WIVA P&G Position Paper on Research Needs and Challenges for Hydrogen Technologies

1 Introduction

The present position paper is structured primarily in terms of **technological research needs**. It should also be noted that most current national and international research programmes have a clear technological focus. However, the authors of the present position paper would like to explicitly point out that in addition to technological research, at least accompanying research on economic, ecological, legal, and social aspects must be carried out. The optimal implementation, however, would be simultaneous research in the context of the dimensions explained, in addition to technological R&D. Furthermore, there is also a need in the context of a systemic topic, such as hydrogen for specific questions, to put the actual focus on developing and answering new economic, ecological, legal, or social aspects.

Hydrogen as energy carrier, as well as related systems in different fields of application, is a **key enabling technology to achieve the CO_2-neutrality of Europe** announced by the EC in the "Green Deal". The objectives and topics of the WIVA P&G energy flagship region exactly focus on these technologies, their development and first pilot applications/demonstrations.

The objectives of the Green Deal can only be achieved if in parallel, Europe as well as all member states bundle their research efforts. In Austria, the targets of hydrogen research and applications were compiled in the AT-H_2-strategy elaborated in 2019. WIVA P&G partners provided significant input to the development of the H_2-strategy. Based on the more general objectives of the Austrian H_2-strategy, as well as the specific research needs identified by the partners of the WIVA P&G energy flagship region, this position paper was developed. This position paper should provide an **overview and outlook on short-, mid- and long-term research needs** in order to finally achieve

- CO_2-neutral energy generation and conversion/production of CO_2-neutral, distribution, and storable energy carriers – summarized under "Green Energy",
- CO_2- neutral mobility of persons and goods, summarized under "Green Mobility" and
- CO_2-neutral industry sector summarized under "Green Industry".

These three areas are heavily interlinked – e.g., the well-known chicken-and-egg problem of fuel cell vehicles (FCV) and hydrogen refueling stations (HRS) can only be solved if Green Mobility is introduced simultaneously with Green Energy. In order to initiate a fast market introduction of hydrogen technologies, also new business cases need to be developed by efficiently interconnecting these sectors (Green Energy, Green Mobility and Green Industry) to establish first (regional) green hydrogen economies.

Further, Austrian research and development in the context of hydrogen will also ensure **significant domestic added value along the entire – quite diversified – value chains** in the medium to long term. A direct and obvious value-added gain lies (with included positive effects on the labor market) in the development and resulting market establishment of technologies and technological systems for the production, storage, distribution and use of hydrogen and chemical compounds based on it. In addition, domestic research and development on hydrogen also has other significant value-added effects, for example through resource efficiency due to the possible seasonal storage of energy, through the generation of domestic energy production (and substitution of energy imports), through the planning and construction of new plants or through the possible continued use of existing transport and storage infrastructure. Thus, Austrian research along the entire value-added chain will generate **high value added for the Austrian economy** in the medium to long term if the results are implemented.

Finally, to guarantee the broad acceptance and fast market introduction of hydrogen technologies, training and teaching must be increased, not only in education but also for users and employees. Furthermore, laboratory infrastructure for research and development work is needed. Focus should therefore also be put on

- R&D infrastructure for component and system development
- Optimized test benches for (mobile) fuel cells (systems) and hydrogen storage technologies
- Simulation tools and development methods to advance R&D processes in hydrogen technologies

In addition, research topics in basic research up to TRL 4 are also needed.

2 Green Energy

2.1 Feed-in/blending and feed-out/deblending (Injection) of green hydrogen into existing gas grid

- <u>Research and development needs</u>
    - Simplification of feed-in and feed-out systems regarding efficiency, technology and regulative
    - Efficient and low-cost purification systems to extract pure hydrogen from gas streams

Both the feeding in and the removal of hydrogen from the gas infrastructure contain additional research needs. In the dimension of extraction, projects are desirable that use new technologies - such as membranes - to extract the hydrogen from the gas network, so that direct transport is made possible. Optimal locations and technologies are to be demonstrated in the dimension of the feed-in.

2.2 Methanation of renewable gases

In order to use the existing gas network, methanation can play an important role for many applications. Three projects (Renewable Gasfield, Underground Sun Conversion, Carbon Cycle Economy Demonstration) on this topic are currently being worked on within the WIVA P&G energy flagship region. As there are different methanation technologies, further projects can be of interest if they make a significant improvement (for different target parameters) of the processes possible.

Short/medium term research needs of high relevance:

- Advances in materials (for catalysts)
- Long term operability / load flexibility / response time
- Scalability / modularity
- New reactor design
- Heat management
- Process control / high automation of the plant / remote control
- Concept / system for carbon intermediate storage

2.3 Seasonal gas storage for renewable gases

- Research and development needs
  - New materials for high pressure storage (e.g., polymers)
  - Behaviour of hydrogen in porous reservoirs (depleted reservoirs)
  - Chemical based hydrogen storage
    (metal hydrides, LOHC, -> low pressure materials)
  - Compression technologies (mechanical, electrochemical, and thermal compression)
  - Enhancement of reservoir modelling tools for hydrogen applications
  - Safe, efficient, and low-cost hydrogen storage technologies in TWh-scale
  - Inspection and testing methods for new materials (e.g., composites) with high pressure H2 load
  - Inspection and testing methods for hydrogen storage technologies

If electrical energy, and consequently green hydrogen, is generated from wind, water or solar power, peak loads occur in electricity generation or in H_2 production. These peaks must be buffered by means of continuous storage, e.g., as pressurized hydrogen. The storage of hydrogen in metal hydrides also represents a corresponding option. These (new) storage possibilities should be dealt within the projects.

Another promising option to store large quantities of hydrogen (in TWh-scale) is to use depleted natural hydrocarbon reservoirs. This is probably the only option to manage inter-seasonal shifts of renewable energy from summertime to energy demanding wintertime. In addition to storage in the form of hydrogen and methane, there is also the possibility of storage as ammonia or in the form of other hydrocarbons.

2.4 Use and adaption of existing gas and electricity infrastructure

- Research and development needs
  - Hydrogen uptake and influence of existing gas infrastructure
  - Analysis and possible adaption of existing underground gas storage facilities on their ability to accept hydrogen (-admixture)
  - Purification systems for enriched natural gas to extract pure hydrogen

  - Establishing know-how for future parallel hydrogen infrastructure
  - Adaptation of testing and inspection methods for existing infrastructure in respect to specific requirements for hydrogen

The use of existing transport & storage infrastructure is an important and inherent component in the conversion of the energy system. Projects that focus on the optimized use of the pipeline and storage infrastructure (in the context of green hydrogen or hydrocarbons based on it) can also be submitted as showcases for existing technologies.

A special focus should be laid on the "energy supply of the future": research has to be done to combine volatile power production by renewable energy sources with demand and storage possibilities and cultivation. Hydrogen systems have to be integrated into existing energy grids in view of

- sector coupling
- seasonal energy storage
- operation strategies
- simulation models (demand, supply, peak shaving)
- optimized energy utilization

2.5 Green hydrogen production

- Short and medium-term research and development needs
  - Small scale electrolysers, materials for higher efficiency, longer lifetime and cost reduction (polymers, industrialisation, …)
  - Balance of plant components (gas drying, water purification, cooling)
  - Non-precious metal catalysts
  - Highly efficient and highly reliable alternative electrolysis (AEM, …)
  - High capacity storage
  - High temperature/pressure electrolysis
  - Recycling of materials
  - Methane pyrolysis
- Long term research visions
  - Photo reforming (direct conversion from sunlight to hydrogen)
  - Salt water electrolysis

In addition to the production of hydrogen by electrolysis, other possibilities can also be considered - whereby CO_2 neutrality must be given in any case. This means that biomass can be used for hydrogen production as it is CO_2 neutral.

Research and development for electrolysis is still needed and should focus on:

- Materials and production technologies
- Process management and control
- Inexpensive and efficient auxiliary units (BoP components)

For electrolysers in general, the main issue is to optimize the technology with a focus on cost reduction. Key areas of development comprise increased operational flexibility by improving ramp-up rates, start times and stand-by energy use especially of high temperature electrolysis, and modularity of electrolysers and the respective flexibility of power capacity. Considering costs, target values are provided in (Fuel Cells and Hydrogen 2 Joint Undertaking, 2018). For example, the goal for PEM and other low temperature electrolysers (e.g., AEM) should be to reduce costs to USD 800 per kW (€ 700 per kW) till 2024 through optimized manufacturing, more resistant polymer membranes and reduced noble metal content as well as the use of non-noble metal catalysts. Total efficiency should be increased to more than 80% (HHV), the lifetime to at least 80 000 hours and the stack capacity to multiple MW. In total, system capacity should be increased to the 100 MW scale and ramp-up rates complying with the primary control power market must be achieved.

Clean hydrogen needs to become cost-competitive with conventional fuels. For example, fuel cell (FC) cars are projected to achieve cost parity with diesel at commercial production volumes at a hydrogen cost of 5 €/kg. Clean hydrogen as a feedstock can reach parity with fossil-based inputs if the cost of carbon is included.

Hydrogen production via electrolysis in general is currently more expensive than via other methods due to the capital costs and dependence on electricity costs. Renewable electricity could be a major driver to reduce costs due to their low specific costs compared to other origins of electricity. Nevertheless, fluctuating production and a resulting low number of full load hours have negative influence on the utilization of electrolysers. A second objective is to improve the efficiency of electrolyser systems to reduce costs and the electricity consumed. Together with improvements in efficiency, the resulting cost reductions should make it possible for electrolysis to be capable of producing zero emission hydrogen at a cost of below € 3/kg in the long term (Michael Ball, 2016).

A long-term target is the process of photo reforming, which enables direct sunlight-driven conversion of abundant feedstocks like H_2O, hydrogen containing waste or post-consumer plastics into hydrogen. This direct conversion of low-density solar energy into a high-density H_2 that can be transported and be used on demand has to be benchmarked against the two-step approach of power production via PV and splitting of H_2O into H_2 and O_2 in an electrolysis.

2.6 Central and de-centralized sector linkage

- Short- and medium term research and development needs
    - Waste heat usage (integration in production as well as consumption systems), overall system optimisation
    - Small scale flexible fuel cells
    - Fleet refuelling based on local H_2-generation
    - Flexibility in hydrogen production based on fluctuating renewables supply
    - Grid supportive operation of hydrogen systems
    - Economics and business economics and systemic aspects (e.g., new co-operations, usage of synergies)
    - Norming, regulation, …
  - Optimised distribution networks incl. energy efficiency (e.g., pipeline, trailer, ship)
- Long term research visions
  - Exergy-optimised overall energy systems under boundaries of low cost and fulfilment of the Paris Agreement - e.g., examine interlinkages of de-centralised and centralised sectors

Green hydrogen based on electrolysis can be used for active sector coupling. On the one hand, this process path offers the possibility to relieve the capacity of the electricity grid and to perform long-term storage functions by transporting and storing green hydrogen (optional SNG) in the gas system. On the other hand, electrical energy can also be used for new areas and applications regarding the energy and mobility sector – specifically in the gas system, in the mobility system, in the heating system, in industrial processes. In this way, these processes and technologies promote increased integration of the various sub-areas of the energy system in the sense of optimum use and relocation. In this context, development projects that focus on active sector coupling should refer to the results of existing projects in the showcase region (such as wind2hydrogen).

Furthermore, when looking at the distribution network of fuels, in the case of hydrogen there is still work needed for the optimized logistics concerning hydrogen distribution via trailers on-road, via trailers by train, liquid transport and pipeline transport.

3 Green Mobility

3.1 Hydrogen fuel cell components and systems for affordable FC electric vehicles

- Short term research and development needs
  - Fuel cell stack technology
    - Stack level improvements to increase fuel cell system durability and reliability.
    - Developing a low-cost stack concept and improving stack manufacturability.
  - Fuel cell system technology
    - Developing FC system manufacturability.
    - Optimisation of the FC system to different use cases (e.g., hybridized drive trains, range extender etc.).
    - Thermal and energy management
    - Enhanced and real-time process management and control
- Medium term research directions
  - Fuel cell stack technology
    - Improvements in aerial and volumetric power density of fuel cells (single cell level).
    - Improvements in fuel cell durability, reliability, and lifetime performance (single cell level).
    - Specific attention to new needs of marine and rail applications.
  - Fuel cell system technology
    - Low-cost BOP components (ionic exchanger, humidifier, air filter, etc.).
    - Volumetric & gravimetric density of FC systems.
- Long term research visions
  - Medium temperature, non-noble-metal catalyst fuel cells with oxide ion transporting membranes
  - Water-free fuel cell systems
  - Higher tolerance of contamination

Electric vehicles with hydrogen-powered fuel cell systems enable long ranges, short refueling times, good driving performance and offer a high utility value. The challenge is to develop more efficient, durable, and cost-effective fuel cell components and systems with improved dynamic performance and low noise emissions. These components and systems should be the basis for a local (supply-)industry nestled in the energy flagship region, thus, creating a sustainable society (with reduced/low energy needs for transport of employees and goods) also from an employment/economy view.

Emphasis should be laid on

- Materials and production technologies
- Process management and control
- Inexpensive and efficient auxiliary units (BoP components)
- System and vehicle integration - spatial and functional integration
- Thermal and energy management
- Control and regulation of the entire drive train (battery, power electronics etc.)

For fuel cells in general (mobile and stationary), both capital costs and efficiency have to be optimized. For mobile PEM FCs, real-world manufacturing costs have to be reduced to below EUR 50 per kW through optimized manufacturing and reduced need for precious metals, while keeping lifetime to at least 7000 for light vehicles (cars) and 28000 hours for heave duty vehicles (including busses) (Fuel Cells and Hydrogen 2 Joint Undertaking, 2018).

The goals have to be:

- Improve on-road fuel efficiency up to 0.6 kg of hydrogen per 100 km to reduce the size of the tank while achieving at least 500 km range (by 2035)
- Reduce the volume and the weight of the hydrogen tank. Reduce specific costs to at least below USD 15 per kWh
- Achieve a price premium of 15 % or less of investment costs compared to hybridized ICE vehicles at higher volume annual production rates.

To be able to do that, main technology building blocks that can be applied across a range of different applications like fuel cell stacks and hydrogen tanks have to be improved; fuel cell systems from other vehicles (urban buses / cars) have to be adapted for long distance coaches and HDV.

This will be driven by two factors:

- Scale – economies of sale will be critical in taking cost out of the fuel cell component supply chain, with a 4x effect available in moving from today's volumes to 100,000 units/year.
- Technology – new lab-based technologies need to progress through the TRL levels and into final products to further reduce cost.

Central long-term KPIs are

- Stack costs: 25 €/kW
- System costs: 50 €/kW
- Energy density Stack: 5 kW/L
- Lifetime: 25.000 h
- Efficiency: 60%

3.2 Hydrogen fuel cell for electrified heavy-duty mobility sector

- Short term research and development needs
  - Preparing the market for wider roll-out, e.g., by training technicians to maintain the vehicles etc.
  - Collecting and analysing empirical evidence on performance (technical and commercial) of vehicles and associated refuelling infrastructure.
- Medium term research directions
  - H_2-FC truck technology for a range of truck sizes and duty cycles incl. development tools such as modelling and optimisation.
  - Prototyping activities, development of control systems, interfaces between sub-systems and integration of FC systems into trucks.
  - H_2-FC systems designed specifically for train- and maritime applications
- Long term research visions
  - Zero-CO_2-Zero-Emission-Zero-Waste durable, reliable, fully recyclable HD fuel cell systems for a fully circular economy

Only by means of fuel cell systems can electrified heavy-duty vehicles be represented, which offer a high utility value and can therefore be used economically. This applies to all areas of heavy goods traffic on the road, rail and water as well as all areas in which special vehicles are used (construction, mining, airport apron etc.). For these applications, fuel cell systems – including the components as well as efficient development tools for reduced time-to-market - must be developed that meet the high robustness and durability requirements.

3.3 Hydrogen in fleet use

- Short and medium term research and development needs
  - Adaption of existing FC systems to urban buses, coaches and minibuses
  - Coupling across all public transportation systems
  - Sector coupling and considering the whole value chain from supply via distribution to use/re-use
  - Optimised refuelling strategies for energy efficient refuelling of hydrogen-fleets (production, cooling, storage, operation)
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- Long term research visions
  - Industrialised Hydrogen and FC propulsion systems for large-scale usage

In this context, taxi-, truck and bus-fleets as well as rail-vehicle fleets are relevant. Demonstration projects with corresponding business models should be implemented. In particular, the existing process chains in the public and commercial transport system of people and goods must be taken into account. Moreover, off-road and water transport needs also to be addressed.

Further support for the end-use application will be focused on adopting refuelling technology and networks for applications such as urban and long-haul bus fleets and transport-trucks, as there are many hydrogen vehicles already implemented across Europe and no early development research is needed.

3.4 CO2-free Logistics

- Short term research and development needs
  - Adaption of existing FC systems to vans etc.
  - Sector coupling in distribution centres
  - Transport and logistics solutions based on renewable hydrocarbons
  - Bio-LNG Production development
- Medium term research directions
  - Demonstration of medium-sized fleets and identification of further optimisation potential for industrialisation
- Long term research visions
  - Industrialised Hydrogen and FC based logistics systems for mass market
  - Industrialised and reliable infrastructure solutions

The logistics sector accounts for a significant proportion of CO_2 emissions in road transport. Hence, an overall reduction of CO_2 emissions from well-to-wheel is required. Potential project ideas should comprise the development and demonstration of zero-emission vehicles from tank-to-wheel in combination with lowest CO_2 well-to-tank solutions. The solutions developed for the logistics sector may be designed for both urban and rural areas.

The goal is the development and demonstration of zero-emission freight logistics scenarios (trucks, delivery vans, last mile, industrial trucks etc.), including the use of locally zero-emission vehicles and integration of appropriate refueling infrastructure solutions. The development, integration and testing of fuel production and refueling infrastructure solutions as well as operational demonstration are crucial. The economic sustainability of the development, as well as the option to transfer to regular operations, must be demonstrated at the end of the project period.

The involvement of industry logistic partners, public transport providers, mobility services or fleet solutions is welcomed.

3.5 Hydrogen refueling infrastructure

- Short and mid term research and development needs
  - Process management based on improved controls
  - Establish an international standard for refuelling pressure and shape of the nozzle for all applications
  - Refuelling infrastructure (stations, local and centralized production, hydrogen transport, logistics and distribution)
  - Calibrated and mobile mass metering technology at the HRS
  - Mobile quality metering technologies to validate ISO 14687 2019-11
  - Process optimisation and input for standardisation
  - Focus on component efficiency (compressor, storage systems, …) and process efficiency (energy consumption, …)
  - Optimization of overall system layouts (e.g., integration of new H_2-logistics concepts)
  - Material based storage tanks (e.g., hydrides, liquid hydrogen carriers, metal fibre)

  - Adaptation and development of testing and inspection methods for related infrastructure
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- Long term research visions
  - Pure electrochemical compression

4 Green Industry

4.1 Green hydrogen in (current) industrial processes

- Short and medium term research and development needs
  - Reduction of costs of green hydrogen production and adaption of processes to enable transfer from fossil-based to green hydrogen
  - Development of certification systems for green H_2 in industrial processes
  - Development of integrated concepts with multiple green H_2 applications

- Long term research visions
  - Professional, optimized marketing and scheduling of hydrogen utilisation services can generate significant revenues that support a deployment route for roll-out and scaling of the technology

Hydrogen is already used today for many industrial processes (mostly obtained by steam reformation from natural gas). Projects using green hydrogen instead of grey hydrogen must be demonstration projects with corresponding commercial potentials.

Additionally, upscaling the amount of produced green hydrogen for e.g., the steel/metallurgy, chemical/ammonia and refinery industry have to be further developed, as there will be huge amounts needed. Research in using hydrogen as energy carrier within the industry (fuel flexible and 100% hydrogen burners and combustion chambers).

4.2 Carbon cycle economy

- Short and medium term research and development needs
  - Establishment of a carbon cycle economy by capturing process gases with a carbon potential (CO_2 and CO components) from industrial location and transporting them to a storage facility, incl. the conversion and storage together with green H_2 leading to a storage facility for renewable natural gas for the industrial location.
  - Efficient CCU-processes with the utilization of CO_2 with green H_2 to form syngas and synthetic fuels
  - Development of flexible carbon utilization technologies (fluctuation and non-stoichiometric compositions of substrates)
  - Novel direct air CO_2 capture technology
  - Intermediate CO_2 storage facilities

- Mapping of Austrian hydrogen storage requirements
    - Increase the efficiency of synthetic fuel production
      Development of testing and inspection methods for e.g., periodical verification of CC quality

- Long term research vision
    - Upscale to industrial processes

Hydrogen can be used to bind carbon and at least one further utilization step of the CO_2 recycling process (with at least 50% CO_2 savings) should be achieved. The overriding goal is to achieve a carbon cycle economy. Therefore, total carbon cycles have to be demonstrated, the implementation of new technologies for the implementation of the carbon cycle is worthwhile within a demo project.

4.3 New technology for the use of hydrogen

Based on hydrogen, completely new processes can be developed in industrial processes. One example is the transition of the steel industry from coal input to hydrogen input.

- Short term research and development needs
    - Scale up of steel production up to 20kg batch process & optimisation of process parameters
- Medium term research directions
    - Continuous H_2 supply for steel production including adequate storage solutions, optimisation of hydrogen consumption of steel production, development of semi-continuous process of steel production
- Long term research visions
    - Evaluation and determination of the key design figures for the scale-up factors of steel production
    - Development of operational experience for semi-industrial plant and upscale to industrial process of steel production

The demonstration of other industrial processes for this transition can be demonstrated over an entire value chain or also over partial aspects of this transition with the integration of new technologies and systems. Another area particularly relevant for a change towards C-free processes is the entire process and chemical industry.

Hydrogen can be combined with CO_2 (from capture plants) to replace oil and gas in a range of petrochemical applications such as:

- Producing liquid fuels: methanol, gasoline, diesel, jet fuel.
- Producing important petrochemicals such as olefins or BTX.

Developing these applications could put Europe at the forefront of a clean industrial revolution.

4.4 Stationary fuel cells for decentralized use in facilities

Furthermore, the costs are a major aspect to accelerate market introduction. Measures to be taken are:

- Reduce investment costs to below USD 800 per kW by reducing both the cost of the stack and the cost of balance of plant.
- Increase system efficiencies to at least 50%. Increase lifetime to above 80 000 hours.
- Reduce sensitivity to hydrogen impurities and prove feasibility at large stack capacities.
- Achieve megawatt scale in production.

In order to facilitate a widespread uptake for domestic and commercial buildings (with the aim of 0.5 million FC CHP units deployed and numerous European manufacturers producing >100,000 sales/year by the end of 2030), the most immediate focus of the research agenda should be put on R&D on new stack technologies and components to reduce costs and improve flexibility in operation. Next step should be the development of reversible fuel cell concepts that lead to deployment of distributed commercial systems capable of linking electricity and gas grids at medium and low voltage levels. Additional support for mass market activation can be provided through funding of flagship projects (or Hydrogen valley).

In detail, R&D should be done concerning:

- Industrialisation of production
- Reduction of expensive noble metals
- Reduction of storage costs
- Recycling of materials
- Modification of conventional gas boilers
- 100 % hydrogen boilers

5 Funding Instruments

In accordance with the vision that WIVA P&G, as coordinator of the showcase region, has set itself to demonstrate the possibilities of converting the economic system to a hydrogen-based system, the projects must also be as broad and comprehensive as possible. This is the reason why it is so important that all existing funding instruments such as

- Cooperative projects of oriented basic research
- Cooperative R&D projects, experimental development, and industrial research (fundamental research with low TRL for knowledge expansion, industry-related research for knowledge transfer)
- Flagship projects (industry-related research for knowledge transfer)

which are also listed in further detail in the table below, should also be available in the future. This is particularly so, because it can be assumed that there will still be major developments in many areas of technology. It can be expected that there will be a demand for technologies that are only available today on a laboratory scale, which is why the instruments of the entire R&D chain must continue to be available.

5.1 Description of existing funding instruments

	R&D services	**Cooperative projects of oriented basic research**	**Cooperative R&D projects**	**Flagship Project**
Short description	Fulfillment of a specified tender content	Cooperation of several partners within a research project with a common goal	Industrial Research or Experimental Development	Industrial Research and/or Experimental Development Both research categories can be included in one project; industrial research must not exceed 15 % of overall project costs.
Min. funding	Tbd	EUR 60.000	EUR 100.000	EUR 2.000.000
Max. funding	Tbd	EUR 2.000.000	EUR 2.000.000	None
Max. funding rate	directly financed - 100 %	up to 100 %	85 %	85 %
Max. duration	24 months	36 months	36 months	48 months
Coop. required	No	Yes	Yes	Yes

However, to be able to meet the demands of the WIVA P&G energy flagship region, namely, to actually demonstrate its feasibility, new funding instruments such as

- R&D infrastructure and
- Demo infrastructure and demo plants

are required, which are further presented in the following table:

5.2 Description of newly required funding instruments

	R&D infrastructure	**Demo infrastructure and demo plants**
Short description	Acquisition and construction of R&D infrastructure for basic research as well as for application-oriented research	Demonstration of overall infrastructures and plants
Min. funding	EUR 100.000	EUR 5.000.000
Max. funding	EUR 2.000.000	EUR 50.000.000
Max. funding rate	85 %	50 %
Max. duration	60 months	60 months
Coop. required	No	Yes

5.3 Project and Funding Volumes

Based on the compilation above, it is clear that there will have to be significant budget increases in particular for demonstration plants.

Considering the facts of the recent calls organized within the WIVA P&G energy flagship region, approx. 20-30 project sketches per year - with participation of SMEs, universities, research laboratories and industries - can be expected leading finally to typically 10-15 full proposals with a total annual project volume (sum of all planned project budgets) in the range of 100 – 120 M€ and a request for annual funding of approx. 50-80 M€.

Abkürzungsverzeichnis

ABKÜRZUNG	BEDEUTUNG
AEM	Anion exchange membrane (electrolysis)
BOP	Balance of plant
BTX	Benzene, toluene and xylene
CCU	Carbon capture and utilization
CHP	Combined heat and power
FC	Fuel cell
FCV	Fuel cell vehicle
HD	Heavy duty
HDV	Heavy-duty vehicles
HRS	Hydrogen refueling station
ICE	Internal combustion engine (vehicles)
KPI	Key performance indicator
LOHC	Liquid organic hydrogen carrier
PEM	Proton exchange membrane (electrolysis)
PV	Photovoltaics
SME	Small and medium enterprise
SNG	Synthetic natural gas
TRL	Technology readiness level
TWh	Terrawatt hours

6 Literaturverzeichnis

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