27 May 2016

# EUA-EPUE Response to SET-Plan Consultation

## Key Action No. 8: "Strengthen market take-up of renewable fuels needed for sustainable transport solutions"

**BACKGROUND**

This response provides the perspective of the European Platform of Universities in Energy Research & Education (EUA-EPUE) to the consultative process on the European Strategic Energy Technology Plan (SET Plan) - Key Action No. 8 "Strengthen market take-up of renewable fuels needed for sustainable transport solutions".

EUA-EPUE responds to the consultation from the perspective of the universities' role in society. Universities constitute a significant part of the research capacity in Europe. At the same time, they educate the highly skilled work force of our societies. We consider therefore that setting up the SET-Plan projects with ensured integration of innovative research with education, including industrial partners, will provide a high pay-off towards achieving the energy system transition, which is a major objective of the SET Plan and the European Union.

**QUESTIONS**

**For the main expected outcome: To make specific recommendations on the priorities/targets proposed in the issues paper(s)**

- Do you agree with the targets set in the issue paper?
- Do you think that the level of ambition is correct?
- Are there any standing issue(s) in the way to reaching the proposed targets/priorities?

It may be useful to understand the broader context in which these targets/priorities need to be achieved. If possible, we suggest that the following is addressed as well:

- *What are your specific recommendations on prioritising R&I activities on these issues (and building where appropriate on relevant existing initiatives)?*
- *Who are the best placed actors to implement the targets/priorities (Industry, EU, Member States, regions, groups of countries/organisations/etc.)?*

**General introduction**

Europe relies upon imports for more than 50% of its energy needs; yet the figure is over 90% for oil, critical for the current road transport system, and 66% for natural gas. The EU's Renewable Energy Directive (2009/28/EC) sets a binding target of 20% in the final energy consumption from renewable sources by 2020. To achieve this, EU countries have committed to reaching their own national renewables targets ranging from 10% in Malta to 49% in Sweden. They are also each required to have at least 10% of their transport fuels come from renewable sources by 2020. All EU countries have adopted national renewable energy action plans showing what actions they intend to take to meet their renewables targets. These plans include: (1) sectorial targets for electricity, heating and cooling, and transport; (2) planned policy measures; (3) the different mix of renewables technologies to be employed at national level; and (4) the planned use of cooperation mechanisms.



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Greenhouse Gas (GHG) ambitions and EU global energy goals and targets were reiterated in the Energy Union Package of 2015[1]. They were also cited in different reference documents[2], as illustrated in Figure 1 *Evolution of Europe`s Energy Goals and targets*:

FIGURE 01 | EVOLUTION OF EUROPE'S ENERGY GOALS AND TARGETS


These climate goals sit alongside with others focused on supporting energy security through a greater use of indigenous resources, including renewable energy sources (RES), and better energy efficiency, whilst there is also formal recognition of the need for a more sustainable and competitive European economy. It is widely recognised that the transformation of the European energy system will be achieved through a variety of measures, including the wide-scale introduction and deployment of innovative energy technologies. Fuel Cell and Hydrogen (FCH) are highly efficient and extremely versatile technologies and, through the use of green hydrogen (H2), can provide zero-emission solutions to a range of energy and transport challenges.

The Issues Paper No. 8 provides a good synopsis of the current situation with respect to renewable fuels needed for sustainable transport solutions in Europe. It helps to structure the discourse about reducing the energy intensity of Europe's industry in line with the overall goal of the SET Plan.

Nevertheless, it should be mentioned that the first two pages of the document focus exclusively on biofuels. The introduction should be more elaborated about renewable fuels produced from electricity like hydrogen or alternative fuels as defined in Challenge 3. This would help to understand the reason why these other renewable liquid and gaseous fuels appear specifically in the targets and the order of magnitude of the figures.

Furthermore, the production of biofuels raised several well-known and serious issues in terms of energy consumption and GHG emissions. These issues seem carefully avoided in the introduction, and more generally, in the rest of the document, which focuses mostly on the amounts of energy produced. The definition of a clear methodology to determine greenhouse gas saving, as well as the energy consumption related to their production (or the net fossil energy saving) must be part of the targets for all renewable fuels

**Comments on biofuels**

- The analysis of alternative fuels, for reducing GHG emissions, must be conducted in correlation with energy industry and other industries. Primary energy consumption is approximately 30% in the energy (electricity and heat) domain, 30% in the transportation domain and 40% in other industrial sectors, among which an increased consumption is in agriculture.

[1] Energy Union Package: A Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy COM (2015) 80 Final.

[2] Fuel Cells and Hydrogen Joint Undertaking, Program Review Report 2915

- Since transport is the fastest growing sector with increasing GHG emissions, it needs ambitious actions to implement larger amounts of renewable fuels of all sources. The issued paper clearly summarises the needs and the complexity of the topic. With the main target on reducing GHG emissions in the transport sector, the whole production chain needs to be taken into account, as well as the related key fuel distribution and end-use (vehicle manufacturer and purchaser) players.
- It is important to note that for practical reasons, the biofuels targets are set according to uptake, when the goal is actually to reduce carbon (greenhouse gas) emissions. System modelling tools to assign carbon emissions to different types of biofuels exist; it is undoubtedly better (though more difficult) to set renewable fuels targets based on carbon emission reductions in the transport sector, rather than renewable fuel uptake.
- The global (full life-cycle) analysis of GHG emissions allows choosing the best solutions of alternative fuels usage, as some processes (and in particular the ones in engines), are very sensitive to deposits in engines or a share of biofules may be toxic (e.g. methanol).
- On fuel provision, a major influence on utilisation of biofuels is the oil and natural gas price. Low prices of the incumbent fossil fuels will make it difficult for biofuel producers to be profitable and therefore to meet supply targets. Volatility in fossil fuel prices is a major barrier to investments in alternative fuels. In addition, the widespread diffusion of electric vehicles will decrease the utilisation of biofuels in specific sectors (e.g. the light duty and domestic transport sectors).
- The two industrial concerns (policy and financing) are underpinned by fuel price uncertainty. Since the value of biofuels are tied to current energy market prices while the costs are only partially, policy is the only viable instrument to ensure their medium and long term financing. This policy stability is needed to reduce the capital investment risk from fluctuations in energy prices. It is important to note that agricultural costs are strongly tied to fuel prices (biodiesel, 1st generation biofuels) but lignocellulosic fuels (especially from wood) are much less.
- It is clear that an ambitious approach is needed to achieve significant impact but needs strong support and commitment from all related parties. This commitment needs to be made for the coming decades.
- Bio products will represent value-added options on biofuels (e.g. bioethanol and biodiesel), but as with petroleum, the fuel market drives volume, which dominates capital investment. This dichotomy is essential, as the underlying large-volume market for biofuels will drive bio refining, with the value-added products representing future investment rather than a starting point to justify biofuel production.
- The whole-chain logistics are very sensitive to the feedstock production and collection systems as highlighted through existing knowledge concerning production chains (e.g. sugar production from beet). These supply chains need to be conserved and used to provide the capital investment foundations to build the logistics for 2nd and 3rd generation of biofuels in the context of bio refining. A better understanding of the approaches necessary to produce not only biofuels but also other higher value products to contribute to whole chain and competitive bio economy is urgently needed.
- Integrated "smart scale" production systems need to be developed based on existing technologies but with the aim to be a bio refinery from the beginning or at least to be extended to a bio refinery in the medium term (5 to 10 years).

- The Issues Paper statement is correct that aviation fuel goals are longer term (10+ years). Electrification will take a very long time (at least 30 years with current vehicle turnover rates). As such, liquid biofuels are likely both a short and medium term option and for heavy-duty transport may be more important post-2050 than is currently the case (IEA, World Energy Outlook, 2015[3]).
- The specific implementation of EU targets in the member states strongly depends on their possibilities, structures and cultural history. Therefore, the specific needs and possibilities of the regions need to be included in R&I activities.
- Specific attention should be paid to projects and research on biofuel production supported by the production of higher value substances or material as "by products". Public engagement and 'buy-in' is critical in this respect.
- The obstacles for utilisation of biofuels are technical, societal, political and economic. It is believed that the societal, political and economic barriers require as much attention as the technical challenges.
- The Issues Paper states that the food crop-based biofuels can increase to a maximum of 7%. A source not yet considered for increasing the share of alternative fuels is represented by hydrogen, for which there are no major technical challenges for its combustion in the engines. The main challenges for directly using hydrogen in engines are related to the infrastructure for producing, transporting, storing, supply and generating costs of hydrogen.
- Also, an important source of biofuel feedstock is from the biological waste streams of the food and materials sectors. One interesting example are the wastes from leather industry, which are currently 160 000 tonnes/year in Europe. Almost a third of the leather wastes can be directly used in a blend with diesel, after chemical pre-treatment, for combustion in engines. The Longer Heavier Vehicle (LHV) of the wastes from leather industry is about 40 MJ/kg, very close to that of diesel. The percentage of leather wastes in the blend can reach up to 10%. A third of the leather industry wastes is represented by protein wastes which can be used to produce biogas with a LHV of 20 $MJ/m^3$.
- The crops to contribute to biofuels production are: starch-rich crops (cereals, potatoes), sugar crops (sugar cane, sugar beet), oil crops (rape, sunflower, soya, etc), lignocellulosic crops (willow, poplar, miscanthus, arundo donnax, etc). Currently, only 2% of the global biomass production is used in the transportation sector. In 2015, the Council and Parliament (Directive 2015/1513 Article 3d) set a limit of 7% for the contribution of biofuels produced from food crops and established an indicative target of 0.5 % for advanced renewable fuels in transport by 2020. Biomass is considered a carbon-neutral source of energy at the point of use, where the carbon dioxide released during combustion is re-absorbed by crops when they re-grow and in this way contributes to maintaining the GHG emission level.
- Whilst the so-called carbon-neutrality of biomass for energy remains controversial, much work and new standards were established allowing the industry to demonstrate net carbon and GHG emissions in the supply and use of biofuels. Indirect impacts have been shown to be minimal in the major biofuel production supply chains.

[3] http://www.worldenergyoutlook.org/weo2015/#d.en.148701

***Do you agree with the targets set in the issue paper?***

The energy targets should be set in term of net fossil energy saving (i.e energy production minus energy consumption) according to a methodology that must be clearly established.

**Target 1. Total renewable transport fuel produced by EU projects (TWh/year)**

**1.1. Advanced Biofuels**

2020, 25 TWh advanced biofuels (this corresponds to 0.5% of the approximately 5000 TWh total transport fuel consumption and to 3 GW installed production capacity).

2030, 200 TWh advanced biofuels (this is not a regulatory target but a projection based on estimates made by leading companies involved in advanced biofuels and equates to a 4% contribution to total transport fuels consumption and assumes no growth of total energy consumption by transport).

a) The target for 2020 of 25 TWh advanced biofuels is difficult to be reached. The "advanced biofuels" are not necessarily the desired outcome while decarbonisation of the transport sector is. Some of the main barriers consist in oil and gas prices evolution and methanol toxicity.

b) There is the need of a strong and powerful policy to achieve this goal considering the multi-feedstock and multi-product system including investments in production and distribution. Bioethanol in Brazil has an implementation and optimisation period of more than 30 years and several main routes are already available, but the smart combinations to bio refineries will be the key to success. Integrated and flexible co-production of sugar, heat, electricity and ethanol has been a key driver of the success of Brazil's sugarcane ethanol fuel programme.

c) Bio-ethanol, bio-butanol and dimethyl ether can be easily used in mixtures with diesel fuel. The main barriers imposed by these fuels consist of slow cost reduction and corrosion of supply systems. The evolution will depend on the development of materials resistant to this corrosion. Other novel fuel molecules are emerging (e.g. from US research) and this area is likely to evolve. EU should not be overly constrictive in terms of regulations.

d) The target of 200 TWh advanced biofuels for 2030 is possible to be reached, but is strongly correlated with continued investment in R&I and demonstration, and with the widespread diffusion of electric vehicles. Developing a focus area of using biofuels in the agriculture and food provision sectors could make the target more reachable, as e.g. agricultural equipment does not require sudden variations of torque compared to the road vehicles. Therefore, the deposits of materials in the engines as corrosion phenomena are reduced.

**Target 1. Total renewable transport fuel produced by EU projects (TWh/year)**

**1.2. Other renewable liquid and gaseous fuels**

2020, 5 TWh renewable liquid and gaseous fuels (for example using renewable electricity to produce gaseous or liquid fuels, including the capture and reuse of CO2, as well as synthetic fuels made by other innovative processes).

2030, 25 TWh renewable liquid and gaseous fuels (ibid.).

In 1995 the final energy consumption for transport in EU (28 member States) was 306.8 Mtoe/year (= 3568 TWh/year); in 2013, it was 348.5 Mtoe/year (= 4053 TWh/year)[4]. The activity of the transport sector is expected to grow significantly with the highest growth rates occurring from 2010 to 2030, driven by developments in economic activity. 2020 and 2030 consumption levels are expected to be close to 350 Mtoe = 4070 TWh/year[5].

a) Target values provided in the issue paper for *Other renewable liquid and gaseous fuels* (5 TWh in 2020 and 25 TWh in 2030) represent only a fraction (respectively 0.12% and 0.61%) of the final energy consumption for transport in EU (28 member States). The figures, although challenging, are consistent with existing roadmaps. They could contribute to the evolution of Europe's energy goals and targets by 2020 and 2030.
b) It would be better to provide an exhaustive list of processes that can be used to convert primary renewable energy sources into liquid or gaseous fuels and to set specific targets for each of them instead of aggregating targets for 2020 and 2030. For example, hydrogen could play a central role as energy carrier because it can be used for the large scale storage of electricity but this is also a fuel or a chemical intermediate for power-to-liquid conversion.
c) A SWOT analysis of these processes should be performed. Identification of scientific or technological limitations could serve as a basis to define Research & Demonstration (R&D) plans and implement roadmaps.
d) In several biofuel production processes, CO2 (bioethanol) as well as CO2 and H2 (e.g. butanol production via ABE fermentation) are produced in a very concentrated and easy to capture forms. Further, reuse of such sources should be implemented first (bio refinery concept) alongside continued R&I of looking to CO2 sources which need large efforts (and costs) for capturing and purification before further use.
e) The target of 2020 of 5 TWh, in the existing context of low fossil fuel prices, is almost impossible to be reached. Only a strong regulatory decision of the European Union can help in reaching this target.
f) For 2030, the target of 25 TWh can be reached by focusing on, for example, industry and food system wastes and by-products. One example, through this value generation approach in the leather industry alone, could provide about 1.5 TWh. In addition, more support is needed for lignocellulosic feedstock production, coupled to whole system, integrated agriculture and forestry, approaches to the sustainable provision of biomass.

[4] EU Energy in Figures, Statistical Pocket Book, European Union (2015), ISBN 978-92-79-48359-2 ISSN 1977-4559 doi:10.2833/105662
[5] EU Energy, Transport and GHG Emissions, Trends to 2050, European Union (2014), ISBN 978-92-79-33728-4

**Target 2. Estimated GHG savings**

Total GHG savings through use of advanced biofuels and renewable fuels will be at least that required in Directive (EU) 2015/1513 where Article 7b (amended) states that greenhouse gas emission saving from the use of biofuels shall be at least 60%. The greenhouse gas emission saving from the use of biofuels shall be calculated in accordance with Article 7d(1) of the same directive.

a) Target No. 2 covers the estimated GHG savings from using biofuels, and the European Directive 2015/1513 with amendments states that greenhouse gas emission savings from the use of biofuels shall be at least 60%. The capture and reuse of $CO_2$ is neutral with respect to GHG as the natural process of reuse is based on photosynthesis and transformation of $CO_2$ in biomass, and in the end, in this case, into biofuel. Thus, it is at least a semi-closed cycle.

b) Closing the carbon cycle, requires energy inputs to split the $CO_2$ molecule into C and $O_2$ (provided by solar radiation in photosynthesis), and afterwards re-emits the energy when C and $O_2$ are combined e.g. through combustion. The $CO_2$ reduction needed to produce energy-rich molecules is achieved by combining the splitting with hydrogen production technologies using non-polluting energy sources (wind, solar, hydro), if GHG emissions are to be minimised. The hydrogen produced in this way appears to be a solution to reduce GHG emissions and also for the management of electricity peaking and grid storage. If $H_2$ fuel cell technology is improved to a level that it is viable for transport, for example, then use of $CO_2$ capture and reduction would not be as desirable.

c) A proper design, implementation, monitoring and verification of the whole production chain is required. Whilst these assurance and certification systems are being pioneered in bioenergy supply chains they will need to be applied to the biological food and materials sectors too.

d) The increase in railway transportation is an important and increasing source of GHG emissions in transportation. The European Union can go enhance the rate of electrification in railways, developing fast railway routes both for freight and people. However, a substantial share of energy dense, low GHG liquid fuels would still be required for marine, long-distance road and aviation (see IEA, World Energy Outlook, 2015).

e) The aim of the transport pillar of the Fuel Cells and Hydrogen Joint Undertaking (FCH-JU) is to accelerate the market implementation of hydrogen technologies in transport through demonstration and research projects. Hydrogen technologies can play an important role in the reduction of emissions, including GHG and other emissions such as SOx, NOx and particulate matter (PM) from Europe's transportation activities, especially road transport.

f) Hydrogen technologies can be used to achieve zero-emission transport. The UK H2 Mobility Phase 1[6] report shows that FCEVs would generate 75% fewer emissions than diesel vehicles by 2030 and zero by 2050 when all hydrogen fuel would be RES based.

g) For example, it is estimated that the introduction of FCEVs into the UK vehicle fleet would reduce well-to-wheel $CO_2$ emissions by 3m tonnes annually by 2030 (1.6m FCEVs), and by up to 32m tonnes by 2050 (17m FCEVs, 50% of UK fleet). A similar reduction could be replicated

[6] UK H2 Mobility Phase 1 results April 2013, quoting DECC 2050 Pathways Analysis

in other EU countries. The new FCH JU financed bus study[7] indicates that over 2 million tonnes of CO2 could be saved annually in Europe through the deployment of about 2 500 buses by the 45 participating bus operators.

h) Since there is no defined and accepted methodology to determine greenhouse gas saving for renewable fuels (for example power to gas or power to liquid that do not use biomass as feedstock), it is urgent to do so.

**Target 3. Cost or price targets are not foreseen.**

a) Cost is a key driver that determines investments required for large scale implementation of renewable fuels. It also facilitates the comparison of different technologies. Cost analysis should be performed to assess the viability of different technologies.
b) The target price in 2020 and 2030 for advanced renewable fuels should be at least comparable to the target price of the other competing transport options including renewable electricity from wind and solar and within a reasonable margin from parity with the fossil based fuels. This will require in particular improvements in process efficiency and energy balance through the application of innovative practices. To determine the price margin, input from stakeholders and Member States is needed.
c) "Smart bio refineries" need to contribute to the economics of biofuel production and incentives should be implemented.
d) The target price should also be in line with potential carbon emissions savings. The more advanced the biofuel, the more valuable it is under such a scenario.

***Do you think that the level of ambition is correct?***

a) The level of ambition set in the issue paper seems to be in line with the 2015 EU Energy Strategy.
b) However, considering the situation in 2016 (demonstration platforms that store renewable energy sources into hydrogen of electrolytic grade are scarcely found in Europe; hydrogen refuelling infrastructure is almost not-existing; the implementation of Fuel Cell Electric Vehicles (FCEVs) has started but the transition that could make a significant impact in the transport sector could be realistic for 2050 and beyond), the targets set in the issue paper n°8 need a higher level of ambition by the Member States.
c) All available FCEVs were developed and manufactured outside Europe. The ambitions for demonstration of state-of-the-art refueling stations and imported FCEVs is therefore considered to be sufficient.

***Are there any standing issue(s) in the way to reaching the proposed targets/priorities?***

a) A fiscal frame that would offer mid to long-term stability and favour investments for large scale implementation is recommended.

[7] Fuel Cell Electric Buses – Potential for sustainable public transport in Europe 2015



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b) Carbon taxation is also an issue; this is potentially a key driver that could fasten the energy transition towards larger share of renewable energy sources in the energy mix.
c) Safety of the fuel infrastructure is a critical issue for large scale implementation. It can have different impacts, especially in public acceptance of innovative technologies.

***What are your specific recommendations on prioritising R&I activities on these issues (and building where appropriate on relevant existing initiatives)?***

a) Regarding Fuel cell and Hydrogen, the FCH Joint Undertaking is a key actor in European R&D. They cover the whole spectrum of hydrogen technologies (hydrogen production, storage and distribution to end users). They can act as referent for prioritising R&D efforts.
b) To exploit the full potential of these innovative technologies, European universities should cooperate to implement appropriate teaching and training actions and meet manpower requirements.
c) Regulations related to the production of pressurised hydrogen for mobility applications should be reconsidered. They should also become more homogeneous throughout European countries. The challenge is to facilitate decentralised production and the implementation of an appropriate hydrogen infrastructure.

***Who are the best placed actors to implement the targets/priorities (Industry, EU, Member States, regions, groups of countries/organisations/etc.)?***

a) No single actor can, alone, be charged to implement the targets. A cooperative effort is needed among different actors because the technologies and markets still need improvements.
b) Member States should support academic research on innovative materials and processes. Joint Initiatives are still required to pursue the effort already made over the last decades and stimulate the development of market-ready technologies.
c) Regions and territories are called to play a significant role for the implementation of synthetic fuels such as hydrogen.

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## COMMENTS ON ANNEX II

### CHALLENGE 1: ADVANCED (SECOND AND THIRD GENERATION) BIOFUELS

- For reaching the 0.5 % target by 2020, new production plants for advanced biofuels will have to be built in the next years. From the European Union, stable and long-term policy frameworks for biofuels should be adopted to increase investor confidence. This can include binding targets for 2020 and afterwards, as well as the deployment of advanced biofuels requiring further important researches and innovation activities.
- The process optimisation, valorisation of side-streams into higher value products and new financing mechanisms for large biofuels projects are key elements to reach this goal by 2020 and thereby effectively contribute to the de-carbonisation of the transport sector.
- It will also be important to explicitly recognise the co-benefits of well-implemented advanced biofuel production chains, e.g. with regard to ecosystem service delivery, climate mitigation, adaptation and enhanced resilience in food materials production.

### *ADVANCED RESEARCH PROGRAMME*

*Action 1*: Develop low-cost integrated process concepts to reduce the investment needed for the production of biofuels and bio products

- It is important to recognise co-benefits (see above) and co-products.
- Targets and incentives for advanced conventional biofuels should be integrated (but separately identified) with targets and incentives for advanced novel biofuels (within the bio refining concept, see below).
- Action 1 needs to be implemented with the target of optimising the whole production chain and not only focusing on investment costs. This is a question of setting the boundary conditions to achieve the optimal results not only on economy, but also on reduction of GHG emissions on the whole production chain.

*Action 2*: Develop innovative biological, chemical and thermochemical routes for biomass conversion to obtain biofuels and bio products from all fractions of biomass

- Action 2 must be co-implemented with Action 1. The large volume product (the biofuel) must drive innovation. The integrated co-products, while immensely important to stable economics, are both longer-term aims and necessarily derivative of the central process.
- Sustainable feedstock provision is as important as the development of novel conversion technologies. More support is urgently needed to stimulate the supply of feedstocks in advance of demand-side policy interventions
- Specific R&I funding streams must be identified for both short, medium and long term options.

***INDUSTRIAL RESEARCH AND DEMONSTRATION PROGRAMME***

*Action 1*: Demonstrate processes at TRL 6 and 7 that decrease Capex and/or Opex and increase the overall sustainability of advanced biofuels processes to various end-use applications (road transport, aviation, etc.)

- Lessons from the US advanced biofuel and novel bio refinery implementation can be valuable. Novel science is still required to develop advanced (2nd Generation), cost competitive biofuels.

*Action 2*: Evaluate feedstock chain and process flexibility for relevant biomass sources at demonstration scale (TRL=6-7)

- The actions are feasible, with the consideration of feedstock production chain and the production of valuable by products.
- Consultation with local communities and integration of social with natural science is key to the development of sustainable feedstock supplies.

***INNOVATION AND MARKET-UPTAKE PROGRAMME***

*Action 1*: Implement advanced conversion technologies at large scale energy-driven bio refineries and implement sustainable, reliable and efficient value chains at large scale (TRL=8)

- Support continued demonstration of bio refineries throughout the EU.
- Ensure proper stakeholder and community consultation prior and during implementation of demonstration projects.
- Ensure full life-cycle assessment and monitoring programmes from the outset.

*Action 2*: Improve large scale logistics and storage of feedstock to provide a continuous supply (TRL=8)

- The actions are feasible but should be linked well to the other challenges, in particular new solutions for biofuels production demonstrated at least TRL=4 through the significant support of Europe's universities which having the expertise to effectively tackle the major scientific and technical barriers.
- In addition to actions and efforts mentioned above, it will be very important to develop the acceptance of the consumer along with the development of the technologies.

**CHALLENGE 2: HYDROGEN AND FUEL CELLS**

- Improve performance and reduce costs of the next generation of FCEVs by a factor of 2 (compared to cost of small fleet FCEVs in 2015), whilst increasing lifetime towards 6 000 operational hours.
- Improve modularity, refueling time, reliability, safety and availability of hydrogen refueling infrastructure, while reducing investment intensity and operational cost.
- Demonstrate competitive Fuel Cell Electric Vehicle (FCEV) and infrastructure solutions, by targeting around 100 000 FCEVs and around 1000 publically accessible hydrogen refueling stations to transition the transport sector to sustainable renewable fuels.

- Contribute to the integration of intermittent renewable energies (wind, solar) by providing Multi-MW cumulative hydrogen conversion capacity for use in transport and stationary applications, including chemical feedstock or injection into the natural gas grid.
- Develop a portfolio of cost-competitive, energy efficient and sustainable hydrogen production, storage and distribution processes, with 50% of hydrogen used for H2 energy applications produced from renewable sources or from near zero-CO2 -emission sources.
- Develop and demonstrate APU applications for road, aircraft, rail and maritime applications by 2020 with a focus on the usage of biofuels.
- Assure development and production of competitive hydrogen and fuel cell technologies in Europe.

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