Global Alliance
Powerfuels

Guidelines for Market Development

Principles and instruments to foster the development of global markets for powerfuels

powered by

dena
German Energy Agency

Imprint

Publisher:
Deutsche Energie-Agentur GmbH (dena)
German Energy Agency
Chausseestraße 128 a
10115 Berlin, Germany
Tel.: +49 (0)30 66 777-0
Fax: +49 (0)30 66 777-699
E-mail: info@dena.de
www.dena.de

Authors:
Kilian Crone
Christoph Jugel
Diego Rojas
Stefan Siegemund

Conception & design:
Heimrich & Hannot GmbH

Printed by:
copyprint, Berlin

Image credits:
Title - shutterstock/polygraphus

Date:
06/19

Table of Contents

1 Executive Summary

Powerfuels are synthetic gaseous or liquid non-biofuels that draw their energy content from green electricity. They are renewable and climate-friendly and can be used as energy carriers and feedstocks. This understanding of powerfuels includes, but is not limited to, hydrogen, synthetic gas (e.g. methane, propane, ammonia) and synthetic liquid fuels (e.g. methanol, Fischer-Tropsch products) and is hence technologically neutral.

By transforming electrons into molecules, powerfuels enable renewable electricity to be stored over long periods and transported over long distances. Technologies for production of powerfuels are proven and tested in many installations worldwide, but processes have not yet been scaled up to industrial-scale.

The Global Alliance Powerfuels was initiated with the strategic objective of fostering the development of a global market for powerfuels. The main goals are to raise awareness and acceptance, to stimulate global project development and to enhance the regulatory framework to stimulate demand.

The following guideline paper presents the Alliance's perspective on the most important principles and instruments to foster global market development. Powerfuels can provide all sectors with low emission fuels. They thus will be vital towards achieving the global goals on reducing greenhouse gas (GHG) emissions stated in the Paris Agreement on climate change.

Bearing in mind the important role of powerfuels for future energy supply and the time required to penetrate markets with new technologies, policy makers have to start creating a new global market framework today for the continuous market development of powerfuels. This will stimulate a new technological development with global benefits for sustainable fuel and feedstock supply, local employment and technological expertise.

To stimulate and foster the market development of powerfuels, the Global Alliance Powerfuels recommends to:

- bring powerfuels as missing link for the reduction of global GHG emissions to the **highest level of national and international climate and energy debate** between politicians and business leaders;
- develop a **consistent, long-term GHG emission policy** with instruments that give market players long-term planning stability and investment security. As a first step on a national level, **powerfuels auctions** can be an effective instrument that can create competition between powerfuels producers while bringing a set amount of powerfuels into the market;
- set **fuels blending quotas for powerfuels** on a national, but especially international level coordinated by supranational institutions (e.g. ICAO, IMO). This would leverage the demand for powerfuels, create long-term investment perspectives and pave the way for real GHG reductions;
- ensure a **consistent framework for pricing fossil fuels**, with final consumer prices determined by energy content and GHG emissions. This means successively phasing out fossil fuel subsidies and implementing carbon pricing regimes to create an increasingly level playing field between renewable and non-renewable fuels. Additional revenue can be used to facilitate the market development of powerfuels.

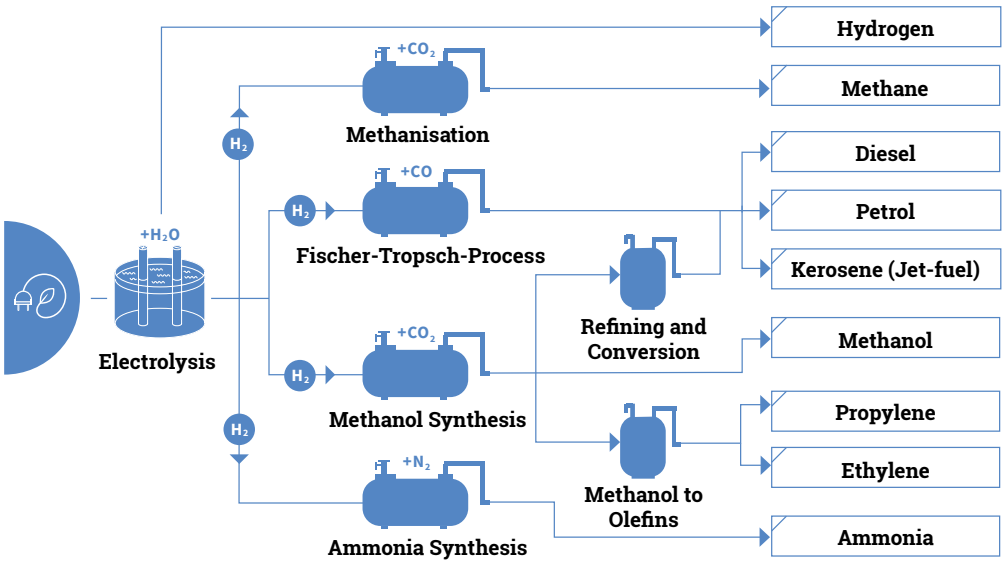

Figure 1: Production of powerfuels. Source: Dena

2 Introduction

By 2050 – the time horizon of the Paris climate goals – the world population is set to increase to 9.8 billion[1] with continuing unprecedented economic growth. Climate targets must be achieved while potentially facing an even higher energy demand than today. This situation highlights the importance of developing and supporting technologies that will guarantee such an energy supply and that will help to get on track with the 2-Degree Celsius Scenario (2DS) contained in the Paris Agreement. To reach its targets, a profound transformation of the global energy system is essential.

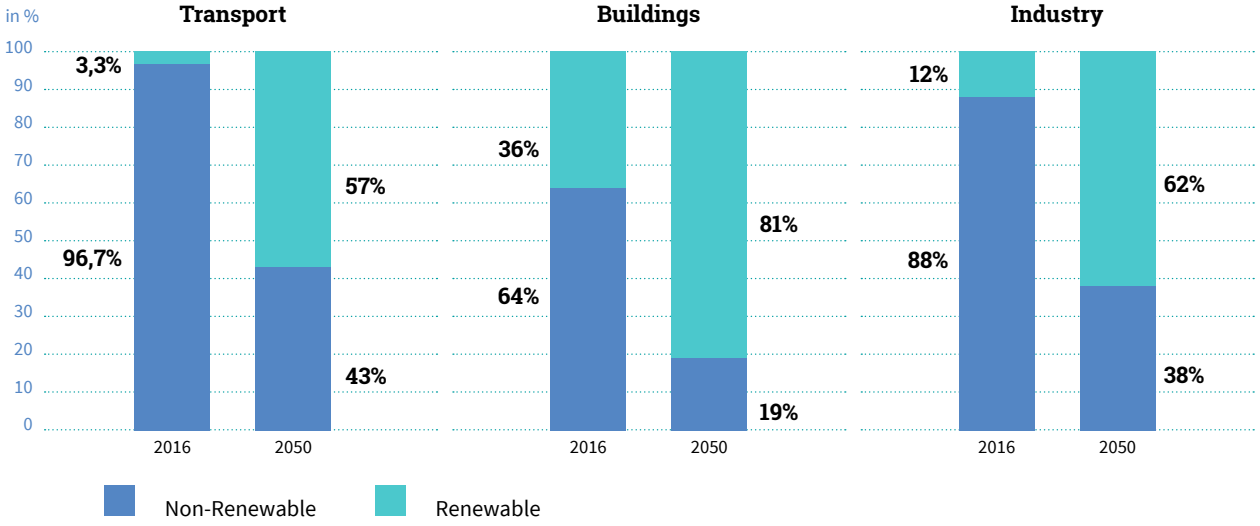

Figure 2: Future share of final energy consumption in key sectors by source. Source: data from IRENA, 2019[2]

Energy efficiency plays an important role. According to IRENA's "Global Energy Transformation" study, global final energy consumption can be reduced from 395 EJ in 2016 to 351 EJ in 2050[3] (IRENA, 2019). At the same time, the share of renewable energy needs to increase substantially from 17 to 66 per cent across all sectors by 2050. In this scenario, renewable electricity is used directly wherever possible. It is complemented by sustainable biofuels, up to the available quantities. The missing link for reaching climate targets is renewable fuels and feedstocks of non-biological origin – powerfuels.

Powerfuels are gaseous or liquid fuels and feedstocks, produced using renewable electricity. This includes, but is not limited to, hydrogen, synthetic gas and synthetic liquid fuels. According to the World Energy Council[4], the global demand for powerfuels may reach 10.000 to 41.000 TWh by 2050, the equivalent of 16 to 66 per cent of today's global demand of crude oil[5]. Creating and running the associated production facilities means new global energy supply chains – and new opportunities for value creation.

[1] United Nations. (2019, March 28). Department of Economic and Social Affairs. Retrieved from world population projected to reach 9.8 billion in 2050: https://www.un.org/development/desa/en/news/population/world-population-prospects-2017.html
[2] IRENA. (2019). Global Energy Transformation, a roadmap to 2050. Abu Dhabi: IRENA
[3] IRENA. (2019). Global Energy Transformation, a roadmap to 2050. Abu Dhabi: IRENA
[4] WEC Germany . (2018). International aspects of a Power-to-X Roadmap. Germany: World Energy Council Germany and Frontier Economics.
[5] IEA, Oil Market Report. (2019, May 02). International Energy Agency. Retrieved from https://www.iea.org/media/omrreports/tables/2019-04-11.pdf

3 Challenges and opportunities

Fossil fuels as we use them today have many advantages: they have a high energy density, are storable over a long period of time, flexible in their use, easily transported and production costs are low. The basis of these advantages comes from sedimentary processes and natural storage mechanisms occurring over previous millions of years. The amount of fossil fuels used within one year took a million years to be produced[6]. According to the understanding of the modern economy, such production time would be associated with very high costs. Therefore, when discussing the costs of renewable fuels, people have to be aware that these costs are not part of today's fossil fuels costs, but are very much part of the costs of renewable resources.

Compared to fossil fuels, renewable fuels depend on the availability of renewable energy sources such as solar radiation, wind speed, water, or biomass feedstock. To increase flexibility in the use of renewable fuels and to be able to store and transport them, energy and cost-intensive conversion and refining processes are required.

Therefore, all renewable fuels (e.g. electricity, biofuels, powerfuels) are facing production constraints or competitive disadvantages compared to fossil fuels. Nevertheless, these renewable fuels are key for the future global energy supply and necessary to reduce GHG emissions. Consistent support for the development of renewable fuels today will be the driving force for learning and scale effects, that will guarantee affordable and socially balanced energy costs in the future. Facilitating powerfuels markets through the development of entry and growth mechanisms is an important prerequisite to increase the use of renewable energies in all sectors.

3.1 The specific role of powerfuels and its opportunities

Gaseous and liquid fuels and feedstocks will still play an important role in an optimized future energy system. From today's perspective, energy carriers with high energy density as well

Complement to direct electrification in all sectors

Powerfuels provide an opportunity to use renewable fuels in all sectors and in nearly all available applications. They complement the direct use of renewable energies and will have an important role where for example direct electrification is not possible or economical.

Use of existing infrastructure

Powerfuels can be integrated completely or partly into the existing gaseous and liquid fuel infrastructure, as well as in applications with very long investment cycles.

Energy security and diversification

Since powerfuels offer high flexibility, they contribute to energy security and energy stability, e.g. as a flexibility option for electricity grids. As renewable power resources are widely distributed around the world, they offer a way to diversify the supply.

Sustainability and costs

Powerfuels can be more efficient and less resource-intensive than biomass products, but are currently more expensive. In the future, costs will converge due to technological progress and a wider variety of available sustainable resources.

Global commodity and new markets

Powerfuels could become a tradeable global commodity. Countries with low natural resources but good solar and wind conditions will get the chance to improve their own energy supply and become a new player in the global energy market.

Technologial progress and local benefits

The development of powerfuels offers benefits such as technological innovation and new employment in industry and in research and development for advanced and emerging market economies.

Figure 3: Opportunities of powerfuels

[6] Rahmstorf, S., & Schellnhuber, H. (2018). Der Klimawandel. München: Verlag C.H. Beck oHG.

as specific raw materials have great difficulties being replaced. This can be seen especially in both the chemical and transport sectors. Powerfuels are the most sustainable solution to meet the energy demand of a growing global economy, even in the future. Technological progress and cost reductions in wind and solar power, as well as electrolysers, have been significant in recent years. Therefore, even from a cost perspective, there has been an increasing amount of interest in creating a market for powerfuels. Combining these factors will mean that powerfuels can offer new opportunities.

3.2 Challenges of powerfuels

Worldwide, private and industrial consumers are accustomed to energy prices that exclude external costs and often include subsidies[7]. Under such conditions, renewable fuels – especially powerfuels – are unable to reach competitiveness with their non-climate-friendly competitors.

Currently, one of the main challenges are relatively high production costs for powerfuels due to the lack of industrial scaling of technology, which means high investment costs (CAPEX). In addition, state-induced price elements can substantially increase operational costs (OPEX).

To make powerfuels more cost-competitive, political support is needed to guarantee an increasing and continuous global powerfuels demand that enables an expansion of renewable energy production. Evolved regulatory frameworks can positively affect the market-value of powerfuels, for example by recognizing powerfuels in allowances and quotas. This would create long-term planning stability for producers and thus enables investments in production capacities.

Especially in the early market phase, political decision-makers should be aware of the following challenges:

High investments (CAPEX), but lower running costs (OPEX)

Powerfuels are currently a relatively new product with high investment costs (CAPEX) that offer great potential to reduce the cost of the final product. If renewable power generation is considered part of the plant, operational costs (OPEX) are comparably low.

Trade-off: avoided infrastructure investments vs. additional costs

Powerfuels are currently more expensive than other renewable options. However, they can reduce the need for infrastructure investments in the overall system. This trade-off is difficult to quantify and communicate in the energy policy debate.

Reduction of production costs

Powerfuels are at a very early market stage. They have a very high cost reduction potential, which can only be achieved through economies of scale and scope in combination with applied research.

New global renewable energy perspective

Some of the best powerfuels production spots are in markets that are not relevant fuel demand markets today and can still be considered developing markets in terms of renewable investments.

Investments risks

Some of the best potential powerfuels production sites are located in countries with relatively unstable investment conditions. It is important to initiate dialogue with decision makers in such countries to identify the potential for local benefit and to reduce investment risks.

Figure 4: Challenges for powerfuels

[7] Phasing out inefficient fossil fuel subsidies is the target of the most important economies, like the G20 members, the EU28 or the Asia–Pacific Economic Cooperation (APEC). There is a wide range of fossil fuel subsidies. The International Energy Agency (IEA) focuses on the price-gap approach, which compares average end-user prices with reference prices of full costs for fuel supply (Source: IEA, Fossil-fuel subsidies, 2019). The OECD's Inventory of Support measures for fossil fuels uses a wider approach (Source: OECD, Retrieved from Companion to the Inventory of Support Measures for Fossil Fuels, 2018). The EU follows a "bottom-up" approach (Source: European Commision, Energy prices and costs in Europe, 2019) whose methodology and results are described by (Rademaekers, et al., Study on Energy Prices, Costs and Subsidies and their Impact on Industry and Households, 2018)

4 Principles for political action

Powerfuels are a missing link for a future low emission energy system. But although being necessary for achieving climate mitigation goals, powerfuels are facing competitive disadvantages at present. Therefore, political support is necessary for their entry into the global market. The following principles for political action are important pillars for a successful market development.

Cost efficiency

Political support should help to compensate for the higher costs of new technologies and enable competitiveness in the early market phase. To avoid long-term subsidies, an adequate regulative and market frame-work must be established and needs to be streamlined with the global GHG emission goals. Instruments should be market-based to promote innovation and competition with the aim of avoiding overspending and overcompensation. This will enable cost competition in the market.

It is recommended that the regulatory framework primarily supports the development of a stable demand for powerfuels as renewable energy carriers and feedstocks to encourage competition and avoid stranded investments. To keep the burden on public budgets as low as possible, focus should be on sectors, where near-term market-driven demand is possible, for example due to sector-specific CO_2 abatement costs that allow to more easily close the cost gap between powerfuels and their fossil-based counterparts.

Investment and planning security

Long-term security for investment and business decisions are key for scaling the powerfuels market. Alternating political decision making decreases trust and prevents investments. Investment decisions for capital-intensive assets are made with long-term planning, which require a credible commitment to powerfuels support. The market success of powerfuels will not be traced back to one single instrument. The package of instruments should be consistent and not contradictory. Political instruments should therefore be a long-term enabler for powerfuels.

Focus on GHG emission reduction and sustainability

GHG emissions are the key global challenge. Political actions should focus on supporting solutions which contribute to a sustainable and longer-term emission reduction. Therefore, political instruments promoting powerfuels such that their sustainability benefits are fully recognized and lead to a higher market value, should be part of each country's holistic and comprehensive strategy for reducing GHG-emissions.

Emphasis on polluter-pays principle

Considering the urgent need for a rapid reduction of GHG emissions, it will not be sufficient to only privilege consumers of low emission fuels. In addition, regulation should increasingly strengthen the polluter-pays principle in every sector. However, to gain social acceptance, this should happen gradually and take sector specific characteristics into consideration. Not all sectors can and will proceed at the same pace to implement these principles on a global perspective. Hence the most advanced countries will need to lead these developments, and sectors with less international competition or tight global regulative frameworks, will have to start first.

Overall strategy and sector-specific approach

In a perfect market, the optimal political instruments should incentivise competition between all sectors and applications to reduce GHG emissions. This would probably be the most cost-efficient path to reducing GHG emissions. In the real world, different applications and sectors have very different conditions and a very different level of regulation and market framework. Thus, political actions to support powerfuels have to be aligned considering the specific characteristics and requirements of each key sector.

5 Sectoral frameworks

Discussions regarding powerfuels often focus on the question of in which sectors and for which applications powerfuels are most appropriate. In the long run, a holistic and integrated policy framework across all sectors is desirable. However, from today's perspective and with respect to global markets, it seems much more important to create an environment for early investment in powerfuels within existing sectoral frameworks. In many ways, sectors currently differ from each other in various aspects:

- Energy consumption for different applications in different sectors is subject to different national or international regulation processes.
- Energy taxes and duties in each sector vary greatly from country to country. Thus, the window of opportunity to foster powerfuels will vary by country and sector.
- The level of international competition in sectors and applications differs greatly. Cross-sectoral national mandates towards the use of powerfuels in one region may thus affect market players' competitiveness in some sectors much more than in others (e.g. industry vs. heating market)
- Different applications in the sectors have different GHG abatement costs, which is affecting the attractiveness to invest in powerfuels under the current political and market framework for different industries and sectors (e.g. private transport vs. producing industry).
- Private and commercial consumers are used to different prices for energy consumption depending on applications and sectors, and the acceptance for price increases varies. Moreover, price elasticity differs between applications and use cases (e.g. private transport vs. heating market).

Referring to the early phase of powerfuels market development, the previously mentioned examples show that it is not sufficient for political decision-makers to only focus on technological questions, such as whether there are technological alternatives to powerfuels. More important is the question, which political instruments can trigger the market development of powerfuels today and how that would affect consumers.

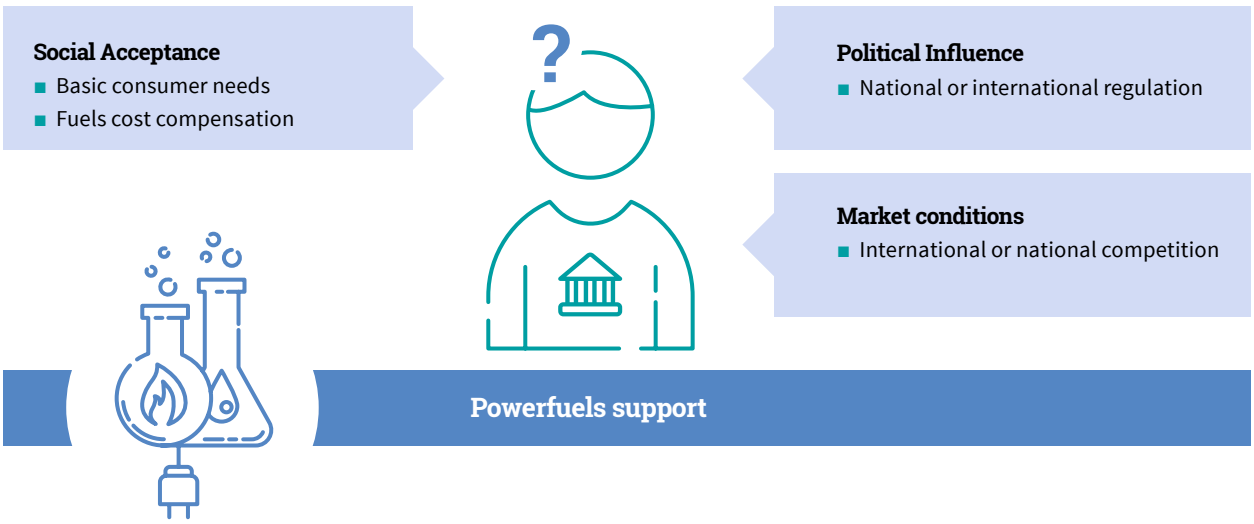

Figure 5: Factors influencing the choice of instruments to support powerfuels. Source: Dena

In this context, it seems relevant to identify the sectors in which consumers have good opportunities or alternatives to compensate for increasing fuel costs (e.g. by switching to more efficient applications), the extent to which basic needs are affected, and which windows of opportunities exist in each sector to start powerfuels market development.

The following figures represent a rough overview of the extent to which consumers may be affected by political actions to integrate powerfuels in the different sectors, the extent to which political actions would affect the competitiveness of businesses in the market and also to which degree the sectors are influenced by international regulation. The figures have to be understood as a schematic description from a global perspective. The importance of certain applications and sectors will always depend on certain consumer and region-specific natural, market and policy conditions.

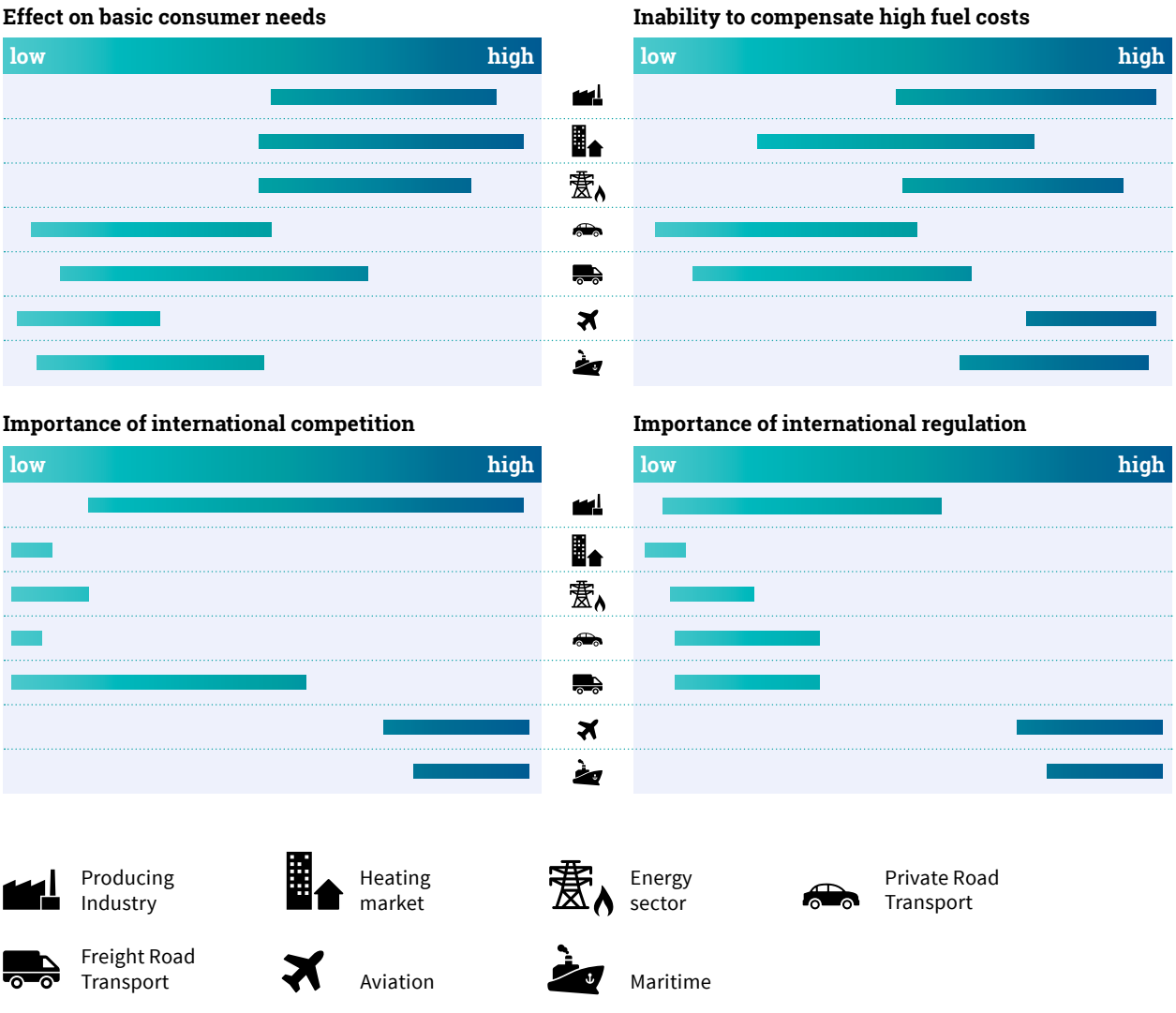

Figure 6: Qualitative assessment[8] of potential effects of using higher amounts of powerfuels in different sectors. Source: Dena

[8] The figures have to be understood as a schematic description from a global perspective. One has to be aware that the importan.ce of certain applications and sectors will always depend on the certain consumer and regional-specific geographic, market and policy conditions.

Effect on basic consumer needs
This category estimates the extent to which an increased fuel price through the use of renewable fuels could affect essential consumer needs. It therefore relates to both the extent of the price increase as well as the relevance of the affected service or good for average consumption. The lighter green part of the scale represents a lesser impact, implying that the general consumer needs are not largely affected. The darker blue areas affect average basic consumer needs even more. These assessments refer to the average consumer on a global scale. Therefore, people's reality can diverge from the figures given, depending on individual circumstances.

Opportunities to compensate higher fuel costs
This category estimates how many technical or other possible opportunities are available to consumers in order to avoid negative effects of increased fuel prices. The more opportunities exist, the better and lighter-coloured the position in the figure. The figure partly shows a wide range of opportunities, because these vary greatly depending on the individual conditions and preferences. On average, there are many options to reduce heating costs by, for example, changing one's behaviour and through the use of new technologies. But in reality, not every consumer has the option to rapidly become a "high efficiency household". A similar situation can be observed for transport. It is not always necessary to travel by car as people's commutes often entail short distances. Public transport can often be also an alternative for necessary longer distances. Furthermore, highly efficient vehicles can compensate for the costs of today's fuels price increases, even today. In contrast, the opportunities for aviation are limited when it comes to long distances or if there is also a lack of other transport infrastructure.

Importance of international competition
International competition between industries determines to this extent the political decision to support the use of powerfuels, as political measures should not lead to disadvantages for competing local industries that wish to use sustainable, clean fuels. The figure shows that there are huge differences between sectors in terms of international competition. For example, international competition for the maritime industry has a much greater importance than it does for private transport, where consumers do not compete with other markets. Furthermore, neither do other markets provide the same service in this case.

Importance of international regulation
In principle, a high degree of international regulation could be advantageous in terms of fostering market development in the sectors without though leading to competitive disadvantages for single markets. Unfortunately, in the past, international regulated markets have tended to be very conservative and slow in terms of progress relating to environmental standards or climate friendly technologies. From a current perspective, it seems easier to guarantee rapid success (quick wins) in sectors which can be influenced by national politics, whilst addressing international markets at the same time in order to foster powerfuels market deployment.

The darker blue areas in the figure represent a strong influence or impact for the sector. The lighter green areas represent less significance of these challenges in terms of the effect on basic needs, the cost increase for consumers, the international competitiveness for companies or in the sense of finding national or bilateral solutions to integrate powerfuels (which are costlier than fossil fuels) in the markets. The schematic illustration shows that powerfuels costs would probably have less of an impact in the transport market than in the heating market (especially in regions with colder winter periods) or in the production industry because there are more alternatives to compensate for the costs and basic consumer needs will be affected less. At the same time, maritime, aviation and industry are facing strong international competition in contrast to the heating market, private transport or most national power markets. The responsibility to regulate the market framework predominantly lies with national institutions in most sectors, except maritime and aviation. Thus, the potential for rapid success (quick wins) in promoting powerfuels is predominantly higher in national or regional markets than it is in international regulated markets.

From the current perspective, it can be concluded that

- Although there are existing universal principles for regulation, and powerfuels find applications in all (above) sectors, there are different policies and instruments to stimulate market development for each sector, which are dependent on the above factors. The choice of political instruments can also vary based on the regional market conditions and policy framework that already exist.
- Some sectors may be more suitable for early market-development of powerfuels, even if other GHG abatement technological options are available (e.g. road transport). This mainly results from the available opportunities to reduce energy consumption without (greatly) affecting basic consumer needs.
- To promote the use of powerfuels in sectors with intense international competition and in sectors bound by international regulations, a much higher level of global awareness is necessary in terms of how important powerfuels are. Concerted action is also essential in order to increase awareness in many of the developing countries, and to create a new market framework there. Furthermore, this also means much more pressure on international organisations to foster the use of powerfuels in internationally regulated markets.

6 Policy levers along the value chain

There is a wide range of measures in place to support the market entry of powerfuels. Many of these measures have been implemented successfully to establish alternative fuels (biofuels, etc.), renewable energy (power) or energy efficiency. Nevertheless, they do not currently consider powerfuels as an option.

The table below lists generic political instruments that can support the use of powerfuels; it also specifies effects and examples of their application. In some cases, these instruments can also be combined, e.g. carbon pricing with subsidy programmes. Many instruments have already been put into practice and just need to be adapted to foster the use of powerfuels. In other cases, there is extensive policy experience (e.g. feed-in tariffs, auctions and so forth). With the aim of having a holistic approach, it is possible to cluster these instruments as follows[9].

Table 1: Policies and political instruments that can foster powerfuels

Measure	Mode of action	Examples
Enabling policies: contribute to further developing renewable energy technologies.		
Carbon Pricing	Cap-and-trade: setting a cap on GHG emissions and allowing trade with allocated certificates, creating a market for avoided GHG emissions within all covered sectors.	■ The EU's and China's Emissions Trading Scheme (energy and industry).
	Carbon tax: puts a flat tax on each unit of GHG emitted, thereby creating a clear and predictable price for avoided emissions.	■ National carbon price floor (UK, California and others). ■ Carbon taxes (Norway, Denmark, Chile, Sweden, Mexico, Ireland and other countries).
Adaptation of fuel prices	Adapting fuel prices with a focus on energy content and emissions reduces the difference between alternative fuels for electricity and fossil fuels. A first step could be to phase out subsidies for the exploration, processing and use of fossil fuels.	■ G20 called to phase out inefficient fossil fuel subsidies (for producer and consumer). ■ APEC committed to phasing out inefficient fossil fuel subsidies.
Integrating policies: integrate the use of renewable energy in key sectors, such as transport (i.e. road, maritime and air), heating/cooling and power, into the end-users' daily life and energy system.		
Instruments for development of infrastructure for alternative fuels	Subsidising the expansion of the necessary infrastructure for refuelling alternative fuels. Especially relevant for hydrogen and CNG/LNG in the transport sector. As alternative fuels infrastructure comes with higher cost and initially lower usage, it allows for infrastructure to be built and consumers to use corresponding applications.	■ EU funding for alternative fuel deployment (under Clean Mobility package). ■ Kreditanstalt für Wiederaufbau (KfW) programmes (Germany) ■ Renewable Energy Standard in Germany that gives funding for district heating/cooling networks supplied with energy from renewable resources.

[9] IRENA. (2018). Renewable Energy Policies in a Time of Transition. IRENA, OECD/IEA and REN21.

Measure	Mode of action	Examples
Direct Policies and instruments: dedicated to supporting the expansion and deployment of renewable energy.		
Feed-in tariffs	Stable tariffs guarantee suppliers a fixed price for each unit produced and lower risks for investors by giving them predictability in their earnings.	■ Feed-in tariff in Germany (wind, PV, biomass), in China (wind and solar) and in India (wind and solar). ■ Feed-in tariff premium in Sweden, Finland, UK, etc.
Emission/ efficiency standards	Defining limits for GHG emissions, usually for new applications. If accounted for in these regulations, technologies become necessary to meet targets.	■ European emission and fuel regulations for four-wheeled light-duty and for heavy-duty vehicles. ■ China VI emission standard for new heavy-duty vehicles. ■ Comprehensive Action Plan on Fine Dust (Korea). ■ GEG Building Energy Law GEG (Germany)
Subsidy programmes	Direct tax-funded subsidies fully or partly covering a supplier's expenses for R&D, CAPEX and OPEX in a certain area. May guarantee the commercial viability of an investment or operation of a plant.	■ Hydrogen and Fuel Cell Technology National Innovation Programme (Germany). ■ Subsidy supporting biofuels blending, 7 per cent cap on conventional biofuels blending rate (EU). ■ New Energy Vehicle credits (China). ■ Subsidy programme for eco-friendly cars in Korea (electric vehicles, hydrogen fuel-cell cars).
Auctions/tenders	The residual between a fossil and GHG-neutral option is subsidised by consumers or taxpayers, while markets determine the price in the bidding process, lowering the risk of under- or overpricing the subsidy.	■ Auctions in the power sector (Germany, China, India, Brazil, Mexico, USA and others) ■ Proposed auctions for powerfuels (Germany – PtX-Alliance)
Fuel blending quotas	Creating a market in proportion to all sales of the fossil commodity. Additional costs of GHG reduction are directly added to the final product, and therefore born by consumers.	■ Fuel Quality Directive (Europe) ■ Renewable Fuel Standard in the US ■ Renewable Energy – recast to 2030 (RED II) in Europe ■ Proposed aviation biofuel mandate (Sweden)

Figure 7: CO_2 emission reduction targets. Source: shutterstock.com/Olivier Le Moal

7 Political recommendations

The development of markets for powerfuels depends on varying regional and national as well as sector-specific preconditions. This means that not all instruments can be implemented successfully in all countries at the same time, and that the development of a powerfuels market needs a regional approach, too.

However, from the perspective of the Global Alliance Powerfuels, the following political actions are recommended with respect to all global markets to foster the market development of powerfuels over the next few years.

1. **Stakeholders should be made aware** of the potential and advantages of powerfuels in politics and economies. The international discussion has to be accelerated using reliable information to expose the potential global market demand of powerfuels and enable global investment in innovative powerfuels technologies, particularly in countries with outstanding production conditions.
2. **Auctions on national level** can be an effective instrument that allows for competition between powerfuels producers to bring a guaranteed amount of powerfuels into the market. Auctions will give the market players the highest level of investment security, especially in markets with fast learning effects and economies of scale.
3. As a first step in creating powerfuels markets, the reduction potential of GHG emissions from powerfuels can be **acknowledged within the existing energy policy frameworks and regulations** in all sectors. In some instances, this can provide sufficiently large incentives for the development of the powerfuels market and contribute to sector integration.
4. **Fuel blending quotas for powerfuels** can – on a national level, but especially on an international level and within supranational regulated sectors (e.g. aviation/ICAO, maritime/IMO) – be an important instrument to kick-start global demand for powerfuels. It would create long-term investment perspectives and pave the way for real GHG reductions in sectors with limited technological alternatives.
5. A **consistent framework for pricing fossil fuels** is necessary, with final consumer prices determined by energy content and GHG emissions. This means successively phasing out fossil fuel subsidies and implementing carbon pricing regimes to create an increasingly level playing field between renewable and non-renewable fuels. Additional revenues can be used to facilitate the development of the powerfuels market.
6. **Further support of Research and Development (R&D)** is important to enhance process efficiency, improve technology readiness and understand the interplay between the technologies involved on a large scale. Beside technological questions, R&D support can help to evaluate the regional potential of powerfuels, costs and define sustainable criteria.
7. Global tradability of guarantees of origin (GOOs) for renewable electricity and used carbon for powerfuels require standards and the **monitoring of these commodities to be standardised globally**. An international energy and carbon emission monitoring system should therefore be developed.

Figures

Tables

Bibliography

European Commission. (2019, May 26). Energy prices and costs in Europe. Retrieved from https://ec.europa.eu/transparency/regdoc/rep/1/2019/EN/COM-2019-1-F1-EN-MAIN-PART-1.PDF

IEA, Fossil-fuel subsidies. (2019, May 26). World Energy Outlook. Retrieved from Fossil-fuel subsidies: https://www.iea.org/weo/energysubsidies/

IEA, Oil Market Report. (2019, May 02). International Energy Agency. Retrieved from https://www.iea.org/media/omrreports/tables/2019-04-11.pdf

IRENA. (2018). Renewable Energy Policies in a Time of Transition. IRENA, OECD/IEA and REN21.

IRENA. (2019). Global Energy Transformation, a roadmap to 2050. Abu Dhabi: IRENA.

OECD. (2018). OECD. Retrieved from Companion to the Inventory of Support Measures for Fossil Fuels 2018: https://read.oecd-ilibrary.org/energy/oecd-companion-to-the-inventory-of-support-measures-for-fossil-fuels-2018_9789264286061-en#page3

Rademaekers, K., Smith, M., Yearwood, J., Saheb, Y., Moerenhout , J., Pollier, K., Altman, M. (2018). Study on Energy Prices, Costs and Subsidies and their Impact on Industry and Households. Rotterdam: Trinomics B.V.

Rahmstorf, S., & Schellnhuber, H. (2018). Der Klimawandel. München: Verlag C.H. Beck oHG.

United Nations. (2019, March 28). Department of Economic and Social Affairs. Retrieved from World population projected to reach 9.8 billion in 2050: https://www.un.org/development/desa/en/news/population/world-population-prospects-2017.html

WEC Germany. (2018). International aspects of a Power-to-X Roadmap. Germany: World Energy Council Germany and Frontier Economics.