present and then not used.
The model [1] uses an electrical circuit in which the battery is represented as an electrical generator (OCV, open circuit voltage), an internal resistance R and an RC (a resistance and a capacitor in parallel) circuit, the values of the resistance R and the RC circuits are those that best fit with the experimental data.
The model is divided into two parts: the first uses the first law of thermodynamics for a single module, to calculate the module temperature when exchanging heat with the box at different box temperatures, the second one uses the first law of thermodynamics to calculate the box temperature, taking a forced air cooling of the box into account.
In Figure 3 (right), results are reported: for high discharge currents (the module has been discharged in about 160 seconds) the thermocouples show different behaviors. In the figure the maximum and minimum values are reported: the highest one grows from 14 degrees to 34 at the end of the discharge while the lowest grows from 14 to 24. The thermal model has been calibrated with the highest value and it can be seen that there is a good accordance with experimental data.
Once calibrated the model for a single module, the complete battery pack installed on a box has been simulated using the first law of thermodynamics; it is represented as a volume with all the modules inside, with a steady-state flow that enters and exits from such volume and a heat generation due to the power losses from the modules.
To verify the performances of the storage system, two configurations have been simulated: the first running in "pure electric" with a driving cycle representative of the real vehicle usage, and the second one in hybrid mode running an "uphill race" driving cycle.
In Table 3, a summary of the results is reported. The instantaneous power supplied by the power unit (thermal engine and the electric motor) is calculated as a sum of the friction (tires), aerodynamic and inertial forces, also taking into account the driveline mechanical efficiency (0.9) and the traction motor efficiency, as reported above else in the text. In the electric mode all the power is supplied by the motor and during brakes only the 50% of the energy is recovered. In the hybrid mode, a simple model to calculate the power from the two units has been developed: the power supplied from the electrical motor is a fraction of the total, where the ratio is the ratio of the maximum electric motor power to the thermal one. In our case such ratio is 0.33: the thermal engine is 300 kW (maximum power) and the electric motor power 150 kW.
In the electric drive the ARTEMIS Driving cycles (urban, rural and motorway) have been simulated; these cycles are obtained from a large database of real driving cycles and they are much realistic than the type approval procedure driving cycle.
In Figure 4, the driving cycles are reported: the first part, the urban cycle, has lower speeds and lower power requirements, the rural part has higher values and the motorway has the highest values of power and speed (up to 150 km/h). In the electric mode the vehicle is not able to run all of the three driving cycles

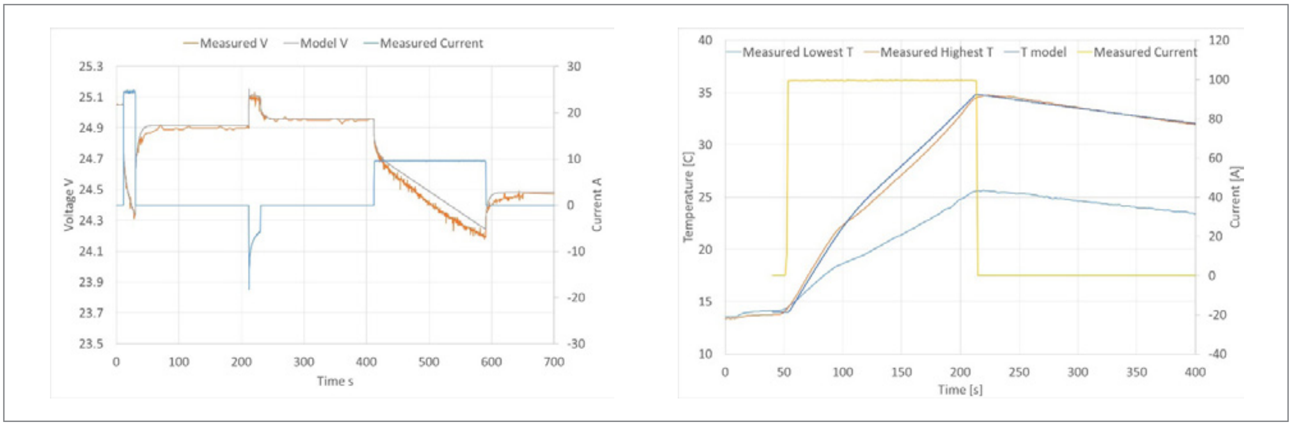

Fig. 3 Comparison between measured and calculated voltages during the test to measure the internal resistances of the module (left); Discharge at 20C current with forced convection and gas speed at 20 m/s (right)

(during the motorway part there is no more energy to continue) and the range is about 41 km (SOC limit: 10%). The average power of the cycle is about 8.6 kW so the electric storage is not much stressed by these driving cycles: the battery temperature increase is about 1 degree. The energy consumption is 126 kWh/km.
In the uphill race driving cycle, the electric motor supplies power in a fixed ratio to the thermal engine power and regenerative braking is able to send to the battery a maximum of 30 kW (only one axis has the electric traction and there is a limitation in maximum charge current, 5C i.e. 25 A). The electric average power of the cycle is more than 60 kW, much higher than that obtained on the Artemis driving cycles, therefore the maximum temperature (differential temperature of 11 degrees) is much higher, but without exceeding the limits.
The energy consumption is 0.32 kWh/km and the range is 14 km, typical for an uphill race (generally 10 km).

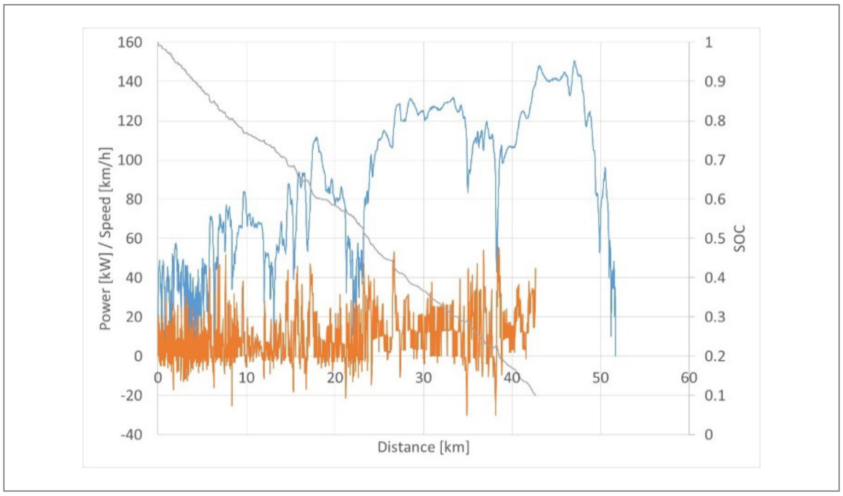

Fig. 4 Artemis Driving Cycles run in electric mode

The electric vehicle

The design phase for the electric vehicle is quite different than the hybrid one. The critical issue is no more the maximum power, but the range starts to have a big importance. The purpose of such vehicle is the uphill race, but with the possibility to run in the street with a reasonable range. An uphill race has a length of more or less 20 km run at maximum power, and for a daily usage the suggested range of the vehicle can be around 150-200 km.
With the vehicle model used also for the hybrid vehicle, a 24 kWh storage can have a range of about 180 km (on the NEDC driving Cycle) for the vehicle. The maximum power for each battery to be supplied is about 150 kW plus Losses, then a C rate Current <15.
The cell technology to guarantee such performances is li NMC produced by KOKAM and specifically the cells SLPB78216216H with the following characteristics:

- Capacity: 31 Ah;
- Maximum continuous discharge rate: 8C;
- Maximum pulse discharge rate: 15C;
- Energy density: 158 Wh/kg:
- Weight: 072 kg.

Each battery is then composed by 96 cells in series with a nominal Voltage of 352 V.
The HIZEV electric model has been tested on different driving cycles, starting from the NEDC and its subparts (UDC and EUDC), passing from ARTEMIS driving cycles and the WLTC, up to an uphill race driving style. The NEDC is used as a reference and the 184 km range can be assumed as a good value. However, a strong dependence on the consumption (and then range) with the driving cycle average speed can be observed: in the urban environment, there are the lowest values (0.1 kWh/km), as the speed increases the value passes to 0.141 for the EUDC driving cycle and 0.229 for ARTEMIS Motorway up to 0.721 for an uphill race (Figure 5).

	Artemis Electric	Uphill Race Hybrid
Range	41 km	14
Electric Consumption kWh/km	0.126	0.32
Delta temperature degrees	1	11
Electric Average absolute Power	8.6 kW	60.1 kW

Table 3 Summary of the results with the two solutions tested

Driving Cycle	Average Speed [km/h]	Range [km]	Consumption [kWh/km]
UDC	18.3	235	0.102
EUDC	64.2	170	0.141
NEDC	32.26	184	0.13
ARTEMIS Urban	17.6	181	0.132
ARTEMIS Road	57.2	179	0.134
ARTEMIS Motorway	99.7	105	0.229
WLTC Class 3	46.5	157	0.153
Race	125	33	0.721

Table 4 Consumption and range results for different driving cycles for the HIZEV electric

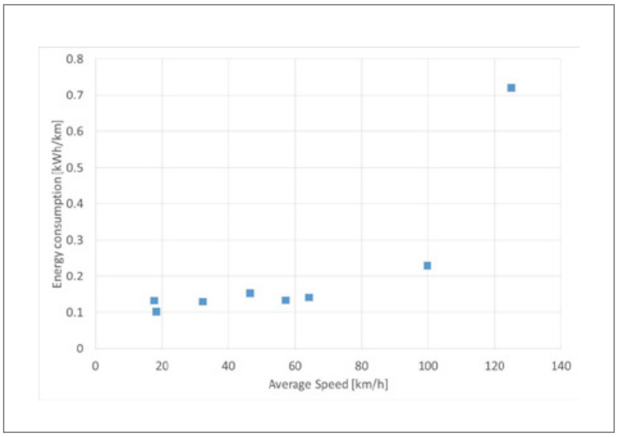

Fig. 5 Influence of the average speed on consumption for HIZEV electric

Once the cells are chosen, the cooling method has to be designed and the maximum operating temperature has to be measured.

Conclusions

Within the "Industria 2015" Italian framework program, the HI-ZEV project has the aim of developing two high-performance vehicles: one full electric and one hybrid. This paper deals with the electric energy storage design and testing.
The design of the electric storage of a hybrid and an electric high-performance vehicle has been designed and a model of the storage system has been developed, simulating each module like an electric generator with more RC circuits in series. To take account of the heat transfer, a forced convection model has been used with the air speed proportional to the vehicle speed.
Such vehicles have been simulated on different realistic driving cycles, in real world cycles, but also on uphill races. The hybrid vehicle in electric mode and an uphill race driving cycle in hybrid model have been simulated in order to check the storage system capability to satisfy the range specifications (30 km in electric mode and 10 km in hybrid mode during a race driving cycle), without exceeding temperature limits (50 degrees for the maximum temperature). The electric vehicle can have a range of 184 km during the NEDC driving cycle and run the race driving cycle for 30 km. The results have shown that for all the tested cycles the designed battery packs are able to run safely, not exceeding the limit temperature and meeting the requirements for the range; the model so developed and validated can be a useful tool in the design phase of a battery pack system.

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Federesco and the Kazakh International Expo 2017

Starting from June 2017, Federesco together with more than 30 private organizations (companies or groups) will be present for three months at the Kazakh International Expo

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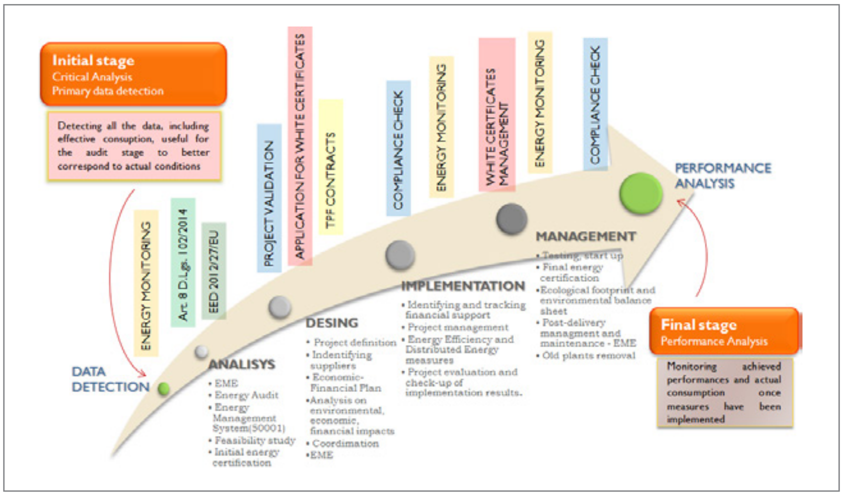
by **Federesco**



Federesco (National Federation of ESCos), as an Energy Service Promoter that has rendered outstanding services to the spreading of energy services in Italy and Europe, has been selected by a Scientific Committee as one of the 30 best innovation projects to be exposed in "Leonardo da Vinci" square within the Italian Pavilion in Astana.

The project met the "theme statement" criteria set by the Expo on future energy with a strong focus on energy efficiency, decarbonisation and environment security, key elements to achieve COP 21 objectives and national priorities in the energy sector.

Federesco has a leading role in promoting change and new approaches, working to facilitate a cultural revolution and, thus, rethink our future.

This projects leads to a new and healthier world, more secure and livable, through energy efficiency in buildings, industry, agriculture and transport sector.

Actually, the idea is very simple, as clearly exposed by the EU Commission: "energy efficiency needs to be considered as a source of energy in its own right"[1], hardly consumed and therefore wasted. It is the best option we have to counter climate change and reduce gas emissions in the atmosphere.

Energy efficiency is largely accessible, but culturally uncommon: outcomes depend on the amount of effort and interest we put in it. Therefore, it is essential for us to change approach and rethink our future pushing for energy projects to be promoted among schools, offices, hospitals, factories and households, facilitating a wide transition towards a social and economic growth.

In fact, energy efficiency is a productive and innovative service, duly supervised and organized. It implies clean and cheap energy consumption, getting to "do more with less", reducing energy costs and waste – usually depending on inefficient and poorly managed systems – by using modern technologies and opting for more conscious and responsible manners.

It is the final outcome of a strategic and operational path demanding a multidisciplinary and synergistic approach through several steps: monitoring, energy audit, executive planning, management, maintenance, raising funds through Third-Party Financing (TPF) and Energy Performance Contracts (EPC).

Created in 2006 to lead this revolution, Federesco was founded as a non-profit association of 60 Italian Energy Service Companies (ESCos) in order to better operate and familiarize with such a large and dynamic area, but also to promote, among public / private economic operators and citizens:

- Good practices and behaviours on Energy efficiency and energy saving;
- The most appropriate best practices in order to achieve the targets under the Kyoto Protocol and the European Energy Policy, according to the directives 2010/31/EU and 2012/27/EU;
- The Third-Party Financing (TPF) mechanism contemplated by the Italian Legislative Decree no. 115/2008;
- Project Financing (PF) financial instruments in order to reduce energy demand and greenhouse gas emission;
- Primary use of energy-efficient technologies to reduce energy consumption;
- Distributed generation plants throughout the national territory, designed to exploit renewable energy sources, cogeneration (CHP) and trigeneration systems.

ESCos are, in fact, the main reference point for setting up energy efficiency measures, operating through a both strategic and operational approach all along the process, implementing every step in a straight and exclusive relation with the client.

ESCos usually perform a wide variety of tasks and activities: a type-measure aiming to rationalize energy consumption is normally split in several phases:

- Energy audit: identifying waste, inefficient or improper use of energy;
- Executive project-planning, including all technical, legal and financial aspects, in order to set up, launch and test plants;
- Monitoring energy and environmental impact, verifying results and performance achieved;
- Supporting ISO 50001 certification on Energy Management System;
- EEO (Energy Efficiency Obligations) Management and CO_2 emissions shares;
- Raising investment funds;
- Organizing workshops and information campaigns on energy issues.

ESCos act as key elements to connect both civil and political communities to current environmental issues as well as to every social opportunity (security, economic growth, life standards, etc.) related to sustainable life and behavior habits.

To Federesco, revolution means evolution, prompting innovation and change for the better; it is about caring and saving, acting for the common good and protecting the environment we live in. It is also about promoting a competitive and efficiency-based economy, useful to facilitate a smart, sustainable, inclusive growth.

Lower waste and energy consumption habits lead to immediate economies on energy bills, to more financial resources to be invested in core business activities and, consequently, to boost and encourage the economy.

Moreover, energy efficiency is not purely a source of profits, but it also provides enterprises with secondary benefits, which, far from being strictly related to energy efficiency measures, bring social and environmental opportunities creating jobs, tax revenue, valuable and high-quality buildings and better life conditions.

Most of all, Federesco believes in energy efficiency as the best opportunity to change life-styles and to restore the link between the Earth and mankind.

New generations can support and facilitate this transition, which is crucial to continue growing. Making them aware of current developments can reduce the cultural gap that keeps up from being conscious of energy efficiency outcomes and benefits. This is why, no one better than new generations – the main characters in our video for the 2017 Expo in Astana – can expose our resolutions, matching our will to start a new life on new values.

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[1] European Commission, Proposal for a Directive of the European Parliament and of the Council amending Directive 2012/27/EU on energy efficiency, COM(2016) 761 final, 30.11.2016. P. 2

WHAT'S UP IN TOWN

The path towards energy transition

di **Bruna Felici**, *ENEA and* **Francesca Insabato**, *Roma TRE University*

Urban planning and Smart City are strictly interrelated concepts towards a sustainable vision. The article illustrates the example of the Lyon Confluence district, Europe's largest regeneration project where Hikari, the first positive energy block realized in France, is located

The previous, first number of the column *Cosa succede in città* (i.e. What's up in town) has highlighted the central role of the multidimensional and integrated vision which characterises the developing process of a Smart City. The concept of Smart City assumed by the EU consists of six different dimensions: Economy, Mobility, Environment, People, Life, Governance.

A similar level of sophistication requires smart policies, in order to face all of the challenges posed by the rapid growth of a city.

In fact, over decades to come, cities will become the elective living places of humankind; therefore, new rules and models of social organization must be implemented, based on strict sustainable practices. Reducing energy consumption represents one of the main targets, since 80% of global primary consumption occurs in urban areas. The Future Energy Expo in Astana represents a step forward on the path towards energy transition, a significant matter for both the public at large and experts in the field.

What is clear now is that giving up on the use of fossil fuels for energy production will not be enough: we need to intervene on the demand side, consuming less and better. This goal can be achieved by rethinking the relational models to disseminate information, creating a virtuous circle between consumers and producers based on the exchange of data flows and transparent criteria. Raising awareness over consumption, tariffs and services provided is a fundamental requirement to reach the energy paradigm shift. From this new kind of relational models, new figures are emerging on the energy market: for example, the *prosumer*, associated with a large-scale penetration of renewable energies. New forms of self-production are

likely to impact the current "centralized "model of energy production and distribution.
A new citizenship model, based on awareness raising and on the request for deeper involvement, is strongly recommended at European level, to "empower citizens to produce, consume, store or trade their own renewable energy either individually or collectively, to take energy-saving measures, to become active participants in the energy market through consumer choice, and to allow them the possibility of safely and confidently participating in demand response;... in this context, a practical common understanding of the definition of 'prosumers' should be agreed at EU level, through a participative process guided by the Commission" (Resolution of the European Parliament, P8_TA(2016)0234)
The diffusion of Smart Grid technologies goes in that direction, allowing the enhancement of consumers' awareness upon consumption and expenditure. Setting this path became possible due to the progress made in domotics: smart metering, wireless networks are just two examples of possible two-way communication between the meter and the central system. Even nowadays, experiences and best practices in the field can be found widely: citizens can already install in their houses devices with wide range of advanced built-in features, such as advanced power measurement and management capabilities, including the ability to remotely turn power on or off, read usage information from a meter, detect a service outage, and so on.
For what concerns urban planning, a careful consideration over the crisis of the current developing models leads to the adoption of a sustainable approach, which has a significant impact on the process of decision-making by stakeholders, who will shape the future urban landscape.
Since the Eighties, an environmentally-oriented project planning has taken the lead: at the beginning, it interested small areas, quartiers and peri urban areas, eco-villages or eco-districts.
One of the milestones in this process consisted in the realization of the "Aalborg Charter" in 1994. It was an international initiative approved by the participants in the first European Conference on Sustainable Cities & Towns in Aalborg, Denmark. It was inspired by the Rio Earth Summit's Local Agenda 21 plan, and was developed to contribute to the European Union's Environmental Action Programme, 'Towards Sustainability'.
The initiative allowed to adopt guidelines to promote ur-

Eco district examples

Hammarby Sjöstad is one of the biggest urban development project in Sweden. Located in Stockholm, the Hammarby model describes the environmental solutions used for energy, waste, water & wastewater.
By around 2018 Hammarby Sjöstad is expected to have approximately 11,500 apartments for just over 26,000 residents, and a total of around 36,000 people living and working within the area.
Orestad is a developing city area located south of Copenhagen, Denmark.
Since the beginning, Ørestad was meant to be a sustainable city district. The urban planning focused on developing mobility infrastructure. The subway is considered the backbone of public transport, a system that also includes Railway, Airport Bridge and good bicycle lanes minimizing private car transport. The City adopted a parking strategy so that commercial and private users can share the available parking spaces.
Linz, an Austrian town is considered as a SolarCity, an energy-saving living district which ensures living space to about 4,000 people. It is an outstanding project which combines both social and environmental sustainability; it resulted from the close collaboration between architects and municipalities. SolarCity has managed to provide high class living comfort using the standard investments required in public housing, harmonising consumption, production and use of energy.
Ekoviikki, in Helsinki, is the largest sustainable building development in Finland. There, a range of environmental and energy concepts are demonstrated and it has paved the way to new planning approaches for sustainable suburbs.
Eco-criteria were set by external consultants mostly in order to maintain the area's high ecological profile: reduction of pollutants (CO_2, sidewater, site debris caused by construction, domestic waste, eco-labels); use of natural resources (reduced fossil fuels, multi-purpose use of space); Healthiness (indoor climate, moisture risk control, noise, the wind-free and sunny qualities of the site, alternative floor plans); Biodiversity (plant choices and habitat types, storm water); Nutrition (plants, soil).

ban, sustainable regeneration, defining new practices for territorial planning to mitigate the adverse effects of climate change. Those principles intended both to enhance environmental protection and human health and to integrate economic growth with social justice.
Many experiences, especially in Northern Europe, have been developed since 2000: all of them conjugate urban development with sustainable models in order to minimize energy consumption and waste production whilst maximizing the value of resources saving and recycling.
Among the most significative experiences which conjugate urban project planning, energy and environment, an initiative carried out by the city of Lyon is worth mentioning, an important project providing for recovery and urban regeneration of abandoned industrial areas.
The experience concerns the Lyon Confluence district that should become the flagship district in terms of energy efficiency mainly thanks to planning of positive-energy eco-district.
The Lyon Confluence district covers a total area of 150 hectares in the very heart of Lyon, where the rivers Rhone and Saone meet.
The interaction between public and private is one of the strengths of the intervention, addressing political-administrative issues and providing innovative technological solution.
Grand Lyon selected SPL Lyon Confluence (a local public redevelopment company) to design, realize, and promote the Lyon Confluence urban development project.

The residential development, with the construction of positive-energy buildings, allows to increase energy efficiency incorporating renewable energy, the main core of the energy project. Thanks to the massive use of cutting-edge IT technology installed in smart buildings, users should be able to control their energy consumption, and manage and analyse data collected by a Community Energy Management System.
Hikari, namely "light" in Japanese, is the name of the first positive energy block realized in France.
As a combination of needs and resources, the block is composed of three buildings, a mix of housing, offices,

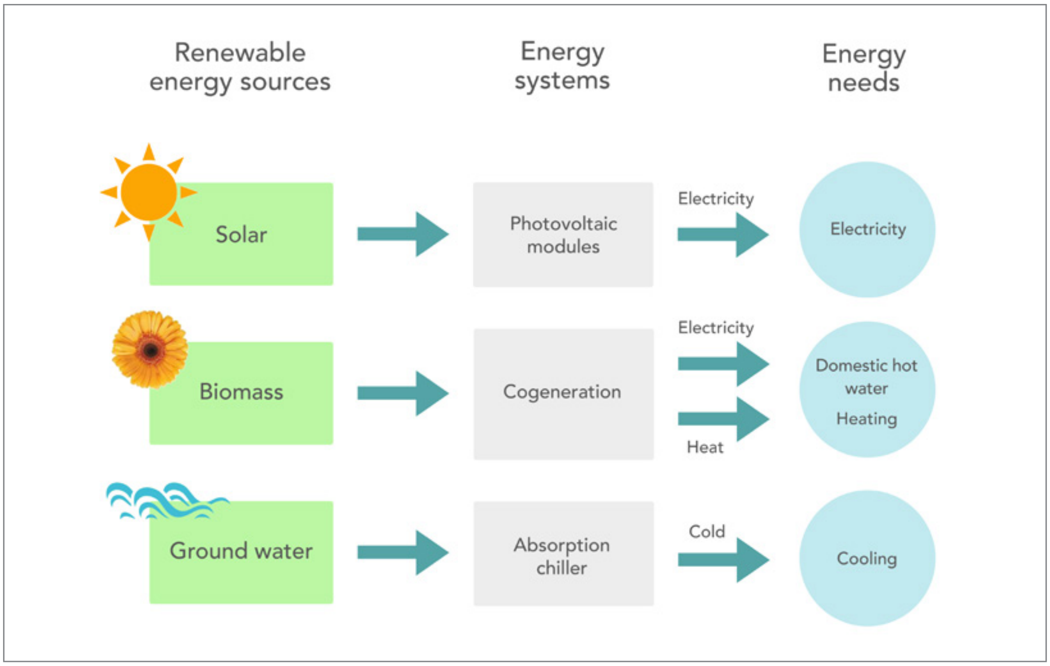

Fig 1 Hikari energy system design

and retail outlets, interconnected and with energy interchange according to the needs of each building.
The excess in energy production is stored and the surplus can be used for housing or offices according to their different needs during the day or night time.
Inaugurated in September 2016, Hikari focuses on renewable energy systems capable of ensuring on-site production of the energy supply necessary to operate the building.
Hikari consumes 50% less energy than the standard targets provided for in current thermal regulations and produces an amount of energy higher than what is consumed.
The project has been realized by Kengo Kuma, considered as one of the most innovative architects on the global panorama thanks to his expertise; he often uses technological advancements to meet the challenge posed by unexpected building materials, such as stone, wood, paper, or membranes.
The project meets the environmental and energy targets set by a specific commission created by the local authority. It combines a wide series of technological and planning solutions, related to both dimensions of energy consumption and production.
The target energy performance and the primary energy factors are based on a feasibility study that has been included in the environmental guidelines used for the international contest that selected Kuma's project.
The architect worked on both the design of the building and technological solutions in order to optimize energy consumption. He focused on the enhancement of lightning and natural ventilation systems, integrated with smart systems able to monitor the habits of the inhabitants, minimizing losses and optimizing energy management.
The energy requirements are met through the combined use of renewable energy sources, solar, biomass and hydro. Its core of 12,000 m^2 consists of three buildings, named after the three cardinal points they point to: Higashi ("East"), 5,263 m^2 of offices distributed on 7 floors, Minami ("south"), 3,400 m^2 split in 32 residential units, and Nishi ("west"), 2,246 m^2 of offices on five floors: on its roof, four urban villas have been realized. Additionally, there are 1,000 m^2 available for commercial uses, parking, and green areas overlooking the edge of the new dock.
Kuma's idea consists in improving natural lighting: as he explained during an interview:
"The architectural line we adopted led us to make deep openings in the façades in order to provide as much natural light as possible, cutting down the need for artificial

lighting and improving visual comfort."

The large glazing areas of office places and the cutting in each façade based on the sun path respond to a visual function, they want to create a sort of link between the inner and the outer space of the building.

Higashi building has a natural ventilation system in order to cool down the building. Lateral inlets favor fresh air circulation while two chimneys in the middle generate an airflow to let the heated air out.

Technological solutions are used to produce energy, to supply electricity, heating and cooling to the building. Three types of renewable energy sources available on site have been used: solar, biomass and groundwater. These sources power 3 main energy systems, solar PV modules, a combined heat power (CHP) system and an absorption chiller. Figure 1 shows the energy systems corresponding to the energy needs.

The photovoltaic system was installed on the rooftop of the 3 buildings and on the facades of MINAMI building corresponding to dwellings. The glazing areas have been used to insert photovoltaic cells that are visible from the street and from inside the flat.

In addition to photovoltaics modules, electricity is provided by a cogeneration system. A 75 kW CHP unit, powered by rapeseed oil that is stored in a 90 m^3 tank covers heat and domestic hot water needs for HIKARI building.

The cooling necessary to office places is generated by an absorption chiller, which uses heat from ground water and from the CHP.

In order to avoid discontinuity of energy production Hikari block can rely on an 8-hour heat storage made of 65 m^3 of water and is also equipped with cooling storage and power storage systems. The power storage system uses a hybrid battery (lead/acid and L-ion) with a capacity of 100 kWh.

All energy systems are managed through BEMS, the Building Energy Management System, that monitors and controls the energy performance of Hikari. More than 10,000 sensors collect information about temperature, CO_2 and humidity, in order to optimise the indoor comfort of users.

BEMS is connected with HEMS, Home Energy Management System, made of a set of devices located in every dwelling – smart water meter, control panel, PC tablet – which provide the inhabitants with energy feedback on energy saving targets.

Inspired by the Smart City approach, the Lyon Confluence project can be considered an interesting example of integrated urban planning in which the high performance of the building is crucial to achieving sustainability targets, particularly as far as the optimization of water resources and energy saving.

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