A EUREKA initiative

For Low Carbon Energy Technologies

TECHNOLOGY ROADMAP

(ANNEX to the MAP)

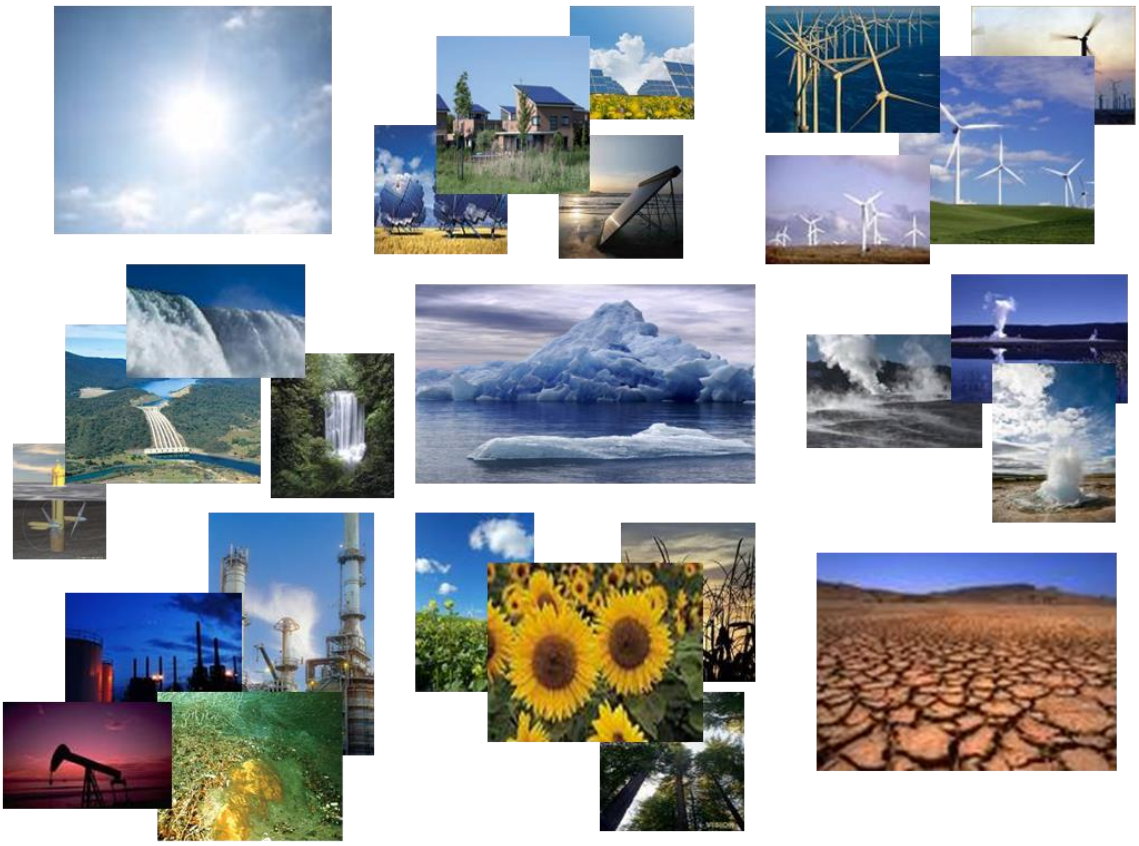

Table of Contents

Introduction to Eurogia2030 Technology Roadmap

As discussed in the White Book, the goal of this Technology Roadmap is to provide a list of topics that can be the object of EUROGIA2030 projects. This cannot be exhaustive; all other topics that feature innovation used in the marketplace to reduce the carbon footprint of the energy system can potentially qualify for a EUROGIA2030 project. But it is hoped that the list provides help to clarify the contours of the EUROGIA2030 domain of low-carbon energy technologies.

The structure of the Eurogia2030 Technology Roadmap reflects the latest strategy adopted by Eurogia, the 5Ds strategy: Decarbonisation, Decentralisation, Digitalisation, Democratisation and Deregulation. The intent is to look at the Low-Carbon technologies "state-of-the-art" in relation to this strategy.

Electric power networks are experiencing large deployment of distributed generation and storage along with electrified transport and heat loads. The efforts towards decarbonization, decentralization, digitalization, deregulation and democratization bring together critical challenges and shape the necessities for network planning and operation. There are also emerging approaches to provide electricity in highly rural and geographically challenging areas far from the existing interconnected grid infrastructures.

Last but not least, it should be borne in mind that the decarbonization of the Industry and Energy Sectors shall be performed as rapidly as possible in order to meet the net zero CO2 emissions objective in 2050 set forth by the IPCC (Intergovernmental Panel on Climate Change).

As a result, the development of new decarbonization related technologies already featuring a high TRL and potentially deployable from mature industries should be accelerated and completed within the next decade i.e. by 2030. This pragmatic strategy, however, should be implemented whilst pursuing a strong R&D policy aimed at bringing up even more efficient and cost-effective new technologies beyond 2030 so as to achieve a successful Energy Transition in 2050.

5Ds Strategy

1. Decarbonisation

Eurogia2030 will support innovative projects on:

- Renewable Energy resources
- Electric vehicles and charging infrastructure,
- Green and zero emission buildings,
- H2 technologies and Storage.
- Carbon Capture, Sequestration and Utilization

a) Renewable Energy resources

i) Biomass

- **Vision**

Biomass is a renewable energy source that can provide energy to be used for heating and cooling, electricity and transport.

Biomass fuels can be stored, meeting both peak and baseline energy demands. In the form of biofuels (solid, liquid or gaseous), biomass can directly replace fossil fuels (solid, liquid and gaseous), either fully or in blends of various percentages. In the latter case, there is often no need for equipment modifications.

Bioenergy is CO2 neutral, if biomass is produced in a sustainable manner. Bioenergy can contribute to important elements of national/regional development: economic growth and employment; import substitution with direct and indirect effects on GDP and trade balance; security of energy supply and diversification. Other benefits can include support of traditional industries, rural diversification and the economic development of rural areas. Additionally, biomass fuels can be traded on local, national and international markets, and it is expected that the international trade in this sector will play a major role for the development of a bio-based economy.

BIOMASS TECHNOLOGY CHALLENGES
Biomass heat • **Boilers/stoves**

• New plants • Logistic network
Combined Heat and Power (CHP) • Stirling engine • Gasification process • Hot air turbine • Micro steam engine • Organic Ranking Cycle (ORC)
Electricity production • Biomass preparation system • Biomass combustion systems • Biomass conversion systems • Biomass-integrated gasification • Biomass externally fired gas turbines.
Biofuels for transport • Biological fermentations • Thermo chemical gasification • Bio ethanol production from lignocelluloses • Biodiesel produced by hydro cracking of vegetable oil and animal fats.
Feedstock • New higher-yield crops • Efficient feedstock collection and transport

ii) Wind

- **Vision**

Modern wind power technology is largely based on know-how gathered from European R&D and deployment activities related to inland (onshore) wind energy. Onshore electricity production from wind energy is a mature technology. Ongoing R&D efforts are primarily focused on maximizing the value of wind energy and taking the technology offshore. Capital investment costs for wind generation plants are of the order of €1000 to €1400 per kW for onshore technology (inclusive of grid connection costs), and €2000 to €3500 per kW for offshore (inclusive of grid connection costs), even up to €7000 for deep offshore in water depth exceeding 50m. Typically, average capacity factors for wind power installations are 1,800-2,200 full-load hours onshore and 3,500-4,000 full-load hours offshore.

The main technological development in recent years is a trend towards ever larger wind turbines (WTs). Since the first commercial WTs of the 1980s, WT size has evolved from 0.022 MW to multi-MW machines of about 6 MW today (onshore wind). Currently the average turbine size in the EU is around 1.3 MW onshore and 2.1 MW offshore. By 2030, average turbine size will still increase with huge turbines of more than 10 MW being developed for both on- and off- shore, with gigawatt (GW)- size wind farms likely for offshore. The recent push in scaling-up of turbine size is driven primarily by the move to take the technology offshore, as higher wind speeds and lower turbulence can be encountered there. Moreover, the move is important as fewer suitable onshore sites are still available due to land constraints. The further up scaling of wind turbines leads to new challenges in the field of load control and wind turbine construction materials. Moving offshore also means increased technological focus on foundations and materials adapted to the marine environment. In the near term, continued wind deployment will need to be accompanied by developments in storage technologies and increased grid flexibility, to be able to accommodate increasing levels of wind energy penetration in the electricity network. However, the availability of suitable shallow depth onshore sites is also reaching a limit or is simply null in many coastal aeras.

New technology is needed to install wind farms in deeper areas using floating structures. With respect to the global wind energy scene, the EU has been one of the front-runners in innovation and is a lead player on the market. However, wind energy is also experiencing a surge in emerging economies, such as India and China, and is finding use in developing countries in non-energy sectors, such as water desalination. Chinese manufacturers are rapidly taking the lead in terms of volume and power installed, so it is critical for European suppliers to continue to develop new technologies in order to remain competitive.

WIND TECHNOLOGY CHALLENGES
Wind Turbine & Component Design Issues • **New materials with higher strength as well as higher internal damping.** • **Advanced manufacturing technologies. flexible blades & hubs** • **Progress in electric generator systems, (variable speed, no rare earth use …)** • **Reliability models leading to higher wind farm availability – particularly relevant regarding offshore turbines.** • **Integration of demand side requirements in the design of turbines,(electrical control system interaction with grid requirement.)** • **Component design, such as longer blades, and electrical components.** • **Recyclable blades**
Mega Watt and Multi-Megawatt Wind Turbines • **Fundamental wind turbine design research (aerodynamics, aero elasticity, structural design, loads and safety, control, etc.)**

• **Development of test facilities to follow turbine developments.** • **Modeling of O&M requirements for large turbines, before installation.** • **Reliability of multi megawatt turbines**.
Offshore Wind Technology • **Higher tip speed designs** • **Special designs of systems and components for erection, access and maintenance of offshore turbines** • **Design studies of systems rated above 10 MW for offshore including possibly multi-rotor systems.** • **Offshore meteorology – shore and long-term forecasting; hardware for measurements.** • **Development of alternative and deep-water foundation structures.**
Floating Offshore wind technology • **Optimized floater development** • **Specific rotor and blade control strategy** • **Combined wind and wave loading.**
Operation & Maintenance • **Advanced condition monitoring** • **Development of early failure detection and condition systems.** • **Developments in preventative maintenance.** • **Standardization of components** • **Certification of service and maintenance concepts.** • **Better techniques for assessing wind turbine and wind park performance in situ.** • **Energy Storage**

iii) Solar

PV Power generation

- **Vision**

Photovoltaic (PV) systems are currently based predominantly on crystalline silicon technology and are mature for a wide range of applications. This technology benefits now from a highly effective industrialisation and economies of scales based on products standardisation and component mass production.

Today the average turn-key price of a small to medium size (3 to 20 kWp) PV system (rooftop) is €5/Wp and for large systems in the multi MWp range about 1 €/Wp. The efficiency of commercial flat-plate modules and of commercial concentrator modules is up to 15% and 25%, respectively.

The typical system energy pay-back time depends on the location of the installation. In southern Europe it is typically over 20 years and increases at higher latitudes. Feed-in tariffs or other incentives can reduce the pay-back time for the end user to only a couple of years in some countries. The average generation cost of electricity (LCOE) today is about 30 c€/kWh, ranging between 20 and 45 c€/kWh depending on the location of the system.

Pay-back times and LCOE should be updated by considering large solar PV farm projects (> 300 MWp) commissioned since 2017 in Europe (France, Spain), India, China, UAE and US which would allow LCOE values now below 50 € / MWhe and in some cases, reaching 30 € / MWhe. However, it should be noted that LCOE is very sensitive to WACC value selected and comparison between 2010 and 2020 figures is not straight forward in this respect.

Crystalline silicon-based systems are expected to remain the dominant PV technology in the short term. In the medium term, thin films will be introduced as integral parts of new and retrofitted buildings. In the longer term, new and emerging technologies will come to the market, such as high concentration devices that are better suited for large grid-connected multi-MW systems, and compact concentrating PV systems for integration in buildings. With the proper research into enabling technologies, it is expected that crystalline silicon, thin films and other technologies will have equal shares in the installed PV capacity by 2030.

The cost of a typical turn-key system may be halved to €2.5/Wp in 2015, and reach €1/Wp in 2030 – already attained in 2020 for large utility-scale solar PV farms - and €0.5/Wp in the longer term. Simultaneously, module efficiencies may also increase. Flat-panel module efficiencies could reach 30% in and up to 40% in the long term, while concentrator module efficiencies could reach 60% in the long term.

Concentrated solar power generation

- **Vision**

After 10 to 12 years of slow development, concentrated solar thermal power sector (CSP) is now reviving due notably to a favourable supporting framework in Spain and increasing investments in the USA. Concentrated solar power plants (CSP) consist, schematically, of solar concentrator systems made of a receiver and collector to produce heat and a power block (in most cases a Rankine cycle). Three main CSP technologies are under development: Trough, Tower/Central and Dish. Today CSP technologies are in the stage of first commercial deployment for power production in Europe.

Due to past developments in the USA (~350 MWe in operation since 1980), the most mature large-scale technology is the parabolic trough/ heat transfer medium system. In Europe, a parabolic trough power plant of 50 MWe power capacity with more than 7.5 hours of storage (Andasol 1) has been constructed in Granada in Spain. Two more plants of 50 MWe each are scheduled to be built on this site.

Central receiving systems (solar tower) is the second main family of CSP technology. An 11 MWe saturated steam central receiver project, named PS 10, is operating in Andalucia. This is the first commercial scale project operating in Europe. Solar Tres is another project under construction in Spain based on a molten salt central receiver system.

Parabolic Dish engines or turbines (e.g. using a Stirling or a small gas turbine) are promising modular systems of relatively small size (between 5 to 50 kWe), in the development phase, and are primarily designed for decentralised power supply.

The solar only average load factor without thermal storage of a CSP plant is about 1800 to 2500 full-load hours per year. The level of dispatching from CSP technologies can be augmented and secured with thermal storage or with hybridized or combined cycle schemes with natural gas, an important attribute for connection to a conventional grid. For instance, in the Solar Tres project, 15 hours molten salt storage is included leading to a capacity factor of 64% without fossil fuel power back-up.

Several integrated solar combined cycle projects using solar and natural gas are under development, for instance, in Algeria, Egypt, India, Italy and Morocco.

Capital investment for solar-only reference systems of 50 MWe are currently of the order of 3 300 to 4 500 €/kWe. The upper limit accounts for systems with thermal storage to achieve capacity factor of between 5,000 to 6,000 hours. Depending on the direct normal insolation (DNI), the cost of electricity production is currently in the order of 20 c€/kWh (South Europe – DNI: 1,700 kWh/m2/a). For DNI in the range of 2,200 or 2,500 as encountered in the Sahara region or in the USA, the current cost could be decreased by 20% to 30%. The important resource base in neighbouring Mediterranean countries of Europe makes it possible to envisage importing CSP energy (and solar PV energy as well). For a given DNI, cost reduction of the order of 25% to 35% should be achievable with technological innovations and process scaling up to 50 MWe. Facility scaling up to 400 MWe could result in further cost reduction of the order of 15%.

Solar Heating and Cooling

- **Vision**

Solar-thermal systems currently installed in Europe (active and passive) are predominantly based on glazed flat plate and evacuated tube collectors. The vast majority of the European capacity (90%) comprises single family house units used for the supply of domestic hot water. The remaining capacity consists of an equal share of domestic hot water – multi-family house units, and, single family house combi-systems that deliver both hot water and space heating. In addition, there are a few large scale systems installed in Denmark, Sweden, Germany and Austria which deliver heat to district heating networks. Some of them are coupled with seasonal heat storage. Finally, there are a limited number of installations in industrial sites for the provision of low temperature process heat.

The average turn-key cost of a solar-thermal system today is about €1100/kWth for pumped systems installed in central and northern Europe, and €600/kWth for thermo-siphon systems, which are used typically in southern Europe. In general, the former type of equipment can meet 50-70% of the hot water needs for a house, generating 500-650 kWh of useful heat for each kWth installed. The latter type of system can provide 70-90% of the hot water requirements of a building generating 700-1000 kWh for each kWth installed.

The solar-thermal technology that can provide all heating and cooling needs of a building with good insulation has already been demonstrated. Further technological developments are anticipated in the near term, which will improve the competitiveness of the technology and facilitate the expansion of the solar-thermal market. These technology improvements include the development of new systems that will incorporate superior collectors based on advanced polymeric materials, vacuum insulation and sophisticated heat storage media, combined with intelligent heat management controls. These systems will be integrated in new and retrofitted buildings with new insulation, such as in facades, to provide hot water, and space heating and space cooling. In addition, the technology of concentrated collectors will be further developed for use in systems that will provide low and medium temperature process heat to the industrial sector. If the solar-thermal capacity in Europe continues to expand, it is expected that system costs for small scale forced circulation units installed in central Europe will be decreased to €400/KWth by 2030.

SOLAR TECHNOLOGY CHALLENGES
Solar PV • Silicon product • Cells • PV systems • Energy storage
Concentrated Solar • Sensors • Heat transfer • CS System • Energy storage
Solar Heating and Cooling • Sensors • Systems • Materials • Heat Storage

iv) Hydro Power Generation

- **Vision**

Hydropower is often seen as a mature renewable power generation technology. At present, it amounts to 70% of the electricity generated from renewable energy sources in Europe or 10% of the total electricity production in the EU. However, market developments continue to bring new technical challenges that require RD&D projects.

The large and medium scale hydropower market (>10 MWe) – referred to hereafter as large scale- is a well-established market in Europe. More than 50% of favourable sites have already been exploited across the EU. Yet, this market is still evolving. Three main drivers are pushing developments in this field: 1) the erection of large new hydropower plants, with a huge market potential in India and China but also, to a lesser extent, in Europe, 2) the rehabilitation and refurbishment of existing hydropower facilities, and 3) the need for additional renewable power capacities.

The refurbishment market segment is of interest for Europe with overall, an aging hydropower park, but also to ensure that no energy capacity losses are incurred with the implementation of higher environmental standards. Efficiency improvements that can be expected from upgrading operations are on the order of 5%. Equally interesting for Europe is the need for new renewable power capacities as embedded in the European targets for renewable energy by 2010 and 2020 and the correlated needs for back-up/firming capacities to ensure grid stability due to increasing penetration of intermittent power generation. Hydro technologies can make a significant contribution to this topic as a storage technology. A renewed and growing interest for pumped storage schemes has been seen in the last 5 years in Europe. These systems develop cycle efficiencies of the order of 80%. For all these markets, hydropower technical and economic performances are very dependent on the site specifications and utilities' operating strategies. Average load factors of large-scale hydropower plants range from 2 200 to 6 200 full-load hours per year in Europe, with an average at about 3 000 to 3 500 hrs. Capital investment costs for building large hydropower facilities (> 250 MW) are of the order of 800 to 3 700 €/kWe. Capital cost for hydro-pumped storage is of the same order of magnitude.

About 11 GWe of small-scale hydropower (<10 MWe) are operating in the EU. The largest remaining potential in Europe lies in low head plants (< 15m) and in the refurbishment of existing facilities. About 65% of Small Hydro plants located in Western Europe and 50% in Eastern Europe are more than 40 years old. Similarly, to large hydropower plants, capital investment costs are project characteristics dependent. Average capital costs for small hydropower plants are of the order of 1 200 to 3 500 €/kW. Of particular interest, very low head hydro turbines (head < 5m) is a promising distributed generation technology that can be implemented, for instance, in presently untapped water resources (e.g., waterways), with about 1 to 1.5GW potential in Europe. These systems are now in the demonstration stage. Typical power rating is of the order of a few hundreds of kWe to 1MWe.

Finally, an additional important driver for the development of the whole sector in Europe can be the multipurpose concept. Hydropower can be implemented in combination with other hydro activities such as flood regulations, wetland management with no additional water resources and environmental impacts. It is noted that climate change can have an important influence on water resources.

Three large European companies are active in the large to medium scale hydropower market worldwide. These companies are currently facing strong international competition (e.g. USA, China and India). The market for small hydropower is more accessible to small companies, with several European manufacturers with a recognised worldwide industrial position.

HYDRO TECHNOLOGY CHALLENGES
Hydro power generation • **Turbines** • **New Generators** • **Grid connection** • **Control system** • **Environmental impact**

v) Ocean Power Generation

- **Vision**

There are several forms of ocean power, such as wave and tidal energy, marine currents, thermal energy. Offshore wind power is sometimes included because it has some specific features shared with other ocean power sources: in this document it is addressed within the wind power section.

It is noted that technology developments in the different fields of ocean energy have taken place worldwide since the 60's, as illustrated by the 240 MW tidal power plant of La Rance in France.

Despite the fact that there is no favorable site around European coasts for some of the ocean power sources (namely oceanic current or ocean thermal energy conversion), these sources of energy are part of the global potential for reducing-CO2 emission worldwide in electricity or H2 production and may constitute development opportunities for the European industry in energy and ocean engineering sectors.

The utilization of ocean power can be particularly considered in places such as islands, remote coastal areas etc as part of an energy mix (including solar and wind energy for example).

OCEAN POWER TECHNOLOGY CHALLENGES
Generic • **Grid connection** • **Fouling assessment and mitigation techniques** • **Specific environment and available resource assessment** • **Environmental impact** • **Electrical energy export (dynamic) line development (including subsea high voltage electrical sliprings, subsea substation etc.)**
Ocean wave and current power generation • **Dedicated Cost-effective Systems development** • **Progress in specific structural modelling techniques and testing facilities**
Ocean thermal energy • **Innovative cold water intake pipe design and installation techniques** • **Innovation in thermal exchangers design and efficiency preservation (antifouling techniques)**

v) Geothermal

- **Vision**

The geothermal energy sector comprises electric power production and heat production sectors.

A further distinction is made for the heat sector according to whether the geothermal energy is used directly (low and medium temperature applications) or indirectly (very low temperature applications or heat pumps).

Capital investment costs related to geothermal electric installations are of the order of 1500 €/kW. In the heat sector, investment costs for direct heat district heating systems range from 300 to 1000 €/kW, and for geothermal heat pumps, approximately €2000 per kW of capacity, with average capacities of 5-20 kWth. Average system availability for geothermal energy applications is around 95%. In the power sector, geothermal energy is used primarily as base load supply, and thus has a high load factor of approximately 8000 full-load hours. In the heating sector the load factor is much more variable.

Various levels of technological maturity exist, depending on the specific energy product (electricity or heat) and, in the case of heat, the conversion process, where geothermal energy may be used directly (e.g. district heating) or indirectly (e.g. heat pumps). In the electricity sector, current focus is on R&D in enhanced geothermal systems (EGS), the main avenue, currently, for expanding geothermal electricity generation in the EU. In addition, possibilities for exploiting low temperature resources via binary plant technology are an area of focus. In the heat sector, for direct-use applications, such as district heating (DH), efforts are directed at identification of new markets, for example in Eastern Europe; while, for indirect-use applications (heat pumps), attention is on deployment.

In terms of development of the geothermal sector as a whole, identification and exploitation of alternative and cascading uses of geothermal energy will be important for improving the economics of the technology. There is scope for transfer of knowledge between sub-sectors, and thus significant savings.

GEOTHERMAL TECHNOLOGY CHALLENGES
Shallow and Deep Geothermal • **Exploration** • **Drilling techniques** • **Production systems** • **New equipment** • **Standardization** • **Environmental impact**
Heat Pumps • **Gas driven HP** • **Solar driven HP** • **HP for cooling**

b)Energy Efficiency

- **Vision**

Another important thus the cheapest energy resource is Energy efficiency. Every analysis of future energy use and corresponding projections of future greenhouse gas emissions show that efficiency gains must provide the largest part of the required reductions in CO2 emissions. The overall efficiency of the world energy systems, from raw primary energy to end-use, does not exceed 1 or 2%. Tremendous efficiency gains are possible with the right technologies.

Improvements must cover all sectors from energy use by consumers (vehicles, heating, cooling, lighting, appliances…) through public use (lighting, airplanes, trains…) to all industrial processes (power generation, energy transport, industrial heating, minerals, metallurgical and transformation industries, cement, electronics…). The range of required R&D is enormous, and touches all branches of science and technology. In addition to end use efficiency, tremendous progress is also expected from better matching of the timing of energy consumption and energy generation; this is often described as “smart grid” but goes beyond just the electricity grid, to include all sources of heating and cooling. Improved technologies for energy storage at all scales from the small and local to the national or even transnational grid scale need to be a key part of these developments.

- **Technology challenges**

It is not possible to list here even a small part of the myriad of challenges posed by reducing energy inefficiencies in all human activities. Efficiency in transport calls for new materials, improved engines and power trains, improved tyres and roads, as well as brand new mobility management systems. Efficiency in power generation involves new processes, systematic heat recovery, improved turbines, improved process control, cost effective combined heat and power generation at various scales… Efficiency in lighting requires the development of new light sources, such as LEDs, and improved lighting management. Efficiency in heating and cooling calls for innovation in materials, in energy storage, in process control, in construction techniques… Efficiency in each industrial sector requires its own set of technological innovations to avoid waste in energy and materials usage.

Materials recycling, although a key component of energy efficiency in the industrial sector, is not per se within the EUROGIA 2030 domain. However, when coupled with energy production from part of a waste stream, it fits fully within the scope of EUROGIA 2030 (e.g. generation of heat or electricity from a municipal waste-stream with recycling of heavy metals contained in the ashes).

c) Electric vehicles and charging infrastructure

- **Vision**

Electric vehicles have an important role to play in meeting air quality legislation and the EU’s commitment to climate change targets. For these reasons, the EU is actively supporting the switch to electric vehicles.

Sales of electric cars have reached to 2.1 million globally in 2019, surpassing 2018 to boost the stock to 7.2 million electric cars. Electric cars, which accounted for 2.6% of global car sales and about 1% of global car stock in 2019, registered a 40% year-on-year increase. The market has been almost doubling in every two years since 2010, with usually above 50% year-on-year growth rates. Despite the pandemic challenges, 2020 was a record-breaking year for electric mobility with over 3 million annual sales and market 43% growth. There are over 10 million EVs on the road globally. The major drivers are vehicle and charger regulations, incentives, targets, industrial subsidies, technology advances towards increased energy density and reduced battery costs together with growing manufacturing capacity and improving manufacturing platforms for EVs and batteries. There are over 80 cars currently available in the market and over 50 more are on the wayAs technological progress in the electrification of two/three-wheelers, buses, and trucks advances and the market for them grows, electric vehicles are expanding significantly. Ambitious policy announcements have been critical in stimulating the electric-vehicle rollout in major vehicle markets in recent years. In 2019, indications of a continuing shift from direct subsidies to policy approaches that rely more on regulatory and other structural measures – including zero-emission vehicles mandates and fuel economy standards – have set clear, long-term signals to the auto industry and consumers that support the transition in an economically sustainable manner for governments.

Energy storage capability of the current cars in the market is between 16.6 to around 80 kWh, while the announced concept models are up to 200 kWh [2]. Driving range is between 90 and 460 km, which is expected to reach up to 970 km with the announced models. In 2030, the global stock is expected to reach 130 to 250 million and annual sales are projected to be between 23 to 43 million.

For many users, with the increase in battery size of electric vehicles, considerably more energy can be stored than the average daily commute requires. A large electric vehicle parking facility creates a major opportunity to provide battery storage capacity to electric system which enables more renewable generation by eliminating network constraints. Other users need a larger range over which a vehicle can travel on a single charge, with a shorter time taken to recharge the vehicle. As a result of greater range supply EV's requires larger battery pack and increasing the time taken to recharge the battery used.

By the end of 2019, there were 7.3 million electric vehicle chargers installed worldwide, of which 6.5 million chargers were private light-duty vehicle (LDV) slow or normal chargers. The stock of chargers increased by 40% from 5.2 million in 2018.

The analysis presented shows that the coverage of charging infrastructure has progressed in line with the electric vehicle market until now. But now more than ever, it is key to have the right regulatory and funding frameworks, indispensable for lowering the barriers for EV adoption for the charging infrastructure deployment to continue progressing in the right direction.

ELECTRIC VEHICLES AND CHARGING INFRASTRUCTURE – Technology Challenges
Electric Vehicles and Grid Operation • **Hosting capacity determination** • **Hosting capacity improvement** • **Battery health preservation** • **Customer interfaces for energy management**
Charging Infrastructure Management • **Grid-oriented charging services provision**

• **Market-centered charging services provision** • **Novel charging methodologies** • **V2G services provision and smart inverter functions** • **Charging profile and customer behavior analysis**

d)H2 technologies and Storage

- **Vision**

Hydrogen is presently used mainly (95 %) as a "chemical matter" for industrial applications including refining, ammonia and fertilizers production, chemicals, methanol, metallurgy, etc.

Industrial hydrogen is produced by steam reforming processes based on either coal or methane, both processes emitting substantial CO2 per kg of hydrogen.

Using large volumes of low-carbon hydrogen will then contribute significantly to the decarbonisation of the Industry Sector needing hydrogen.

Besides, hydrogen is also widely recognised as a potentially important low-carbon "energy carrier" which could contribute to reduce greenhouse gas emissions from the Transportation Sector through the development of a comprehensive supply chain, from mass production to widespread transport and distribution up to the refuelling pump.

Fuel cells are widely acknowledged to be the technology of choice for turning hydrogen into electrical power (although internal combustion engines are another option). These intrinsically clean energy converters can be used for a wide range of energy-consuming applications, including small portable devices, small and large combined heat and power, as well as road, rail, sea transport applications.

HYDROGEN TECHNOLOGY CHALLENGES
Hydrogen production • **Chemical conversion** • **Gas separation technologies** • **Liquefaction processes** • **Electrolysis** • **Development of alternative production routes**
Hydrogen transport, storage and distribution • **Reversible storage systems for transportation** • **Hydrogen management at transfer, filling(cartridges) and refueling (vehicles) stations** • **Hydrogen storage at production sites** • **Pipeline infrastructures** • **System analyses and network strategy** • **Reversible and non-reversible storage solutions for portable applications** • **Liquid hydrogen infrastructure components, reduction of boil-off**

Stationary applications • **HT(high temperature, SOEC technology) FC stack: materials and design (cells, interconnects, seals)** • **HTFC fuel use** • **HTFC system (Balance Of Plant components)** • **LT(low temperature, AEL, PEM or AEM technologies) FC stack (high-temperature ???, polymer membranes, catalysts)** • **LTFC system (BOP components)** • **LTFC fuel processing (to be clarified : water treatment, purification, … ???)** • **Hydrogen turbine systems** • **Hydrogen internal combustion engines (Otto and Diesel cycles)**
Transport applications • **PEM stack (membranes, catalyst)** • **Internal Combustion Engines (H2-ICE)** • **SOFC for transportation** • **Reformer systems** • **Onboard hydrogen storage systems (compressed, liquefied, others)** • **PEM system components (air supply, E-drive)** • **System integration**
Portable applications • **PEFC, DMFC stack (Membranes, New catalysts, Membrane-electrode assemblies** • **Simplified water management in lo temperature systems** • **PEFC system components(Sensors, pumps, Fuel storage systems)** • **Micro-reformers** • **System integration and miniaturisation**

e) Carbon Capture, Sequestration and Utilization

- **Vision**

CO2 capture and underground storage of CO2 from large facilities shall is likely to be a key required contributor to the limitation of CO2 concentration in the atmosphere CO2 emissions reduction. In particular it may become a prerequisite key condition for the continuing use of some fossil fuels (e.g. by the aviation Sector).

The basic technologies required are similar to those currently used in the oil and gas industry. However new technologies are required to reduce the cost of capture, and to ensure storage can be guaranteed over long periods of time. Risk Management and Public Acceptance are also crucial for the timely development of this activity.

CCS TECHNOLOGY CHALLENGES
Capture • CCS processes classification • Multi CO2 sources layout optimization • Absorption • Adsorption • Membrane • Influence of Contaminants
Transport • Compressor pump • Insulated pipe • Insulation of pipes, Internal coating for corrosion • Drag reduction • Monitoring of pipe network • CO2 Carrier (boat and truck) • Transportation networks
Injection well • Well design • Steel, new cement, elastomers • Well abandonment • Monitoring
Geological storage • Site selection, site characterization • Site building (including cap rock integrity, well integrity…) • Geochemical, geo-mechanical studies • Flow simulation • Permanent monitoring (sensors, communication systems, models) • Offshore facilities
Risk Management • Cap rock

• **Pipe failure** • **Long term modelling** • **Permanent sensors (downhole & surface)** • **CO2 migration up to aquifer or atmosphere** • **HSE** • **Societal impact, public acceptance, communication, …**
Feasibility • **Capture pilots** • **Transport pilots** • **Injection pilots** • **Monitoring pilots**

2) Decentralisation & Digitalisation : New Information & Communication Technologies

Renewable Energy applications give rise to decentralization of Energy production which was formerly done in big power plants. Energy is now being produced at or near the point that it will be used. This transforms the regular one directional electricity grid into a smart grid with multi-dimensional flow of both electricity and information.

Eurogia2030 will support innovative projects on:

- 1)Integration, stability (steady-state and dynamic) & interoperability of existing grids
- 2)Smart Grids
- 3)ICT
- 4)IOT.
- 5)IT&OT cybersecurity
- 6)Microgrids

a) Integration, stability (steady-state and dynamic) & interoperability of existing grids & Energy Storage

Recent developments in renewable energy technologies led to a decrease in unit prices that promotes people to invest more in renewable energy. This brings out a new concept of "Prosumers", the consumers with the ability to generate their own energy from renewable resources mostly PVs. By coupling renewable energy resources with energy storage, these prosumers can provide uninterrupted sustainable energy. They can even sell the excess energy to the grid and take part in energy value chain.

The integration of renewable energy resources, energy storage systems at different levels either transmission or distribution grid, has triggered a transformation in the conventional grid which is designed for the flow of electricity from big power plants to customers only. ICT and IOT technologies paved the way to a new grid structure with both information and energy flow in both directions which is called the “Smart grid.”

b) Smart Grids

- **Vision**

Distribution grids are on the frontline of bottom-up transformation of power systems. Challenges such as increasing generation from intermittent renewables, increasing volatility of customer demand and opportunities of higher visibility and controllability of Medium Voltage (MV) and Low Voltage (LV) assets, higher grid-edge computation and communication availabilities require more detailed, larger scale and integrated analysis of power systems.

Smart grids deserve a special mention here: the combination of innovative energy storage capacity, energy transport on both large and small scales, and real-time matching between energy production and consumption on the scale of a continent, is both required to accommodate a significant amount of renewable energy, and at the same time promises to contribute significantly to reduction of wasted energy. Smart grid technologies overlap with many of the challenges already described (intermittency in renewable sources of energy, demand management, role of ICT…). Energy storage is a key enabler that will involve a variety of approaches from batteries, super-capacitors or fly wheels on the small to medium scale, to compressed air, thermal or hydraulic storage on the intermediate scale, and hydraulic or chemical storage on the large scale. Some of the challenges have also been described under the various renewable energy sections.

- **Technology Challenges**

The challenges under this area include, but not limited to detailed LV network modelling and analysis, integrated MV-LV distribution network analysis, integrated transmission and distribution system analysis (including TSO-DSO coordination), large scale network modelling and analysis, quasi-static time series analysis (highlighting the occurrence rate and duration of operational challenges), co-simulation combining several domains and analysis tools, Controller Hardware in the Loop (CHIL) testing, Power Hardware in the Loop (PHIL) testing and real-time coupling of geographically distributed research infrastructures

c) ICT

- **Vision**

Advanced Information and Communication Technologies (ICT), automation systems, computation approaches, related algorithms and methodologies provide promising ways to operate power systems in a more optimized manner and transform conventional grids into Cyber-Physical Energy Systems (CPES). The main trends in power system planning and operation are to increase automation to minimize the need for human intervention in routine processes (to act faster), increase computation abilities to minimize calculation and decision making time, handle higher number of urgent calculations simultaneously or be able to analyze larger scale systems, simulate the interactions between several domains, increase the complexity and accuracy of device and system models and conduct larger scale experimental tests using real equipment.

High uncertainty of supply and demand, occurrence of system events and complexity of decision making considering several factors in power systems require adoption of intelligent methods such as machine learning, fuzzy logic, nature-inspired metaheuristic algorithms, multi-objective decision making and optimization, clustering, pareto optimal solutions and other.

- **Technology Challenges**

The challenges under this category include, but not limited to, co-simulation, cloud computing, multicore computing, clustering methods, segmentation, diakoptics, pipelining, Controller Hardware in the Loop (CHIL) testing, Power Hardware in the Loop (PHIL) testing, real-time coupling of geographically distributed research infrastructures. Intelligent methods to identify the presence or operational state of specific equipment or events in electrical systems (such as intrusive and non-intrusive monitoring and other), predict the short- or long-term behavior of specific actors or equipment and decision making considering several complex and conflicting factors are of importance.

d) IOT

- **Vision**

The term Internet of Energy (IoE) is the use of Internet of Things (IoT) technology with a range of energy systems. It is a smart, responsive, decentralized network for energy, information and business flow. Multi-directional flow of renewable energy is supported by digitalization and big data. It is a data-rich, interconnected, smart, digitized and interactive version of distributed energy systems. Energy internet builds a data and a service-application layer dominantly over the energy end-use level. Big data analytics can allow data clustering and classification, statistical machine learning, neural networks and deep learning, data quality evaluation and modelling. Energy use, weather, GIS, customer service, social media, electric vehicle and third party data can be considered together.

- **Technology Challenges**

There are increasing number of IOT solutions using different communication protocols. Open architectures can be developed to achieve interoperability of wide range of IOT solutions. Increased connectivity and remote access options increase concerns on data privacy and security. Solutions aiming to improve customer and device data privacy and security can allow wider acceptance and use of IOT solutions. Large penetration of IOT devices bring together challenges in handling and processing of big data. Edge computing methodologies, hierarchical coordination of data collection, processing, transfer and big data analytics gain require careful consideration.

e) Green and zero emission buildings

- **Vision**

Smart buildings are aimed to provide higher visibility, improved control and improved human-machine interaction from the energy perspective. Building owners, operators and residents are supported with increasing monitoring hardware and interfaces (mostly in the form of mobile apps) to provide in-depth understanding of energy savings, tariff rates, trades and insights about how to act better. Following the large scale deployment of smart metering and monitoring devices, the next trend is to develop and implement new or control and automation assets (or adapt the existing ones) to empower customers with active roles in energy markets and gain profits or achieve additional energy savings and efficiency gains.

Smart-grid ready buildings, acting as active utility actors can be achieved through improved interoperability and synergies between electricity and other energy carriers and with other relevant non-energy sectors (such as mobility) supported by buildings, improved competitiveness of buildings as flexibility assets for grid and network management and demonstration of large-scale interoperable platforms that bring together different actors and sectors.

- **Technology Challenges**

There are numerous challenges in building operation, such as poor device-level visibility, slow response to request, lack of situational awareness and low automation. Additionally, most of the innovative approaches developed under the main topic of smart grid require huge amounts of data to be collected, transmitted and processed for monitoring, control, analysis and planning purposes. Therefore, it is vital for utilities to define communication requirements for improving system operational efficiency and finding cost-effective solutions.

Home automation protocols are capable of providing sufficient range and speed individually or through a combined use for smart grid applications. However, there is need for increasing the flexibility of configuration tools, application profiles and device control algorithms. Moreover, a common language at the application layer for deploying distributed control actions is needed.

Vendor-independent database structures need be standardized and interoperability needs to be improved. Centralized and decentralized demand side management algorithms and strategies can be applied incorporating smart meters and home automation devices, based on both predicted and real-time information.

Data privacy and security becomes a major concern with increasing connectivity and remote access functions. Cost-effective data privacy and security solutions at building level need to be developed to enable larger acceptance of the emerging technologies by building residents.

GREEN AND ZERO EMISSION BUILDINGS CHALLENGES
Building Energy Management • **Smart grid ready buildings** • **Device-level visibility and advanced control solutions** • **Interoperability between automation and metering solutions** • **Data privacy and security** • **Edge computing** • **Customer-oriented decision-making tools**

f) IT&OT cybersecurity

- **Vision**

Digitalization and increasing connectivity between critical electrical equipment increase the vulnerability to cyber-attacks. There is increasing risk of violation of privacy and security, encountering system-wide outages and permanent damage to critical equipment.

- **Technology Challenges**

The challenges in this area are detection and prevention of cyber attack types (such as malware, phishing, man-in-the-middle, distributed-denial-of-service and other), intrusion detection, anomaly detection against smart meters, smart loads, building automation and energy management systems, substations, power plants and grid operation centers.

g) Microgrids

- **Vision**

Microgrid is a self-sufficient electrical system comprising local generation and storage and has the ability to operate without a main grid (ranging from islanded to off-grid or standalone operation). It can be a small house, a hospital, a town, a large industrial facility, a part of a city or even a region of a country. Off-grid system is also considered as a promising solution to energy poverty.

- **Technology Challenges**

There are important design aspects for both transformation of an existing electrical system into a microgrid and building a new microgrid, such as preliminary planning, load estimation, generation and storage assessment, configuration planning, operation planning and cost estimation. Microgrids require consideration of several technical challenges such as islanding, voltage and current control, system stability, fast fault clearing and phase imbalances. AC, DC and hybrid microgrid systems, analysis of different system scales and topologies, investigation and mitigation of technical challenges, ship microgrids, electic aircraft microgrids, space microgrids, microgrid interaction with larger grids and facilitation of cooperation between several microgrids require considerable attention.

2. Deregulation & Democratisation

Energy deregulation is the restructuring of the existing energy market to prevent energy monopolies by increasing competition. This growing movement allows energy users to choose from multiple energy providers based on rates that suit their needs and specialized product offerings. Moreover, Energy user, also known as prosumers, can produce their own energies via Renewable Energy resources and sell the excess Energy back to the grid.

Eurogia2030 will support innovative projects on:

- Blokchain Technologies
- Flexibility Management
- Virtual Power Plants
- Network Stability
- Education and Training
- Peer to Peer Energy Trade

- Demand Side Management
- Electricity Market

Industry needs to develop new technologies ever faster. Therefore, EUROGIA2030 is aiming to have international collaboration, large market access, Top quality projects resulting from international peer review and project partners better armed to face global competition (incl. R&D). Evolving societal challenges, we aim to satisfy growing worldwide energy demand, ensure security of supply and decarbonize at the same time, competitiveness and job creation in EUREKA countries. Regarding the change in the business model, energy consumers have become energy producers and investments depend on regulatory framework stability. That is the main reason to have to work on deregulation.

a) Blockchain Technologies

- **Vision**

Blockchain is one of the most promising distributed ledger technologies that eliminates the need for a trusted intermediary and allows decentralized applications. The immutable and secure recording of transactions and data allow automated and seamless provision of wide range of services enabling interactions between large variety of stakeholders. There are several areas of use of blockchain technologies in energy systems, such as peer to peer (P2P) energy trading applications, renewable energy and other resource types guarantee of origin certificates trading in local and wholesale markets, integration of small customers in wholesale market operations and many other.

- **Technology Challenges**

The main challenges are the decision of the most suitable blockchain solution (including consensus algorithms) considering the cost, scale and speed requirements of applications, development of customer interfaces and stakeholder portals to allow effective deployment of use cases and consideration of grid technical operation parameters in the deployment of blockchain-based use cases.

b) Flexibility Management

- **Vision**

Flexibility management was conventionally a system wide concern which was handled by coordination of limited number of costly assets. Behind-the-meter large penetration of manageable distributed generators, energy storage systems and smart loads increased the need and options for flexibility management at lower system levels. According to implementation level, flexibility management can be categorized as local, distribution, transmission and system wide. While at local and regional level flexibility for seconds to minutes long voltage flexibility and minutes to hours long transfer capacity applications are of importance, at system level, subsecond to hours long flexibility for instantaneous power and hours to years long energy flexibility activities are more prominent.

- **Technology Challenges**

At system wide advances in power system stabiliser, coordinated voltage control, phase-shifting transformer and HVDC super grid applications require consideration. At transmission level, virtual inertia, topology changes energy storage systems are the areas that require improvement. At distribution level and local level, demand response should be implemented at wider scales.

c) Virtual Power Plants

- **Vision**

Virtual Power Plant is one of the most important developments to enable effective aggregation of large numbers of small-distributed energy resources, allow their integration into electricity markets, providing a wide range of flexibility, power and energy services to both local grids and the utility. Several DERs can be controlled as VPPs to mitigate the arising operational challenges (such as overvoltages, undervoltages, overloadings and other), defer the need for network upgrades, relieve system bottlenecks, reduce depreciation and amortization expense, avoid the costs and losses and even unlock new value streams.

- **Technology Challenges**

There is need exploring different aggregation techniques, effective utilization, advanced portfolio management, improved sustained response and better predictive management.

d) Network Stability

- **Vision**

There is increasing integration of inverter-based distributed energy resources (DERs) and sensitive loads to energy systems with low inertia. Additionally, there are isolated grid developments in rural areas and developing countries that are solely based on power electronic devices and renewable generation. Grid planners consider more and more non-wires alternatives to costly infrastructure expansions for even remote and low population areas that are already connected to the interconnected country-scale network.

- **Technology Challenges**

Growing number of low inertia assets as critical equipment in power systems require development of new solutions such as virtual inertia and fault ride through functions to be deployed by inverters. Use of non-wires alternatives and new approaches with detailed monitoring availabilities bring the system operation closer to technical limits. Use of distributed energy resources to aid stability is another area that requires consideration. Effective utilization of batteries, electric vehicles, smart appliances, thermal loads to provide additional reserve in maintaining stability should be achieved.

e) Education and training

- **Vision**

Technological advances and transformations in the area of energy require up-to-date, high quality, applied educational and training tool representing the latest state-of-the-art and the cases in the field. Moreover, integration of different domains increase the importance of interdisciplinary and multidisciplinary studies. New information and communication tools and services provide new and more effective ways of learning and training.

- **Technology Challenges**

Co-simulation of different domains, reflecting the realistic behavior and interactions between electricity-heat-gas-communication networks, automation and protection systems involving local, regional and wholesale market environments is a major challenge. Real-time simulation, Controller Hardware in the Loop (CHIL) testing, Power Hardware in the Loop (PHIL) testing techniques are still at development and standardization stages. Virtual laboratory environments allowing access to interested audiences from all over the world at any time for educational and training purposes need wider areas of use and more flexilbility. Real-time remote access to laboratories with different equipment and expertise should become more common to aid the educational and training activities.

f) Peer to Peer Energy Trade

- **Vision**

Peer to Peer Energy Trading is a suitable solution for organizing energy exchange especially in microgrids and local energy communities. Effective balancing of local generation and demand with effective utilization of energy storage is investigated while considering minimization of system losses, undervoltage/overvoltage and overloading problems.

- **Technology Challenges**

Exploration of new tariff structures’ and business models’ impacts on local systems are important aspects.

g) Demand Side Management

- **Vision**

Demand side management (DSM) has become an indispensable part of grid operation with its potential to aid supply/demand balancing, reduce peaks, mitigate congestions and improve voltage profiles in the grid. Effective deployments require a huge number of reliable participators who are aware of the flexibilities of their devices and who continuously seek to achieve savings and earnings. Automated deployment, smart appliance integrated advanced control, coordination of different load types, customer-specific user experience, continuous performance evaluation and improvement are the emerging fields in this area.

- **Technology Challenges**

Open standards and/or open source solutions to enable energy smart appliances and solutions in order to accelerate the deployment of demand-side flexibility services, reducing the entry barrier and facilitate replication. Smart appliance embedded monitoring and control availabilities, customer preferences-considered and customer habits-specific adaptive deployment, sustainable customer engagement in DSM programs are major challenges.

h) Electricity Markets

- **Vision**

Electricity markets are having transformational changes with high integration of renewables and energy storage. This is in addition to technological advances that allow shorter market operation windows (involving actors with smaller scale assets and a shift from country-scale markets to regional and even smaller scale markets) to achieve optimal results considering location-specific conditions. Efficient and effective energy markets are among the major enablers of new energy technologies. There are trends to enable feasible market integration of larger number of new energy generation technologies, involve larger number of fast resources to have sufficient reserve capacity to cope with emerging stability issues and utilize new technological tools for accurate prediction and market performance. Aggregators and retailers, act as a bridge between the small customers and wholesale markets, reflecting the market-scale requests and events on pricing rates and incentives provided to small customers to improve technical or economical performance of their operations.

- **Technology Challenges**

The major challenges are accurate estimation of short-term and long-term dynamics from market operator and market actors perspectives in response to involvement of new resources or new actors. The changes in market prices and market share of the current actors, possible revenues for new market participants is of significant importance. The challenges include, but not limited to development of new business models and pricing structures, considering the current and evolving market dynamics are among the considerably prominent and promising areas requiring efforts. Inter-market dynamics (the impact of a new or a changing market on another), regional and local market applications, applicability of shorter time periods for the existing market operations, involvement of fast responding, high number of small-scale assets and customers into wholesale market operation, policy changes in evolving markets, improvements in market participant interfaces and platforms.