# Report of the Horizon 2020 Advisory Group on Energy[1]

*Strategic priorities for the Energy work programme 2018-2020*

*- 14 June 2016 -*

## Contents



[1] More information on the composition of the group, its mandate as well as the meeting records are available through the Commission's Expert Group Register: http://ec.europa.eu/transparency/regexpert/index.cfm?do=groupDetail.groupDetail&groupID=2981

# 1. Executive Summary

The impact and consequences of grand societal challenges and megatrends, such as climate change, digitalisation, sharing economy and the new role of consumers and citizens, changing lifestyles, emerging new business models, globalisation and new future markets for clean technologies are apparent and quite well understood. Against this background the transformation of the energy system becomes more urgent and complex at the same moment. The energy 'trilemma', to secure sustainable, affordable and safe generation and reliable supply, needs more effort, increased R&D Budgets and critical masses. Challenges have to be turned into competitive advantages for European Economy.

One of the Energy Union targets – to become the number 1 in Renewables – is understood as a chance: European implementation of Renewables (delivering demonstration) combined with technology leadership and competitiveness in global clean energy markets. AGE emphasises the importance of an industrial strategy for low-carbon energy in Europe in coherence with energy R&D strategies to maintain capabilities in Europe and safeguarding ultimate competitiveness. Clean energy technologies and the respective infrastructure have to be developed to the local needs of global markets following the challenges and trends mentioned above. RTD efforts should be focussed on Smart Grids, storage technologies and their implementation, market design, a new system analysis and design and management aspects to tap all potential benefits.

Key to increase the reliability, resilience and flexibility, efficiency, and economic effectiveness of the energy sector, is to increase the interconnection between the energy subsectors (e.g. electricity and heat). On top enforcement in research is needed in the heating- and transport-sector (accounting for approx. 75% of energy consumption).

Transport can be divided into light-duty/short-distance transport (e.g. passenger cars and commuting) and heavy-duty/long-distance transport (trucks, ships, airplanes and industrial vehicles). Whereas light duty transport is very likely to undergo full electrification followed by technology and infrastructure needs respectively, heavy duty transport will need high density fuels. Cost-effective technologies for production and distribution of liquid fuels will be important.

The role of cities is increasing in many aspects. The complexity of urban transition processes leads to a growing demand for policy support for a holistic integrated approach based on digital city models, simulation and visualisation tools, which have to be validated (e.g. in living lab concepts). The chance should be taken to use cities to learn about transformation processes in reality. Living Labs are an effective approach in combining research, modelling and simulation, decision support and monitoring, validation and ex-post assessment in a holistic experimental environment around new technology and infrastructure developments, embracing needs, acceptance and behavioural aspects of citizens.

Key success factor for the transition of the European Energy system is the understanding of actual and future citizens needs including diversity in its broadest meaning. Changing life styles, behavioural aspects, expectations, acceptance and economic and non-economic motivation and drivers have to be understood in detail. A special focus should be given towards gender aspects. The full integration of the gender dimension is required in R&I and the design process of technologies and infrastructure.

Consumer behavioural aspects are of utmost importance for Energy Efficiency topics. Energy Efficiency is one key to success for all mitigation scenarios. Beside further technology development, stronger regulatory framework, innovative financial schemes and other measures, customer behaviour and motivation should be researched in Smart City/ Smart Building Living Lab concepts. To increase attractiveness of energy efficiency measures, they should be integrated in the smart building concept covering also health and security issues and featuring an easy and useful user interface.

Planning, implementation and management of energy infrastructure and city development needs decision support and capacity building for policy makers and public management. A core competence to deliver support is modelling and simulation, including visualisation and data analytics. In addition modelling and simulation can be the backbone for policy development by using scenarios as a basis for discussion.

Concerning the Energy 2050 Roadmap, some of the conclusions derived from PRIMES scenarios, seem still be valid and some have to be reconsidered. AGE members pointed to the limitations of the PRIMES model and are missing the open source software that enables stakeholders, e.g. policymakers and regulators, to access reliable, easily adoptable data and guidance on which climate and energy policies will reduce GHG emissions most effectively and at the lowest cost. AGE suggests setting up an-EU wide modelling Forum.

## 2. Setting the scene – megatrends and challenges

*a. Climate Change and decarbonisation policies, including energy transition.*

Globally climate change is already affecting day-to-day life and the economy. More extreme weather patterns are on one side leading to droughts and on the other hand water resource challenges, flooding, landslides, rising sea levels and storm floods; that cause infrastructure costs and endanger human life. Overheating will occur in urban areas and further affect quality of life and health.

Current policy focuses on two areas.

- Climate change mitigation encouraging GHG emission reduction: COP21 now demands even stronger policy targets concerning energy efficiency and renewable/carbon free energy production e.g. EU GHG emission reduction targets: 40% by 2030 and 80-95% by 2050.
- Climate change adaptation influencing infrastructure development: e.g. urban planning guidelines, building standards, land and water management and infrastructure resilience strategies all of which have to be rethought and further developed.

To achieve the targets, the energy system needs to undergo a fundamental change. An integrated approach is needed to tackle both mitigation and adaptation.

*b. Digitalisation*

Digitalisation enables radically new business models.

- In the energy sector, Internet of Things + Big Data Analytics + Modelling + Computing Speed + Cloud Computing + Mobile services + Social Media will lead to new business models, new actors, an increased focus on end customer and a transition from sales of kWh to sales of services (even though 'the Google of the energy sector' has still to emerge).
- The Integrated SET-Plan acknowledges trends by shifting the focus from research silos to integrated energy systems, local energy markets, new business models and new energy related services: Digitalisation is a crucial basis for all these developments.
- The 4th Industrial Revolution is characterised by intelligent amalgamation of product development, manufacturing and logistics with the customer at the centre.
- Increasing computing speeds and the Internet of Things (IOT) will create a paradigm shift; allowing modelling of large-scale energy systems, including its complexity, improving the capacity of decision-makers to support optimised, synergetic and resilient solution development.

The importance of the regulatory regimes that promote or stifle change have to be highlighted.

There was broad agreement that the energy (and transport) sector will go through fundamental changes in the forthcoming decade due to digitalisation. Horizon 2020 should embrace this ICT-based revolution, utilise it and support European society and companies to grasp these new market opportunities.

c. *Changing lifestyles, the sharing economy and the new role of consumers and citizens*

- People's behaviour is motivated by rational and non-rational factors, which might differ for age groups, gender, culture etc.
- Most people are rather conservative and risk adverse and don't change their behaviour unless there are substantial benefits or very positive experiences with something formerly unknown, and then the behavioural change is relatively easy.
- Changing the culture of people for enabling sustained effects is of major importance. However, culture has multiple dimensions and is very difficult to target, let alone change. Nevertheless, without a change of culture the benefits of learning and innovative technologies will not show their full effect.
- A citizen/consumer-oriented approach is possible by activating and working with cities.

d. *Globalisation and future markets for clean energy technology*

- Globalisation means that European manufacturers need to compete on a level platform with international manufacturers emerging from economies, not obeying environmental rules with lower costs and vastly improving quality standards.
- European manufacturers therefore need to invest in research in high technology products, tools and solutions that enable them to be market leaders - faster, more flexible and more competitive whilst not losing the edge in terms of providing first class products and services.
- The focus will continue to be on automation and digitalisation and expanding on advanced manufacturing initiatives such as the Industry Internet of Things and Industry 4.0.
- Further there will need to be more focus on reducing environmental footprints by using less resources (energy and materials), recycling good materials and better management of final waste. Resource and energy efficiency is an opportunity and not a burden.
- Emerging economies have a higher incentive than mature economies to develop and deploy renewable energy systems because they don’t bear the cost of retiring existing assets and infrastructure.

e. *Economic changes and emerging new business models*

- According to some projections, the global growth potential for clean technologies is enormous and could increase by a factor of 14 between 2015 and 2050. Also the contribution of clean technologies to the global GDP is expected to grow strongly. The strongest growth is projected for China, followed by Europe, North America and Asian/Pacific countries. Renewable energies will continue to be the most substantial segment of clean technologies. This growth will come at the cost of retiring existing assets for Europe and other developed economies, because of limited economic growth.
- Overarching trends of the energy sector will lead to new business models requiring stronger involvement of insurers, pension funds and banks in managing climate change related risks, more flexible renewable energy technologies thanks to smart grid development including electricity storage, ubiquitous integration of energy and ICT technologies and infrastructure and more active roles of consumers.
- New business models in the energy sector will be based on energy services, up-cycling and refurbishment, dematerialisation and smart substitution, optimisation and sharing. Tax

policies are an excellent tool to stimulate such development, e.g. by moving income tax to resource consumption tax.

a. *RD&D Budgets:*

- According to IEA figures, the total public energy RD&D budget in IEA member countries in 2014 was about USD 17 billion which is still below the funding level during the second oil crisis (on a PPP basis).
- There are huge differences across countries as regards the ratio of public energy RD&D budget per unit of GDP. While the USA and Japan are leading in energy RD&D investments, Finland and Norway having the largest ratio of public energy RD&D budget per unit of GDP.

## 3. Be No. 1 in Renewables

To be No 1 in renewables can mean many things including: having the biggest installed capacity of renewable energy or delivering the largest amount of energy from renewable resources, having the most people employed in the renewable energy sector or the largest amount of renewable energy technology companies and respective export volume. In order to achieve this, the following focus is required:

a. *Policy to ensure sustainable, affordable and safe generation to all*

The energy 'trilemma': sustainable, affordable and safe generation and reliable supply remains and overall it is expected that electricity and gas will feature more in the energy mix and considerable changes are being made to grid dynamics to enable increasing amounts of variable renewable energy. However it is important to understand from the Member States' declarations of intent (in the context of the SET-Plan), which countries will do what and benchmark against the overall before deciding actions to integrate more renewable energy across the board. For example it will be much easier to make the transition for mature (with respect the renewables), well interconnected countries that do not rely heavily on fossil fuels as part of their GDP. Therefore any policy initiatives including creating an adaptable/replicable blueprint have to be relevant to local energy environments and linked to regional and local resource availability.

b. *Further integration of energy storage*

All storage and conversion technologies such as power to power, power to heat, power to gas (e.g. hydrogen), power to chemicals etc. that enable better utilisation of renewable energy will be required, and there needs to be more focus on improving their efficiencies. Coupling of energy pathways and greater interconnection as well as incentives to flatten demand will all support integration of more renewable energy and there needs to be a robust and dynamic market design that enables this integration. All these technologies (storage and conversion) need to require low investment as they are in use only a fraction of the time.

c. *Priorities for increasing competitiveness of technology and installations:*

- Options that offer a huge technical potential throughout the EU, and those that can deliver other economic benefits (e.g. exports, etc.),
- Making technologies more reliable and more cost-efficient. This includes e.g. wind power where medium-to-long term R&D on technologies for turbines and balance of plant is needed.
- Reducing investment costs in order to become more competitive (this applies to technologies for harvesting, storing and converting energy),
- Minimising possible environmental impact with the use of new planning tools,

- Generating additional system value within the overall energy system,
- Increasing public acceptance and engagement.

Whilst development of renewable technologies was considered a success, it relied heavily on subsidies and government intervention and created cost competition as a result of cheaper imported technology and should therefore be rethought. Other approaches could target exploitation i.e. rolling-out proven technologies and implementing incremental improvements or *i*ntegration (greater focus on systems, integration, interoperability and flexibility) on top of (partial) technology leadership.

d. *Market design for integrated energy resources*

The share of fluctuating power has increased significantly and will increase further and as a result the generation mix is changing i.e. rotating mass large-scale power plants that provide stability and system inertia are diminishing. Current market rules are generally designed for electricity from large fossil fuel generators (e.g. capacity and response are often not priced in). In order to motivate non-conventional and distributed resources to provide services or even be more useable themselves, the market structure needs to reward differently for different services e.g. speed to respond, duration, seasonal needs, losses etc. More specifically:

- Better predictability of electricity generation from fluctuating sources for improved consideration in power plant scheduling,
- Development and integration of large and small-scale virtual and physical storage options in a decentralised and centralised way,
- De-coupled and coupled parts of the grid from and to the overlying grid to improve system stability (e.g. one street, a small village, big industries),
- Coupling of electricity and heat markets to generate services for the electricity grid (e.g. storage of energy, balancing power),
- Establishing a more attractive support structure for balancing technologies for the intermittent-source based future power systems.

# 4. Transition towards a Smart Secure EU Energy System with the consumer at the centre

a. *Integration of all energy resources e.g. electricity with heat, and gas*

- Decreasing the use of fossil fuels cannot be achieved by replacing them with biomass only (insufficient biomass availability) but requires harvesting and use of intermittent energy resources. Harvesting renewable energy will require very large investments, both for central and distributed deployment. Moreover steadily increasing penetration of intermittent resources requires a new system analysis and design and management.
- Focus on only the electricity sector captures around 25% of the total energy consumption, meaning the transport and heating sector (accounting for ca. 75% of energy consumption) are not covered. Future analysis should therefore include all energy sectors, and take into account the different stakeholders that need to be mobilised as well as their interactions, and understand how far the transport and heating sector can be electrified and what is needed to achieve it.
- Key to increasing the reliability, resilience and flexibility, efficiency, and economic effectiveness of the energy sector, is to increase the interconnection between the energy

subsectors (e.g. electricity and heat). Current focus is mainly on interconnection within the electricity sector and therefore new policy on cross-sector interconnectivity is needed.

b. *Better Integration of renewable energy*

This subject is mainly covered under market uptake. Integration of renewable energy should be supported further with 'market uptake actions' targeting cities and citizen/cooperatives (eg. financing RE projects with citizen based solutions).

c. *Smart Grid technologies*

Smart Grid technologies enable unprecedented development and beneficial integration of power electronics and combined with ICT vastly change the operation, transmitting capabilities, safety and flexibility of conventional power systems. Therefore further research followed by large demonstration projects is essential to tap all potential benefits.

d. *Energy storage technologies*

It is critical that energy storage features in all parts of the energy chain and that integration between various energy pathways enable the most efficient and cost effective options to be utilised.

e. *Better modelling to enable optimized planning of energy systems and usage of resources (fuels, water, land)*

A number of important developments have occurred since the publication of the EU Energy Roadmap 2050 (COM(2011) 885 final) in 2011 which have an impact on the modelling results, notably the greater-than-expected cost reduction of renewables, the slower-than-expected economic recovery and the reinforced global commitment to reduce greenhouse gas emissions. Further discussion on this subject is covered under the science supporting policy decisions section (chapter 9).

f. *Technologies and services for consumers*

Going forward, consumer will become more aware and more active and their actions will impact all stakeholders. It is therefore essential to understand consumer behaviour and plan all activity with consumer expectations in mind.

# 5. The important role of cities

Cities are responsible of some 70 % of the GHG emissions. 70% of mitigation measures and up to 90% of adaptation measures are put in place in cities. Long-term plans of cities are starting to include an ambition of becoming carbon neutral. The Covenant of Mayors includes 7000 signatory cities and towns and has 5000+ Sustainable Energy Action Plans (SEAP) under implementation. However, cities will also be one of the biggest victims of the impact of climate change i.e. increasing heat and pollution and it needs to be understood who is responsible for paying and planning for mitigation strategies. Going forward, changing the energy system will require drastic changes: the way we live, the way we consume etc. and solutions need to be found where science, innovation and practice meet and solutions are only successful when they are widely implemented. The work of the smart cities programme is widely recognized; however, in addition, engaging cities in the energy transition requires the following:

a. *Creating cities as hubs*

- Rooting research and innovation into practice: The energy transition needs to happen with cities and citizens and calls for a collaborative approach – bringing city administration, universities, business, civil society together. In Europe there are some examples of transition platforms that focus on finding new solutions together with different actors. Such experiments need to become more mainstream. A truly collaborative approach needs to be established where all stakeholders collaborate to find solutions that ultimately motivate society as a whole towards a new energy system.

- The transition is technological and social: In addition to deploying new technologies, new ways to manage, finance, do, are an essential part of innovation processes and not an 'add-on'.
- An integrated and systemic approach – avoid silo thinking, find solutions that serve multiple purposes: Cities define themselves via their local strategies and their climate and energy plans how they want to develop. 'Smart' should not be pre-defined by putting together certain policy areas (such as energy, transport and ICT) or overstress specific solutions (for example electro-mobility). 'Smart' is about taking a holistic approach and ensuring a proper integration of different policy areas; locally and create solutions that are based on the needs of the cities and their citizens.
- Understanding that smart is not linked to size. Europe has a large number of small and medium sized cities that should be supported to become 'smart'. There are already many examples of how small towns can also be very innovative. They have the capacity to work (more naturally) with different stakeholders including local companies in their territory, as well as integrate different policy initiatives. This should be further supported.
- Understanding the cost benefits and how energy efficiency can reduce energy poverty.

b. *Scientific based policy support and living labs to test scenarios*

- Cities are key actors in climate adaptation and mitigation and related energy transformation policies. The necessary developments have never lead to such a complexity for decision makers and city administration. On top of this, citizens are willing and demanding to be engaged in shaping their future surroundings. This leads to a growing demand for policy support for a holistic integrated approach for example in: urban planning, urban design, transportation and infrastructure planning, energy and natural resource supply, along the whole policy cycle for decision development and implementation. This demand leads to the need for a new generation of integrated digital city models, simulation and visualisation tools, which have to be validated (e.g. in living lab concepts).
- Further public financial resources are decreasing and justification and transparency are ever growing topics. Investing in large, sometimes unproven, infrastructure that will contribute towards better living in cities is often hard to justify without evidence. Therefore testing and demonstration through living lab scenarios relevant to different cultures could provide the evidence necessary to make investment decisions.
- Living Labs are a new approach in combining research, modelling and simulation, decision support and monitoring, validation and ex-post assessment in a holistic experimental environment. The concept was originally created in the context of innovation research including technology development, open innovation, user involvement, specific ecosystems and is meant to take place in a regional context.
- A living Lab should guide the whole policy cycle addressing major societal changes; starting with the planning stage, including bottom up processes and participation of various stakeholders, developing visions and concepts, up to implementation, incorporating feedback and improving the socio- technological set-up.
- Technology demonstration projects should also include behavioural (and other relevant SSH-related) aspects following the living lab concept. Principles for the urban energy transition management, development and validation transition pathways for urban energy systems.

c. *Knowledge sharing of best practices to encourage replication*

- Firstly, projects need to be desirable for the citizens of cities and this links into the market uptake measure discussed in other chapters.
- Secondly, there needs to be a way to foster knowledge sharing among cities in terms of what was successful and what was not, especially those subjects that delivered the best efficiency results and greatest market uptake.
- Further, to provide instruments that make successful infrastructure investments attractive to future investors e.g. rankings, scorecards etc.

d. *Create a competitive landscape*

- Create inter-city environmental or energy efficiency competitions.
- Communicate performance indicators of cities to citizens to encourage them to demand more.

# 6. Energy Efficiency

Energy efficiency is at the core of the EU2030 targets. By removing the barriers for a wider up-take of energy efficiency investments, it reduces its costs and thereby increases its cost-effectiveness. This cost-benefit assessment is also heavily influenced when taking into account the multiple benefits of energy efficiency: energy security and savings at the supply side, increased independence and flexibility throughout the energy system, welfare gains for society including battling energy poverty and local job creation, improved air quality, health and productivity gains inside renovated buildings and reducing greenhouse gas emissions.

Energy efficiency policy is an unquestionable element of future energy policy both in the EU and worldwide. EU energy efficiency technologies can enable the energy transformation; however, it is important to consider the approach towards the diversity and ability to pay between emerging and mature country groups and the general insights towards consumer needs and behaviour in these groups. Further energy efficiency cuts across all sectors i.e. power generation, power and gas grids, transport, industry, buildings, and households.

H2020 can contribute towards energy efficiency in the following ways:

a. *Accelerate development of competitive, more efficient technologies*

Some contributions towards energy efficiency may require no consumer behavioural change whatsoever; if it is possible to incentivise technology developers to improve the efficiency of their products. For example it is difficult to change the behaviour of a person wishing to use a washing machine. They will not do it during the night when electricity is cheap. Therefore a relatively easier solution would be to improve the efficiency of the machine. Efficiency solutions should target both new products/services as well as existing assets.

b. *Support policy and policy tool development*

- Strengthening policy, legislation and regulation and securing long-term commitment towards energy efficiency,
- Further support for standardisation (CENELEC, IEC) setting standards for energy efficient products, services, and energy saving monitoring and verification procedures,
- Support for the EU Emissions Trading System (EU ETS) reform (policy, technology development, economics, social issues) as well as alternative schemes that stimulate sustainable and low-carbon energy vectors.

c. *Change consumer behaviour to accelerate changes in energy use patterns*

- Horizon 2020 needs to contribute to a fundamental redesign of the market in order to allow new business models for a consumer-centric Energy Union. More effort is needed to incentivise consumers, allowing them to make informed choices and become more aware of their role in the energy system. Too often, the current market development focuses on the investment in energy infrastructure, rather than engaging consumers with the right signals and tools.
- This subject is largely discussed in the market uptake section of this report (chapter 7); however digitalisation and artificial intelligence offer great opportunities, in particular with regard to user's lifestyles, thermal management and interaction between system elements and need to be further developed. Further, the concept of testing public reaction to specific initiatives and technologies may help to identify early successes.

d. *Providing instruments to enhance investments and improve investor confidence*

- Facilitate development and implementation of new financing instruments/models. For example, financial instruments such as the European Project Development Assistance (PDA) or the EIB ELENA facility should be further enforced and elaborated as they bridge the gap between local sustainable energy plans and the mobilisation of investments.
- Capacities of cities on alternative financing schemes and their implementation will need to be increased. At the moment, good examples are isolated and very context-dependent, which creates barriers to replication.
- Cultivating the concept of pitching to investors during (for example) start-up events - similar to in the US; enabling technology developers to bridge the gap from start up to commercialisation by providing access and exposure to more funds.

e. *Cultivating, capturing and utilising data and artificial intelligence including:*

- Better coverage within energy modelling tools that include timescales from minutes to years,
- Standardised energy efficiency assessment tools to boost economy and solve social problems at different levels, e.g. national, local and municipal,
- Reliable and affordable methodologies and tools for energy management, and monitoring and measurement of energy savings,
- Better access to tools and websites that promote energy efficiency,
- Standardisation needs to lower transaction costs: work needs to be done on feasibility assessments, procurement processes and measurement/verification.

f. *Multi-disciplinary collaboration to deliver smart buildings*

- There is still great potential for energy savings, notably in buildings, through improved technologies, especially as regards new construction materials, heat recovery and heating and cooling and further opportunities through better integration of renewable energy.
- To increase attractiveness of energy efficiency measures, they should be integrated in the smart building concept covering also health and security issues and featuring an easy and useful user interface.
- Solutions addressed by ambassadors of technology adoption e.g. architects.

g. *Transport*

Transport shall become a subject of stringed EU regulations on energy efficiency. Closer co-operation among policy makers, regulators and automotive industry is required to come to realistic and customer acceptable solutions.

# 7. Influencing market uptake of sustainable energy solutions

Horizon 2020 priorities for 2018 to 2020 include market uptake actions that will include both a top-down approach focused on enforcement of legislation such as the Energy Efficiency Directive (EED) and the Energy Performance of Buildings Directive (EPBP) and a more bottom-up approach based on consumer/energy actors. Legislation will be reviewed to ensure that it is sufficient to meet COP21 and EU 2050 goals and activities will be focused around research and innovation, capacity and skills development, regulations, and financing.

On the bottom-up side, further specific attention is required to the following areas:

a. *Consumer behaviour and needs, and incentives to encourage behavioural changes*

   Lack of awareness of benefits of energy efficiency remains one of the main barriers in energy transformation. When considering how to encourage behavioural changes that will contribute to energy efficiency and uptake of renewable energy, it is critical to judge the 'readiness of society' to change and understand the behaviour of consumers or the citizen in general, including having a gender perspective. People i.e. women, and men, different age groups and cultural backgrounds, different levels of wealth etc. have specific habits that need to be addressed when considering change. E.g. price incentives to one group may be of no interest to other groups.

   Behavioural studies with a clear focus towards transition management, adapting to new technologies, incentive schemes and business models should receive more support than in previous years.

b. *Capacity building of policy makers*

   Specific capacity building towards policy makers is required to ensure that incentives designed to cultivate change in one policy area do not negatively impact progress in other policy areas, especially when both are aimed at achieving the overall objectives. The same is to be applied for decision making tools.

c. *Public private partnerships to share knowledge and accelerate progress*

   To improve attractiveness for business, the existence of long-term support structures (e.g. public-private partnerships) facilitating market entry of innovative solutions is helpful. In addition, the development of conducive standards and certification is crucial. Inducement prizes in the area of energy-efficient buildings could be an interesting instrument for stimulating innovation. Innovative public procurement as a tool should be supported to help creating first markets for innovative solutions and hence market uptake. Close monitoring is needed in order to share experiences and good practices in procurements.

d. *Multi-sector uptake e.g. energy efficiency and renewable energy in buildings*

   Future buildings could be included as part of the renewable energy system and therefore encouraged to participate in the same incentive schemes therefore encouraging uptake. Clear information and business cases that demonstrate the balance between savings and uptake of renewable need to be developed. Labelling and information that cuts across all factors impacting energy efficiency (including building insulation and heating, with ranking for those with the greatest impact) need to be more clearly defined and available. Extending new build policies towards existing buildings would create even more value.

e. *Public procurement with obligatory criteria on energy efficiency can play a crucial role in products and services market transformation towards more sustainable solutions.*

f. *Modelling investment profitability for decision-making support*

   Integration of tools to enable measurement of profitability of various solutions, scenarios and portfolio effects for optimised funding decisions.

## 8. Sustainable Transportation

Transport is lagging behind all other energy sectors in terms of its rate of $CO_2$ reduction. It therefore needs dedicated attention. The transport sector can be convenient split into two segments, namely light-duty/short-distance transport (e.g. passenger cars and commuting) and heavy-duty/long-distance transport (trucks, ships, airplanes and industrial vehicles).

The light-duty/short-distance transport will likely undergo full electrification. Many challenges relevant to the integration of EVs with the Smart Grid, such as number and capacity of charging points, demand-response, flexibility management, etc. are currently under development. However new focus will need to be on the development of a transportation system with self-driving cars, enabled by disruptive technologies such as the Internet of Things, Big Data Real-time Analytics, Cloud Computing, e-Mobility and Social Media.

Vehicles that are used for heavy-duty and/or long-distance transport will resist electrification and likely rely on fuels with high energy density. Laws of physics do not permit storage of enough energy in 'charge separation' as compared to 'chemical bonds'. Sustainable fuels will eventually be derived from water and optionally, atmospheric $CO_2$ via natural photosynthesis (biomass, e.g. bio-fuels and biogas) or via artificial photosynthesis (electro or photolysis of water), optionally combined with capture and reduction of atmospheric $CO_2$ (solar fuels). In the long term, sustainable fuels should be burned using high-efficiency fuel cells and electrical engines (e.g. hydrogen fuel cells). In the meantime, however, they may still rely on less-efficient combustion engines, as applied for conventional and advance bio-fuels. Needless to say, fuel-cell technology could be advantageously applied as a range-extender for electrical vehicles.

In the mid-term, however, natural gas could represent a valuable energy vector. Firstly, LNG/CNG could replace heavier and C-richer fuels in the heavy-duty sector (e.g. replacing diesel and residual fuel in trucks and ships). Secondly, natural gas could be combined with CCS to provide carbon-free electricity and $H_2$ for transportation.

The transition from a fossil to a renewable transportation will require research in the following areas:

a. *The transport-energy nexus and integration of both systems that includes disruptive technologies such as driver-less vehicles and the Internet of Things.*

b. *Cost-effective technologies for production and distribution of liquid fuels:*
    - Biomass conversion to liquid/gas bio-fuels, the biomass being harvested in a sustainable manner.
    - Photo/electrolysis of water to hydrogen
    - Liquefying/pressuring and storing gases (e.g. $H_2$)
    - Cost-effective and fast charging systems

c. *Cost-effective power trains for sustainable energy and fuels*
    - Battery capacities
    - Fuel cells for burning $H_2$ and liquid (bio/solar) fuels

d. *Cost-effective power trains for sustainable energy and fuels*

# 9. Science supporting policy through system level modelling

Important European policy documents are based on results of major modelling exercises as is the Energy Roadmap 2050 (see above). The Roadmap's main conclusions for the decarbonisation of the energy system were the following:

- Energy savings are crucial,
- Electricity plays an increasing role,
- Decentralised and centralised systems increasingly interact,
- Gas can play a transitional role,
- Nuclear energy continues to provide an important contribution,
- Energy imports and imports bill reduced,
- Renewables rise substantially in all scenarios,
- Higher capital expenditure and lower fuel costs,
- Electricity prices may rise until 2030 and then decline,
- Decarbonisation is technologically and economically feasible.

Some of the conclusions seem to still be valid and some have to be reconsidered. Further, AGE members pointed to the limitations of the PRIMES model, notably its limited capability to take time-scale of events sufficiently into account as well as shortcomings due to its top-down approach and lack of transparency regarding assumptions. Attention was drawn to alternative models that are capable of accounting for additional dimensions and time scales, as well as integrate more complexity and thus arrive at different results and conclusions.

Further, some AGE members are missing the open source software that enables stakeholders, e.g. policymakers and regulators, to access reliable, easily adoptable data and guidance on which climate and energy policies will reduce CHG emissions most effectively and at the lowest cost.

Given the importance of models and the limited time available for planning the energy system of 2050, a new more detailed modelling approach should be developed with the help of research. This approach should be based on integration of best available top-down & bottom-up approaches, supporting transparency, be built on the most recent assumptions and overcome some of the other constraints.

Drivers for new or improved modelling techniques include an holistic approach, the increasing penetration of distributed generation (dynamic accounting for generation, transmission, distribution and usage incorporated) and the new viability of energy storage, changes in the transport infrastructure, integration of heat into the energy value chain, changing socio-political landscapes and consumer behaviour, the emergence of new business models and market entrants and the rapid development of new technologies. AGE members recommend the following approach:

a. Firstly, the objective (if different to recent objectives) of the model need to be clearly defined with validated benchmarks in terms of cost benefits and how to pay for any development including the vast amount of data collection.

b. There are two types of models: top-down, which account for macro-level influences on the behaviour of system, and bottom-up, which tend to be agent-based and account for detailed interaction of stakeholders with the existing and evolving technologies and infrastructure. A conceptual approach to dynamic model development, which integrates top-down and bottom-up approaches is required that includes the macro and multi-stakeholder dimensions as well as considerations for the diversity of consumers, policies and regulations, and different energy transition scenarios. Models also need to be useable across a broad group of stakeholders.

c. Structure for decision-making requires synthesis of results from such a model, requiring a particular emphasis on pre and post processing, as well as visualization tools.

d. As the SET-Plan calls for development for existing models such as PRIMES to consider short-term changes, it is important to carry out a gap analysis to understand the capability of these models vis-à-vis current requirements and see if they can be reasonably developed or whether new models and scenarios are required. To start the discussion the suggestion is to set up an-EU wide modelling Forum.

e. Activity on system integration and model development can be enriched by interdisciplinary research, especially SSH-related research.

# 10. Being competitive in a global market

Clean energy is completely different subject to launch compared to consumer technology products. Firstly, as a homogenous product, it is difficult/almost impossible to create brand desire, and investors and consumers really care about cost vs. returns. Secondly regarding both climate change and energy security matters, only a few, reasonably industrialised countries would contemplate substituting the import of fossil fuels with import of low-carbon energy infrastructure. Thus, both energy security and the associated employment generation matter significantly.

Policy can be considered as an enabler, but careful consideration has to be made to the diversity of Member States. For example, strong policy in mature environments accelerates investments in technology; however costs are also higher. Whereas, countries with less strong policies invest more in lower-cost/fast-to-market, new technologies or take a 'wait-and see' approach, until cost-competitiveness without incentives has been achieved. And as has proved true recently, changing governments and changing supply costs can mean a complete U-turn in regulation and incentives or subsidies.

Further, whilst the EU has a very strong research and IP background, many start-up technologies fall into 'the valley of death' and fail to seek critical funding that would take them on their journey to commercialisation. Others achieve commercialization in a highly protected or subsidized policy environment but do not diffuse into less incentivised markets.

In the context of a forthcoming European Innovation Council and SET-Plan Declaration, AGE offers the following considerations.

*a. Learning by simulating*

First, understand the impacts of inevitable and surreptitious policy changes for technology during the R&I cycle and use this to make calculated predictions about what works and what doesn't. Due diligence of regulatory changes and their impact on technology acceptance and diffusion in different markets is key.

Second, While developing NOW technologies to meet the 2030-2050 targets, EU also needs to look towards effects of long term climate changes; their social-economic impact, their cost and risks. Therefore, technology and capacities that can respond flexibly to the challenges that will develop over a longer-term horizon need to be developed.

*b. Create a competitive 'tech' environment during the R&I cycle*

- Learning from other Government programmes such as ARPA-E in the US and their equivalent in Japan and China; by allocating empowered programme managers who are responsible for taking a vision to prototype and beyond. Each programme manager has to pitch their innovation to communities and investors in a 'shark tank' environment where they are also able to accept valuable feedback, thus creating a personal commitment and Introducing 'emerging' or breakthrough technologies

- New business environments to launch technology from the lab to the market e.g. incubators and accelerators that attract advisors and funders, and financial instruments to support Venture Capital (VC) and Angel investments.
- More collaboration between universities and industry with specific project development challenges. Maintaining manufacturing capabilities for low-carbon technologies in Europe to capture 'learning by doing' and enable multi-generational technology development in Europe. With regard to the forthcoming EURICS strategy, AGE emphasises the importance of an industrial strategy for low-carbon energy in Europe to maintain capabilities in Europe and safeguarding ultimate competitiveness. Outsourcing the crucial 'learning by doing' stage inevitably leads to a decline of R&I leadership and control and cost flexibility along the value chain.
- Fostering close collaboration between technology development by large companies and European SMEs along the entire value chain. Creating this synergy between large companies and SMEs during the R&I phase should allow industry to prepare for global market diffusion and next generation R&I development.
- Avoid lock-in either at the pre-maturity or maturity stage by fostering both technology improvements during the R&I cycle and cooperation/race to excellence with international researchers. The danger of lock-in of technically mature or semi-mature technologies that are deployed under the shield of comfortable incentives or numerical EU targets is one of the greatest dangers to EU's competitiveness in the low-carbon energy field.

*c. Transition from a supported R&I market to global competition*

The need for long-term and substantial government support of low-carbon energy technology development along the entire R&I cycle is by now universally accepted; particularly in the absence of a meaningful carbon price. However, very little has been written as to how industry and R&I actors will be weaned away from support, subsidies and targets and be ready for global competition. This is very relevant for Europe; the leader of targeted low-carbon interventions and instruments.

In the medium-term Europe offers a substantial market for low-energy technologies, albeit primarily a restructuring/refurbishing market. Thus, the immediate need to 'go global' is not a priority for many firms. On the contrary, the stable regulatory environment in many EU countries encourages firms to focus only on 'the home market'. This is further strengthened by the long-term vision of 'inevitable' low-carbon energy growth in Europe as fossil fuelled transport is substituted by carbon free electricity or hydrogen. This seemingly secure European market together with a 'sufficiency' approach to profits and growth of many European companies may well be a hindrance to European companies venturing into riskier, but rapidly growing global low-carbon energy markets.

The competitiveness of the European low-carbon industry will be tested in a few protected markets:

- In global energy growth markets, i.e. emerging and development countries;
- Other OECD markets,
- Europe itself, where relatively stable regulations attract cost competitive, 'nimble' competitors from the US, Japan, Korea and the BRICS countries.

It cannot be the role of the European Commission to further subsidise or intervene in internal industry decisions during the marketing stage of mature technologies. However, AGE wishes to point out that the competitiveness of European low-carbon energy industry is in danger unless:

- European low-carbon industry actors are prepared to compete in the global and growing energy markets; learn to adapt to country specific incentives, adapt to regulatory changes, cost, consumer/city preferences and system adaptation needs that are very different than in Europe.
- Explore competitiveness along the entire value change of each low-carbon technology from components/EPC and Installation/O&M to system integration/digitalisation. Different markets may well require different business models along the value change.
- Take the challenge of competitiveness in the European 'home market' from more nimble competitors very seriously.

## 11. Gender & Diversity Aspects

Use of energy differs among men and women: women use more energy in the household, men more in transport. While expectations and acceptance of energy solutions often differ between sexes, it is more often the male-dominated energy sector that influences views with regards to market needs, user expectations and behaviour. Even though women make the majority of household decisions, this bias might explain why smart homes have not yet entered the market despite being around for some years – because those spending most of the time in homes (women, children, elderly) have not been appropriately addressed.

Gender is part of Research Excellence and enhances the societal relevance of produced knowledge, technologies and innovations, contributes to goods and services better suited/accepted by potential markets, questions gender norms and stereotypes. Therefore full integration of the gender dimension is required in R&I and the design process wherever it is needed and further full attention has to be given to gender balance in teams and for funding.

For example new innovative building solutions for energy savings in heating, cooling will have a different perspective considering gender and may impact integrating circular economy ideas and integrating smart applications that are flexible and demand oriented. Women are homemakers and therefore want safe, secure and nice homes and therefore their drivers are different. As an example they would be more focused to

- Security in energy supply,
- Ease of handling and flexibility,
- Close proximity services in case of problems,
- Smart integration of health and safety issues on demand.

Due to specific talents of woman it is advised to have their role more prominent in the areas related to integration, system thinking and holistic planning solutions.

## 12. Open issues to be further discussed

It is acknowledged that it is important to consider additional issues for the Horizon 2020 Energy Challenge. However, due to short time frame available for drafting the report, it was not possible to adequately cover all and those remaining will be discussed in a later meeting and the report subsequently be updated.

a. Carbon Capture and Storage/Use (CCS/U)

   One of the main issues to be addressed here is risk communication and public engagement in decision-making processes around controversial facilities. Also more efforts in the field integrated monitoring and early warning would help to deploy this technology. One topic to be discussed might be to refocus much more together with the scientific community and industrial partners on CCU, this approach probably is supported by more driving forces and trends. New funding frameworks and financial instruments to enable CCS/U research and industrial implementation are needed.

b. Nuclear energy/safety

- Article 10 of the Council Directive 2011/70/EURATOM focuses on 'transparency' but this is not defined in practice and therefore, differently understood by Member States. Developing guidelines on self-assessment and peer review in collaboration with different stakeholders and taking into account differences between Member States can help harmonise practices in this field.
- Implications of decommissioning nuclear power plants in Europe considering socio-economic challenges, future regional development models, attitudes and opinions

c. Communication of scientific results: How to improve the communication and understanding of scientific methods and scientific results (safety analysis, models, underground research laboratories, etc) as well as provisions for emergency preparedness and response so that they are understandable to different stakeholders, by taking advantage of information and communication technologies (ICT)?

d. Incentives to change behaviour of local actors: Understanding the potential impacts of providing incentives to local communities in the short, medium and long-term (such as economic consequences, influence on the social and political dynamics, infrastructural arrangements, etc).