The VII Global Energy Prize Summit

Energy Center – Politecnico di Torino

April 18th 2018

Final Report

1. The climate change and the need for an energy transition

The VII Global Energy Prize Summit 2018, titled "Modelisation & simulation of energy mix in the future digital world", has provided a contribution to the scientific debate on the possible future evolution of the global energy system on the basis of two main pillar concepts:

- The energy transition towards decarbonised energy systems
- The digitalisation of the energy sector

The energy transition

The energy transition identifies the mid-/long-term evolution of the energy systems towards a scenario characterised by a significant increase in the penetration of renewable energy sources (like wind, solar, hydro, biomass and geothermal) and a correspondent reduction in the use of fossil fuels.

The need for this transition is driven by climate change phenomena, which include the global temperature rise and the consequent effects on the natural environment, in particular:

- The reduction in the Artic sea-ice extent
- The increase in the global mean sea level

As stated by international bodies and institutions, like the Intergovernmental Panel on Climate Change (IPCC), the causes of these changes are related to the increase in anthropogenic greenhouse gases (GHG) emissions with respect to the pre-industrial era. These emissions have led to atmospheric concentrations of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) that have not been reached during the last 800,000 years.

Focusing, in particular, on the CO_2 emissions, it can be noticed that the majority of them (which, at the global level, accounted for 32.3 Gt in 2015, i.e. 57.3% higher than the 1990 level) is due to six countries or regions. In fact, according to the data provided by the International Energy Agency (IEA), China (28%), the United States (15%), the European Union (10%), India (6%), Russia (5%) and Japan (4%) are responsible for 68% of the overall CO_2 emissions.

Long-term agreements and targets

This underlines how, especially for these countries, effective strategies for mid-/long-term decarbonisation are needed.

Among the most relevant international agreement, is the 2015 Paris Agreement, defined in the framework of the COP (Conference of the Parties) 21 of the United Nations Framework Convention on Climate Change (UNFCCC). The main goal of this Agreement is to counteract the impact of climate changes by limiting the increase in the global average temperature well below 2 °C above pre-industrial levels, pursuing efforts to keep it below 1.5 °C. To reach this target, the parties have been requested to set and implement their own national decarbonisation targets (expressed in the so-called Nationally Determined Contributions, NDCs), within the general aim of the Agreement. According to these goals, for instance, the EU pledged to reduce its GHG emissions by 40% from the 1990 level by 2030, while Russia proposed – for the same year (2030) – a decrease in its GHG emissions by 25-30% with respect to 1990.

During the summit, the relevance of the climate issues and the need for counteracting them has been emphasized by **dr. Marta Bonifert**, Member of the Global Energy Prize International Award Committee, Head of the Environment and Sustainability WS Leader of the Hungarian Business Leaders Forum (HBLF), who recalled that on “spaceship earth” there are no passengers, but we are all part of the crew. Bonifert stressed the need of considering that the amount of available resources is limited and consequently it is necessary to use and reuse them in and efficient and rational way. By the end of last Century, the humankind came to a crossroad: either to continue business as usual that might lead very soon to major environmental catastrophes or to re-think our way of life and establish a new way forward.

She reminded the audience that 17 of the 18 hottest years have occurred since 2001. Furthermore, according to the German insurance company Munich RE, natural disasters caused more damage in 2017 than in the previous five years, with many extreme weather events linked to climate change, including severe hurricanes, flooding and fires. Last year, natural disasters caused damages that can be quantified as nearly 330 billion USD, which is almost double the amount recorded in 2016 (175 billion USD) and second only to the year 2011 when 354 billion USD of damage was recorded. According to the UNFCCC:

- In August 2017, Tropical Storm Harvey (which led to torrential rains falling on Texas) caused damages of approximately 85 billion USD
- Hurricane Irma, which impacted Florida, Hurricane Maria, which impacted the Caribbean, and the huge forest fires in California, have also been particularly severe in terms of economic damage
- In Asia, the monsoon was unusually intense and caused the death of 2,700 people and a damage of 3.5 billion USD
- In Europe abnormally low temperatures in April 2017 caused 3.6 billion USD in damage to agriculture, of which only 650 million were covered by insurance

The mega-trends currently ongoing (like fast urbanisation, climate change, shift in global economic power, demographic and social changes and rapid technological innovation) requires visionary long-term actions driven by transformational leaders, governments, scientists, businessmen and by the society as a whole.

Regarding this point, two positive examples can be mentioned:

- The previously described Paris Agreement
- The UN 2030 Agenda for Sustainable Development, entered into force on January 1, 2016.

The 2030 Agenda, in particular, proposes 17 goals that represent, according to the former United Nations Secretary-General Ban Ki-moon, "a to-do list for people and the planet, and a blueprint for success". Among these goals, the followings can be cited as highly relevant:

- Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
- Ensure access to affordable, reliable, sustainable and modern energy for all
- Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
- Make cities and human settlements inclusive, safe, resilient and sustainable
- Ensure sustainable consumption and production patterns
- Take urgent action to combat climate change and its impact
- Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development

Both the Paris Agreement and the UN 2030 Agenda show that humankind (stakeholders, state and non-state actors, etc.) could and should work together for building a better world for generations to come and leave no one behind. Trust, partnership and cooperation are three key pillars required to face effectively the climate and energy issues in the sense of a strong global transition.

The technological options for the energy transition

The energy transition and the achievement of these environmental targets require significant structural changes in the whole energy chain, from production to the final uses of energy as well as its transmission and distribution.

For this reason several possible strategies, pathways and scenarios are currently proposed and investigated worldwide by scientific research institutions, in order to asses from a qualitative and quantitative point of view their technical feasibility and their pros and cons.

During the Summit, some of these possible perspectives and options have been described and critically discussed by the participants.

In particular, **prof. Francesco Profumo,** the Global Energy Prize expert, President of the Bruno Kessler Foundation, highlighted the possible crucial role that electricity could play, according to the "electricity triangle", which couples electricity production from renewables, transmission and distribution of electricity through ad hoc connection systems and electrification of the final uses of energy (buildings sector, industrial production, and mobility by means of electric vehicles penetration).

For doing this, two possible extreme paradigms can be followed: micro (smart) grids and large (global) interconnections:

- Micro grids allow the exploitation of locally available resources
- Global interconnections aim to link large world production zones (like Artic for wind and deserts for solar) with consumption areas through Ultra High Voltage Direct Current (UHVDC) grids for long distance (2000-5000 km) connections.

Electrification coupled to energy efficiency could represent an effective option for reaching the global decarbonisation goals, even if technical, geopolitical, market and regulatory **issues** have to be carefully considered under a holistic perspective. The energy transition can be considered a global challenge, to be addressed through innovation and cooperation, which can be assumed as keywords also for the Summit.

The role of electrification has been explored also by **dr**. **Klaus Riedle,** the 2005 Global Energy Prize laureate, honorary Professor at the University of Erlangen-Nuremberg institute of engineering thermodynamics. In particular, he investigated one of possible key element for the achievement of decarbonisation goals, i.e. the so-called “sector coupling”.

His starting consideration is that the majority of decarbonisation efforts up to now have addressed only the power sector, which is responsible for about 40% of the total primary energy consumption, taking in a limited account the other three main sectors, namely industry, transportation and buildings. The power sector uses about 40% of the primary energy and has already a share of 22% renewables, while the three other sectors – that use about 55% of the primary energy – have a share of only 8% renewables. For this reason, more inclusive and aggressive measures have to be implemented.

Among them, in particular, Riedle focuses on the “sector-coupling”, which makes electricity from renewables the backbone of all energy related services.

As for Prof. Profumo, in this approach the key commodity of the energy mix is electricity generated from renewable sources. Electricity, supported by storage systems, can allow the following options:

- “Power-to-heat”: electricity is converted into heat by means of heat pumps, thus heating houses directly or through heat storage systems.
- “Power-to-gas”: electricity can be converted into hydrogen or methane, which can be stored and/or fed into the gas pipelines and ultimately used for producing power when renewable generation is not available. A part of this gas could also be used for heating houses when requested.
- “Power-to-chemicals”: electricity is used for producing feedstock for chemical production, like ammonia, methane or hydrogen.
- “Power-to-liquid”: electricity is used for producing liquid transportation fuels, like methanol.
- “E-mobility”: electricity is used for charging batteries of electrical vehicles.

Even if theoretically simple, this process to be fully implemented requires enormous efforts, as all the existing infrastructures have to be replaced by new (and probably more expensive) ones.

Riedle analysed the effects of a possible future complete “sector-coupling” with reference to Germany. Several studies – base on different models – are available investigating the “sector coupling” in the long-term (up to 2050). The comparison among them, however, shows a huge variety in the obtained results: for instance, the expected gross electricity demand in 2050 ranges between 450 TWh and 1100 TWh (and in one model even rising to 3000 TWh); moreover, the installed capacity of wind and solar can rise from the current value of 100 GW to 160-540 GW. This demonstrates that the "sector coupling" approach is not fully settled yet. Form the cost perspective it is difficult to provide reliable numbers, but some analyses speak about 1.5-2.5 trillion euros, i.e. a really high cost, comparable to the cost of a country's reconstruction after a war.

On the basis of these findings, Riedle suggested the need for testing the "sector coupling" at a demonstration scale (in terms of development of the requested components and subsystems and assessment of their interaction, bringing them to maturity and competitive costs), in order to understand if this holistic solution could really represent a feasible long-term decarbonisation strategy to be implemented.

Even if a strong enhancement in renewables penetration is a mandatory requirement for the implementation of energy transitions, it has to be highlighted that at least in the near future, the global energy mix will be characterised by a strong dominance of the fossil fuels, as put into evidence by Professor of Hydrogeology and Engineering geology at Polytechnic University of Turin **Stefano Lo Russo**.

Lo Russo, in fact, recalled that currently about 40% of the world energy consumption is supplied by oil and about 25% by both natural gas and coal. Furthermore, future outlooks forecast an increase in the energy demand, mainly driven by the expected simultaneous growth in population and in urbanisation.

In 2050, more than 66% of the human population will live in cities. Urbanisation usually supports an increase in people's quality of life (which is positive), but also an increase in their energy consumption. A key role in this possible scenario will be played by European and Asian countries. Eurasia includes large energy consumers but also producers. For this reason, a strong integration between Europe and Asia is needed to face future energy challenges. Projects like those related to the Chinese Belt and Road Initiative (or "new silk road") – in particular, to the economic corridor linking Eastern China and Europe – and the Artic Northern Sea route could represent a significant step forward in this sense. As for prof. Profumo, also for prof. Lo Russo, however, even under a different perspective, the sharing of knowledge and the technological and scientific cooperation are crucial elements for ensuring a full efficacy in defining suitable strategies related to the evolution of energy demand and production patterns.

Like Lo Russo, **dr. Rodney Allam,** the 2012 Global Energy Prize laureate, Member of the Intergovernmental Panel on Climate Change (IPCC), awarded with the Nobel Peace Prize in 2007, emphasised that future increase in population and urbanisation will lead to a relevant increase in energy demand, which – in turn – will still rely on fossil fuels. In fact, renewable sources, hydro and nuclear account together for about 15% of the global final energy consumption, and their forecasted contribution seems not adequate for counteracting the continuously increasing emissions of CO_2, whose atmospheric concentration is presently higher than 400 ppm. For this reason, an effective decarbonisation strategy cannot avoid the introduction of technologies able to prevent the CO_2 from entering the atmosphere

Current technological options for cleaning the power generation from fossil fuels through CO_2 sequestration and storage (oxy-fuel combustion, pre-combustion capture by means of gasification, post-combustion capture via flue gas scrubbing) are characterised by a high economic impact, increasing the electricity cost by as much as 50-70%.

For this reason, Allam developed an novel power cycle (called “Allam Cycle”), which is based on the capture and use of CO_2 as working fluid. A demonstration plant is presently in the start-up phase in Texas. In this innovative cycle, the fuel (natural gas, gasified coal, or another carbonaceous fuel) is burned in a combustor using pure oxygen instead of air. The mixture of CO_2 (which represent 97.25% in mass of the total) and water (2.75%) is used in a turbine and the exhaust gas cooled in a heat exchanger. The steam is then condensed and separated from the CO_2, which – in turn – is compressed. 3.25% of this CO_2 is captured (in order to balance the amount continuously added by the combustion process) and it is ready for transmission via pipeline. The remaining 94% of CO_2 is reheated in the heat exchanger and recycled as working fluid. This cycle allows for capture of more than 97% of carbon produced and it is characterised by a high efficiency (up to 59%) and by a power generation cost that is the same as that of conventional gas turbine combined cycle systems and about 20% lower than that of of coal fired systems. This is due to the fact that this cycle require only one turbine and relatively minor other components (because it operates at high pressures and, consequently, at high power density).

Furthermore, Allam proposed another strategic option for decarbonising one of the most critical sectors of the energy system, i.e. the transport sector. In the U.S., the contribution of the transport sector to CO_2 emissions is larger than the contribution of the power sector. A possible way for solving this issue is investing in hydrogen technologies. Hydrogen can serve as an option for feeding fuel cells vehicles, which are commercially available from Japanese car manufacturers and will be soon available from Korean and Chinese manufacturers. Hydrogen can be produced in high-pressure units (at 90 bar), where natural gas and steam combined can operate with 100% CO_2 capture, and it can also be used in gas turbines for power production. The production of this commodity can be integrated with a large-scale Allam cycle: such a plant could be thus able to ensure power generation with 100% CO_2 capture and hydrogen production for other purposes, like transportation.

Dr. Tom Blees, the Global Energy Prize International Award Committee member, President of the Science Council for Global Initiatives (SCGI), also underlined the limits of carbon sequestration technologies as possible strategy for implementing an effective decarbonisation. He emphasised, in particular, that – even if the technical and economic issues related to large-scale sequestration could be solved – the focus should be not only on the use of fossil fuels, but especially on their production. In fact, mining and transportation of fossil fuels can have relevant climatic impacts:

- Coal mines release an amount of GHG that can be even higher than the amount of GHG produced by the coal combustion
- Methane (i.e. natural gas) has higher greenhouse effect than CO_2, and thus methane leakages during mining and transport phases constitute an important issue

If fossil fuels are excluded, power generation should be based on four options: solar, wind, hydroelectric and nuclear. However, the actual potential of hydro is significantly limited by the geographical constraints. Referring to wind and solar, it should be highlighted that, in order to bring every citizen in the world to the current per capita energy use of Germany, an area corresponding to the whole South America should be covered by solar panels and wind turbines.

Germany is one of the countries that most considerably devoted efforts for supporting the penetration of renewable sources, through the so-called “Energiewende”. Despite this, during winter, even if Germany had 100 times as many solar panels as they currently do, it would still not able to cover its electricity demand. In the same way, the non-dispatchability of wind does not allow for complete reliance on this source. The estimated high costs of the Energiewende transition, coupled with the fact that Germany is opening coal-fired power plants burning lignite, put into evidence that the choice of shutting down nuclear plants seems not to be the best option.

According to Blees, in fact, nuclear power, which is characterised by a low carbon footprint, can represent a crucial solution for decarbonisation strategies. If wind and solar require a surface area equal to the whole South America to power a world where every citizen has very good access to energy, a surface area approximatively corresponding to just the city of Buenos Aires is sufficient if nuclear power reactors were used instead. Among the future options of nuclear plants, he highlighted the role that low-pressure thorium molten salt reactors could play. According to a project that is currently ongoing, these units can be located on ships (that could be built – for instance – by Russia, China, Saudi Arabia, India or Korea) and moved where it is necessary to deliver electricity. They can thus be a relevant possibility especially for developing countries that have no money for building their own nuclear plants: in this way, they could access in a more easy way to electricity, enhancing the quality of life of their citizens and improving the productive sector of the country.

Dr. Rae Kwon Chung, the Global Energy Prize International Award Committee member, Adviser to the Chair of UN Secretary-General's High-level Expert and Leaders Panel (HELP) on water and disasters, shifted attention from the technical dimension of the energy transition to the policy dimension of the problem. For example, the "Energy Technology Perspective 2017" published by the IEA states that, in order to reach the Paris Agreement targets, strong policy actions have to be set. Those policies are needed, for instance, for doubling the rate of global energy efficiency improvement by 2030.

In general, however, the discussion about decarbonisation policies is characterised by a negative message spread by all the media regarding the economic sustainability of climate policies. In fact, the main question is related to the coherence between economic growth and emissions reduction and a common opinion is that investments in climate policies are too expensive, with an extremely long payback time, and may undermine economic growth.

Chung underlined instead that environmental policies can represent not a limitation but a drive force for economic growth. To reach this goal, thus coupling economic development and environmental targets, it is necessary to deepen the discussion about policies effectively able to support the energy transition and to clearly identify which kind of policies should be considered most crucial. These policies should be capable to turn the zero-sum game among the three "E" (energy, economy and environment) nexus into a win-win positive cycle among the same three "E". An example is the current price structure of the energy systems, which favours fossil fuel, which are four times more subsidised than renewables. In this sense, remove of such fossil energy subsidies and implementation of a carbon tax can be a valuable policy option for supporting a transition in the energy mix. According to several studies – that are not under the attention of media –the introduction of such a carbon tax can actually drive economic growth, new investment opportunities, job creation and the energy transition. This is contrary to the common assumption that a carbon tax would hurt economic growth.

2. The digitalisation of energy systems

The second main topic discussed during the Summit was the digitalisation of energy systems. Digitalisation is a broad topic that encompasses a number of technologies and their applications. Generally, however, digitalisation relates to the collection and translation of data into an analysable format, analysis of the data to gain actionable insights for both situational awareness and business foresight and, finally, the transformation of the insights gained into business value. In essence then, digitalisation is the convergence of the digital and physical worlds to enable entirely new business capabilities and value propositions.

Digitalisation has grown rapidly in recent years because of enhanced access to data, improved analytical capabilities and advances in computing and communications hardware. According to IBM, more than 90% of the world's data has been created since 2015 and the world's internet traffic has already surpassed 1 zettabyte annually, which is equivalent in size to about 250 billion high-definition movies. On the hardware side, microprocessors for desktop computers are now available that are computationally as powerful as supercomputers built just two decades ago. In analytics, machine learning algorithms have rapidly evolved to provide holistic solutions to problems that cannot be solved through reductionist models.

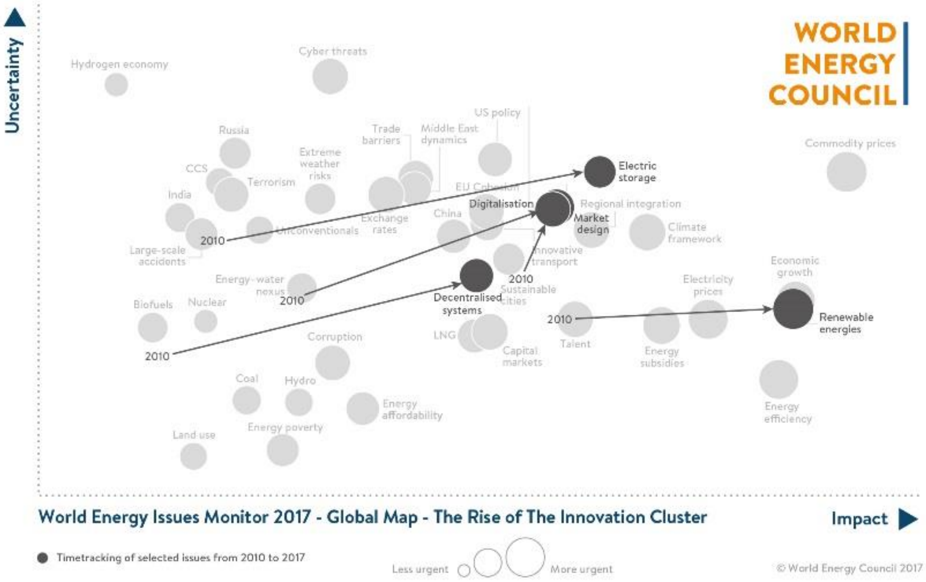
The specific set of technologies that fall under the framework of digitalisation can be classified in a number of ways. However, the following list is nearly, if not fully, inclusive of the key technologies:

- Internet-of-Things (IoT)
- Big data analytics
- Robotics and autonomous systems
- Augmented and virtual reality
- Blockchain
- Additive manufacturing (also called 3D printing)
- Artificial intelligence (A.I.)

Among the listed digital technologies, Artificial Intelligence, otherwise referred to as just A.I., has rapidly become perhaps the most important development. Andrew Ng, one of the most influential minds in A.I., has stated that "A.I. is the new electricity" due to the unprecedented potential that it has to dramatically change society. Fundamentally, A.I. is the provision of computer-based systems with human-like ability to reason, plan, solve problems, think abstractly, comprehend complex ideas, learn quickly and learn from experience. Practically speaking, A.I. is often associated with deep learning, which is a class of machine learning techniques that utilize huge amounts of data to train multi-layered neural networks to do things like identify faces and recognize spoken words. Although a number of experts argue that deep learning and other state-of-the-art analytical techniques may themselves never produce truly human-like cognitive abilities, such methods have nonetheless already begun to demonstrate the incredible potential for A.I. to provide economic value in the public and the private sectors. In the race to capitalize on this potential, multiple countries have already published A.I. strategies and more than USD 15.2 billion was invested in AI startups globally in 2017.

The prominence of A.I. and other forms of digitalisation in the energy sector is apparent from the growing importance placed on it by stakeholders in industry and government. For instance, the 2017

World Energy Issues Monitor published by the World Energy Council ranks digitalisation as one of the most impactful topics for the future of the energy sector.



The specific impacts that digitalisation is having and will continue to have on the energy industry are improved effectiveness, efficiency and safety. We may consider, for example, the following specific impacts that digitalisation is having or will have on end-use energy sectors:

- Buildings
  - Heating and cooling: smart thermostats and sensors are being used to optimize the supply of heating and cooling through demand reduction and demand shifting.
  - Lighting: sensors and software integrated into lighting systems are providing occupancy detection to reduce the use of lighting when not needed while also providing new services to enhance the value of real estate and building occupant well-being.
- Transportation
  - Personal vehicles: shared, autonomous and electric vehicles are expected to substantially reduce transportation fuel demand while improving the travel experience of consumers.
  - Commercial vehicles: drone delivery services and 3D printing are expected to reduce the need for both long-haul and short-haul shipping services, thus reducing overall energy demand from these supply-chain services.
- Industry
  - Energy efficient manufacturing: the industrial internet of things (IIOT) and artificial intelligence are enabling predictive maintenance for improved efficiency of manufacturing plant machinery and operations.
  - Product development and production: 3D printing is allowing for the rapid design of products that require reduced energy consumption during manufacturing and that ultimately are more energy efficient in their final applications.

Digitalisation is additionally at the core of an electricity system transformation in which renewables play a leading role. In order to effectively de-carbonize our global energy system, by 2050 the share

of electricity in final energy consumption will need to more than double and the share of renewables in electricity will need to more than triple from today's levels. Much of this new renewable electricity production capacity will come from intermittent solar and wind energy technologies, which in many cases will be distributed rather than centralized. Digitalisation will be essential to providing the system flexibility needed to accommodate high shares of intermittent and distributed renewable energy. Coordinated flexibility will come from supply side measures, demand side measures, energy storage and electricity grid infrastructure.
In sum, the role of digital and, –more generally, ICT technologies in the energy sector is currently growing and is expected to substantially increase during coming decades. For this reason, analysis of the benefits and challenges of digitalisation should be embedded in the planning and design phase of new energy infrastructure.

The urban dimension of digitalisation

Regarding these aspects, **dr. Steven Griffiths**, the Global Energy Prize International Award Committee member, Senior Vice President for Research and Development of the Khalifa University of Science and Technology (KUST), showed that urbanization and digitalisation are mega trends that, when considered collectively, can support the need for sustainable and smart cities.

As Lo Russo, also Griffiths underlined the expected high relevance of urbanisation (more than 65% by 2050), which highlights the importance of smart cities in future energy systems. Cities will become "smart" thanks to the adoption of digital approaches and technologies, like internet-of-things, big data analytics, artificial intelligence, robotics and drones, blockchain, augmented reality, virtual reality and 3D printing.

In particular, through the internet-of-things, this approach is able to connect the physical world (people, machines, materials, buildings, environment, etc.) to the world of information, represented by big data analytics and the related cybernetic loops, which allow for analysis of data from the real world to gain situational awareness and foresight. The internet-of-things can consequently transform information into knowledge.

Artificial intelligence, in particular, can find several applications along the energy chain, helping – for instance – the predictive maintenance in oil and gas production plants (production section) and allowing the development of autonomous driving vehicles (end-use section).

Digitalization in cities could make urban systems more affordable, environmentally friendly and liveable, in particular impacting on building and transportation systems, by increasing their efficiency. Future cities can thus be seen as a series of overlapping layers: four physical (from the bottom to the top: infrastructure, public realm, mobility and buildings) and one digital.

According to the IEA, a result of digitalisation in the buildings sector will be a cumulative reduction in energy consumption equal to approximately 65 PWh by 2040, which is about twice the energy consumed by the entire global buildings sector in 2017. Moreover, digitalisation could support energy demand response measures, like the shifting of heating loads, cooling loads and use of electrical appliances and optimal charging strategies for electric vehicles. By 2040, 20% of electricity demand could be met by demand response, which will allow the maximisation of the value of intermittent renewable sources (such as wind and solar) and the minimisation of the need for generation capacity dedicated to load balancing: this could reduce solar and wind curtailment from 7% to 1.6% in the EU by 2040.

Referring to the transport sector, digitalisation is likely to result in a significant reduction in the demand for refined oil products, due to the deployment of high numbers of autonomous, shared and electric vehicles. The urban environment is, in fact, ideal for such a transportation system and, according to Bloomberg New Energy Finance, the penetration of these vehicles could lead to a decrease in the global oil demand by more than 5 million barrels per day by 2035.

In general, Griffiths emphasised that digitalisation will probably have a deep impact on the future (but also on the current) global energy system. A large part of world urban population will certainly take advantages from it, while some industries (like the as oil and gas ones) will need to modify their business models in order to accommodate the profound effects that digitalisation will have across sectors.

The impact of digitalisation in the electricity systems

Dr. Sauro Pasini, the Global Energy Prize expert, President of the International Flame Research Foundation, focused his discussion on the evolution of the electricity systemsand on the impact of digitalisation on the electricity sector. The three main pillars of this evolution are represented by:

- Investment in renewables:
  Presently they are starting to be competitive in certain areas of the world with respect to conventional sources; in 2016 they corresponded to 62% of the newly installed capacity worldwide and to 90% in Europe, and are expected to become more than 70% of the newly installed capacity in the period 2017-2040.

- Decentralization:
  Renewable energy is very often decentralised. For instance, during the last 10 years Italy has invested in 20 GW of renewable energy. These 20 GW correspond to about 730,000 power plants, which means that the average size of each plant is around 27 kW, i.e. very small.

- Electrical mobility:
  Currently its penetration it is quite low, but by 2040 the annual sales of electric cars are expected to exceed the sales ICE vehicles, Annual sales of electric vehicles may reach more than 50% of all new light-duty vehicle sales by 2040, resulting in approximately 33% of the total global light-duty vehicle fleet being electric.

According to this possible evolution, the management of the electrical networks will become more and more complex and crucial: intermittency of generation from renewables, decentralised generation, the presence of prosumers, automation and control of connected systems are some of the most relevant aspects that have to be considered in this new management perspective.

In this sense, a strategic role could be played by digitalisation. Data generation through *ad hoc* sensor systems, data acquisition by means of communication protocols and data processing through big data analytics approaches, coupled with the availability of artificial intelligence for machine learning are key opportunities created by digitalisation.

Dr. Pasini described four examples showing how digitalisation has been already developed and is being used:

- Home energy management:
  It is the combination of an energy management system, that manages the sharing of electricity among the various home devices and the integration with the self-electricity production and storage (solar photovoltaic, batteries, vehicle-to-grid system), and of a data management system, which optimises the energy consumption.

- Demand response:
  It is a temporary change in the electricity consumption in response to market or reliability signals, in order to shift electricity use across the daily hours in order to solve the issue of balancing generation and demand arising from the intermittency of renewables like solar and wind.

- Virtual power plant:
  It is a control centre that integrates several types of distributed power sources to give a reliable overall power source (dispatchable and non-dispatchable distributed generation, controlled by a central authority).

- DER management system:
  It allows to integrate more distributed solar, energy storage, demand response and other energy resources on the grid, in order to improve its operation.

In this way, the energy system could evolve according the so-called "internet of energy", a sort of electricity network in which generation, distribution and demand are optimised at an entire system level. In this vision, everything is connected, and – even if electricity is the main commodity in this interconnected and digitalised world – also other commodities like natural gas and heat can enter into this system, making it even more complex but more useful as well.

3. Energy transition and digitalisation: advantages and possible issues

Uncertainties and critical aspects

In his speech, **dr. Dominique Fache,** the Global Energy Prize expert, Chairman of the Board of Directors of RTF, synthesised some of the crucial aspects that emerged during the different interventions in the Summit.

The first one is the radical transformation in the energy system that is already ongoing and that will increase in the future. This transformation leads to several uncertainties regarding the long-term investments in the energy sector. For instance, Germany decided the nuclear phase-out. In France (where about 70% of electricity is produced through nuclear power stations), the government is thinking about a possible closure of some nuclear plants. Investments in traditional fossil sources are strongly affected by geopolitics over long time horizons. Consequently, energy companies have to face these dilemmas and will have to change their business models to survive. For example, more than a year ago Total bought Saft, a lithium batteries manufacturer that does not belong to the oil business, while Elon Musk, CEO of Tesla, is building a giant battery plant.

In fact, technological innovation can create new business and job opportunities, leading to the rise of new companies but also to the disappearance or modification of others.

Regarding the strategies for counteracting climate change issues, according to Fache a price on CO_2 emissions around 100 USD/ton should be put in order to make international targets like the Paris Agreement really effective.

Finally, Fache underlined that digitalisation – besides the positive aspects put into evidence by the other speakers – it is characterised by some criticalities that have to be carefully taken into consideration when forecasting and planning energy system.

For instance, a single transaction bitcoin block creation transaction results in energy consumption corresponding to the daily consumption of an average home. This could represent a huge problem for future energy systems (and, consequently, for the related emissions) if this digital cryptocurrency market should increase significantly in its current form.

Referring instead to the digitalisation of the energy systems, it could open the door to new threats, in particular terrorist threats. Smart technologies and digital power engineering can thus make energy systems more open to cyberattacks, which can especially affect the electrical grid, leading to possible sudden power outages and wide scale impacts.

Coupling and implementing decarbonisation strategies and energy digitalisation: a challenge for a cooperative world

The Global Energy Prize Summit 2018 allowed investigation of the main benefits but also the most relevant issues that can arise from the expected future transition of the global energy mix. Two key aspects, energy transition towards decarbonisation and digitalisation of energy systems, have been analysed according to their different technological dimensions, exploring the possible long-term alternative scenarios. In consideration of these scenarios the role that electrification of final energy uses can play, and the technical, security and political issues that this evolution may encounter must be highlighted.

Some of the crucial aspects of the energy transition that must be taken into account through high level scientific researches and debates include:

- significant penetration of intermittent renewables in the power sector coupled with that result in the need for a radically different structure of power networks, such aslarge global interconnections or small-scale decentralised systems
- the relevance that fossil fuels could still have, at least in the near future
- the effectiveness of the carbon capture and utilization options
- the role of nuclear in future power systems
- the need for *ad hoc* policies (like carbon taxation) able to support the transition phase .

Furthermore, the digitalisation of energy is strongly related to the energy transition and complementary to it. In fact, electricity-based systems will be increasingly coupled with digital systems for their management and optimisation.

Digitalisation could thus ensure an effective support to the energy transition, allowing the control of complex systems and – at the same time – the enhancement in overall system efficiency. From the opposite perspective, digitalisation could represent an issue with respect to new kind of threats, like the “energy terrorism”.

In general, however, the most important element that emerged from the debate is the need for a wide-scale cooperation among all the involved actors: scientists, research bodies and institutions, energy companies and decision makers.

Only an actual sharing of knowledge and best practices and the identification of commons standards from both the technical and regulatory point of view will lead to the development and implementation of a long-term strategic energy planning that is beneficial at a global level and relevant to all the of the key perspectives: environmental, technological and economic.