Global Energy Solutions e.V.

For Prosperity and Climate Neutrality

RESULTS / POSITIONING GLOBAL ENERGY SOLUTIONS [1]

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Preface

Global Energy Solutions e. V. (GES) is working on this topic from a global perspective. As a scientific institution, we are dealing open-mindedly with the question of whether a world with an estimated 10 billion people living in freedom and with growing prosperity, especially energy prosperity, is conceivable with a view to 2050. In doing so, a variety of concerns in the context of the SDGs, in particular human rights, overcoming poverty, preserving biodiversity and stabilising the climate system, are to be taken into account. The assessment of alternatives in climate protection is based in particular on avoidance costs for CO2. It is therefore the question of what it costs to save a tonne of CO2, to avoid it or to remove it from the atmosphere. The considerations are global and strategies are partly organised in phases. Rapid reductions in CO2 emissions appear to be important, especially because of the tipping point problem, which cannot be precisely estimated in terms of time. GES is convinced that there cannot be one solution for everything; rather, we are working on a "solution kit" with several interlocking building blocks.

1. Climate-friendly electricity

A prosperity-compatible energy and climate strategy for the world looking ahead to 2050 and 10 billion people requires - also proportionally - a multiple of today's amount of climate-friendly electricity. This will be generated in various ways: old and new methods of using renewable energies, fossil energy sources with CCUS and nuclear energy solutions.

2. Climate-friendly hydrogen

Climate-friendly hydrogen (low carbon H_2) is also needed, produced with climate-friendly electricity via electrolysis or (without electrolysis) as so-called blue hydrogen from natural gas[2] in combination with Carbon Capture and Storage (CCUS)[3] or as so-called turquoise hydrogen from natural gas without CCUS.[4] Low carbon H_2 plays an important role for sector-coupling and is important for many industrial productions, including steel and chemicals, but also for heating/cooling supply and for mobility on a broad scale. The development of an internationally networked hydrogen economy is a considerable challenge due to the complexity of the supply chains to be created but is indispensable for achieving the necessary "economies of scale" in a timely manner, in order to meet the challenges in the climate and energy sector.

3. Carbon Capture Utilization and Storage (CCUS)

CCUS plays a key role in terms of time to achieve rapid CO_2-reduction effects and has a broad field of application. CCUS facilitates rapid improvements regarding our CO_2-footprint. The methods are application-specific and state of the art for many fields of application.[5] Effectiveness and efficiency are high. The resulting additional costs are bearable if CO_2 is priced. Funding measures, such as those in the USA, are also helpful. In developing countries and emerging economies, financing contributions from the global community are necessary. In the case of storage, a

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[2] Methane emissions must be largely avoided in natural gas production and logistics. Methane is significantly more harmful to the climate than CO_2. Best-practice examples show that a considerable reduction of methane emissions is possible and can be financed. The transport of natural gas by pipeline is significantly lower in emissions than by LNG tankers.

[3] New installations show that this is possible and affordable.

[4] Blue hydrogen generated by gas-reforming, turquoise hydrogen by gas-pyrolysis.

[5] Feasibility and safety have been proven for decades, for instance, through enhanced oil recovery technologies.

permanent carbon return ("cradle to grave") is realised.[6] In the case of CO_2-utilisation, closed carbon cycles can partially be achieved.

4. Scaling barriers for electrolysers

There are signs of considerable challenges (in medium term too) in expanding the required electrolyser capacities. This is due to high costs and the usual "chicken-and-egg" problems in emerging markets with diversely differentiated business models. This puts a strain on the production of climate-friendly hydrogen via climate-friendly electricity. This means that internationally linked projects, in which, due to favorable wind and solar conditions, long runtimes for the electrolysers are achieved at comparatively low transport costs, are particularly important in order to achieve the required economic performance. Europe risks losing these opportunities if European regulations are made mandatory for imports, as is being discussed today (for instance, the supply chain due diligence law). This may impact negatively on the future competitiveness of European industries and may lead to the emigration of entire branches of industries.

5. Use of CO_2 from Point sources

The use of CO_2 from point sources (for instance, from coal-fired power plants, cement plants and in steel and iron production) is urgently needed to rapidly reduce global CO_2-emissions.

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6 Carbon extracted in the form of gas and oil is reintroduced as CO_2 or mineralized.

6. Requirements for the economic use of electrolysers

For the electrolysers to be economically viable, they should be used at least at 60% of their generation capacity on average over the year. The renewables used in each case must provide corresponding volumes of climate-friendly electricity over the year. This can be achieved in a cost-effective manner, especially in special regions of the world, and usually requires suitable combinations of solar and wind power. Examples are southern Chile (wind only), southern Morocco (wind/solar) or Namibia (wind/solar). The use of surplus electricity is an economically unattractive application for electrolysers, due to foreseeable low utilization rates (perhaps 20 – 40 %).[7] Also the cost situation will intensify if electrolysers can, due to specific regulatory requirements, only operate at times, for example if available renewable electricity may not be used temporarily to operate the electrolysers because other types of use of the available renewable electricity are given priority. Also, a restriction to use surplus energy only for hydrogen production is quite unattractive because of the resulting low utilization rates for the electrolysers (only about 20-40%). Due to the inefficiency of reconversion of hydrogen to electricity GES generally recommends a clear prioritisation for the material use of hydrogen over the energetic use. For certain industrial applications, e.g., steel and chemicals, a direct reduction or utilization approach via natural gas and CCUS to avoid the expensive route via low carbon H_2 also seems sensible.

[7] When it comes to direct power supply, high utilisation in power generation is less important. However, volatility in the electricity supply must then be addressed.

7. Synthetic fuels[8]

Synthetic fuels based on low carbon H_2 form a third pillar of any viable solution to the world's future problems in the areas of energy and climate, alongside climate-friendly electricity and climate-friendly hydrogen. They are of great importance for climate-neutral mobility in the future. Such fuels have great advantages in terms of transportability, storage capacity and use of existing infrastructures. In this regard, they are superior to hydrogen. Synthetic energy sources/fuels include climate-friendly methanol, methane, ammonia, and synthetic hydrocarbons (Fischer-Tropsch products) for various applications. Synthetic fuels are needed, among other things, for the climate-neutral supply of today's world's existing fleet of 1.3 billion vehicles with internal combustion engines and 1.6 billion in the future. In this context, we also speak of e-fuels. Especially in Africa, a large growth of the combustion engine fleet is expected. Among other things, this will massively affect the truck sector. E-Fuels are also key issues for the shipping and aviation sectors. In addition to the mobility sector and electricity generation, synthetic fuels can also be used for individual heating-cooling solutions.

8. Climate neutrality of synthetic fuels

Synthetic fuels based on climate-friendly hydrogen are climate neutral if the CO_2 used for production was obtained via direct air capture or captured CO_2 from combustion processes of biogenic material is used in production. They are not climate

[8] In our definition, synthetic fuels include the following material groups: 1. e-fuels, i.e. electricity-based fuels (e.g. produced by means of photovoltaics, wind or hydropower) and 2. biomass-based fuels (e.g. from maize or waste such as straw, slurry or waste wood), in short: bio-fuels. Both groups of materials can be produced in a climate-neutral way. According to our definition, fossil energy sources (coal, oil and natural gas) are not the basis for synthetic fuels.

neutral when using CO_2 from point sources, unless the CO_2 used is not counted towards the climate neutrality status of the respective point source (for example, for a climate-neutral coal-fired power plant). However, climate neutrality of the synthetic fuels can also be achieved in the case of offsetting the captured CO_2 for the climate neutrality of the point sources used, namely by generating and financing CO_2-negative emissions elsewhere to a corresponding extent. This is possible, for example, through nature-based solutions[9] and CCUS (injection or mineralisation). In this context, it is important to use, as far as possible, internationally co-ordinated accounting methods that avoid unnecessary material transports.

9 Nature based solution have to fulfill stringent sustainability requirements according to internationally accepted standards (e.g. ICROA), and may not be at the expense of nature and the native, sometimes indigenous population. Land rights must be recognised, if necessary identified and codified.

Insight for the energy transition in Germany

(Additional association activity-field of Global Energy Solutions e. V., apart from the BMZ-project)

1. A strong climate-neutral electricity system for Germany

For Germany, a combination of (new) renewables and natural gas with CCUS seems viable for achieving high resilience, manageable costs, and stability of the overall power system. The justification for combining renewables with natural gas is a comparatively low-cost approach to managing the volatility of renewables.

2. What is required by a restriction to renewable energy sources?

An electricity system based on 100 % renewables is technically possible if solar and wind power are expanded accordingly. If, for example, we aim for an annual volume of electricity based on new renewable energy[10] of 1000 TWh, the wind and PV plants must be expanded by a factor of 7 compared to the current status. They would then supply about 1300 TWh of electricity, of which 450 TWh cannot be used directly because there is no consumer for it at the time of generation. However, this surplus could be converted into hydrogen by electrolysers and then stored. During dark periods, this hydrogen could be used to produce 150 TWh of electricity again, so that a total of 1000 TWh can be guaranteed to meet the grid load in time The use of this hydrogen requires the respective transport-infrastructure and enormous capacities of suitable storages and adapted gas-fired power plants. This will require a multiple of the currently available capacities. If one wants to use the

[10] Wind and photovoltaics

temporary surplus electricity to a large extent, for instance by including all electricity peaks as far as possible, the utilisation rate of the expensively expanded hydrogen-backed-up electricity supply infrastructure to manage volatility will be very low. This increases costs considerably. Such a conversion will be associated with enormous financial, temporal, regulatory and social requirements and conflicts.

3. Electrolysis hydrogen for all industrial needs

If one wants to use electrolysis hydrogen to supply industrial applications in the areas steel, chemical, etc., an expansion of renewables in direction of significantly more than 1500 TWh per year is required, given the corresponding use of funds. Substantial additional quantities of electrolysis hydrogen (generated by, for example, 700 TWh of green electricity) must then be made available at high cost and in a difficult bottleneck situation, and these must be adequately transported, stored temporarily and burned in order to control volatility. This once again exacerbates the problem situation already described under point 2. This makes it clear that Germany initially will continue to be dependent on the import of natural gas and later increasingly hydrogen and its derivatives to supply its industries in the long term.