ERIG

European Research Institute
for Gas and Energy Innovation

Theses for the european energy future

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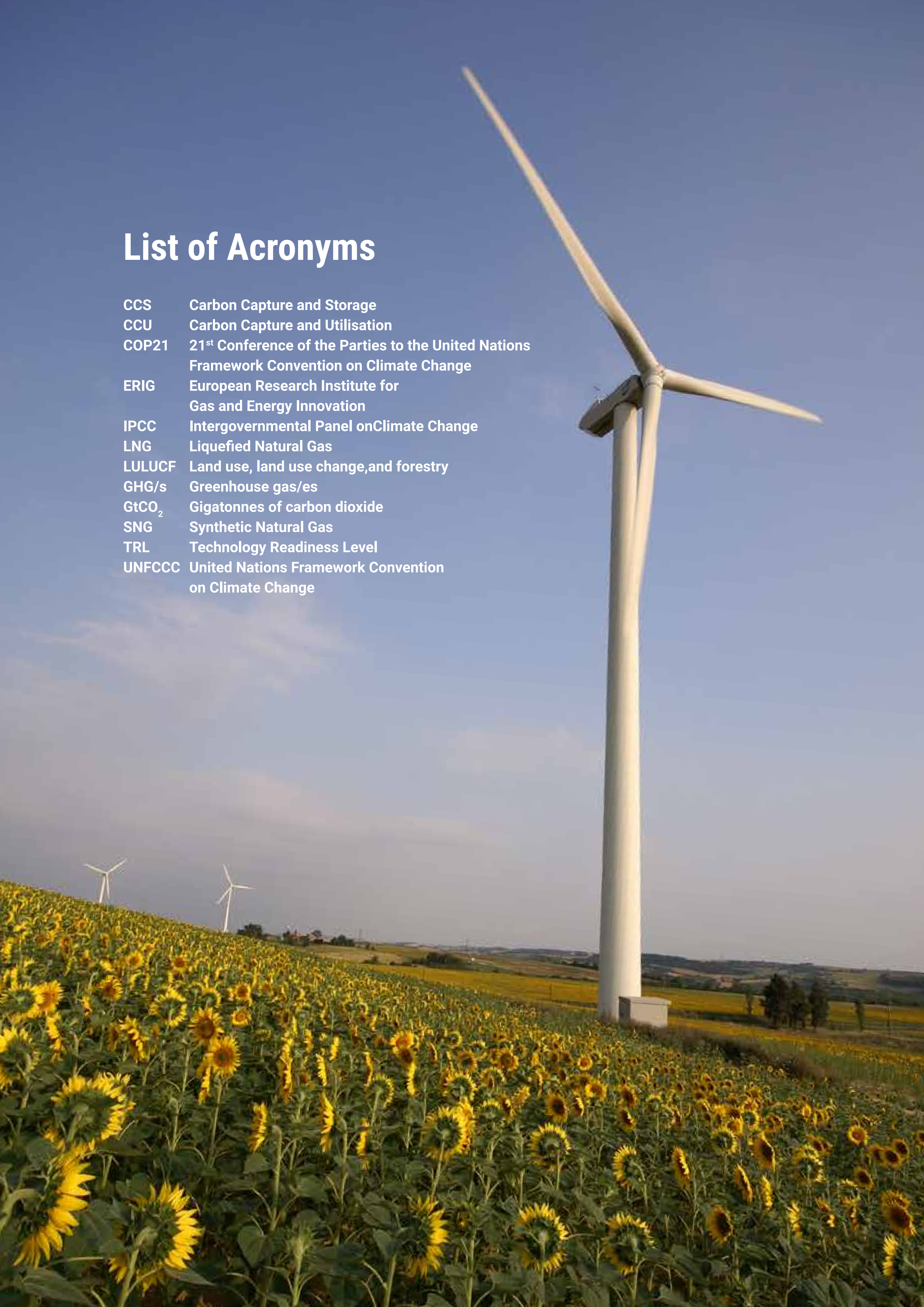
List of Acronyms

CCS	Carbon Capture and Storage
CCU	Carbon Capture and Utilisation
COP21	21st Conference of the Parties to the United Nations Framework Convention on Climate Change
ERIG	European Research Institute for Gas and Energy Innovation
IPCC	Intergovernmental Panel onClimate Change
LNG	Liquefied Natural Gas
LULUCF	Land use, land use change,and forestry
GHG/s	Greenhouse gas/es
$GtCO_2$	Gigatonnes of carbon dioxide
SNG	Synthetic Natural Gas
TRL	Technology Readiness Level
UNFCCC	United Nations Framework Convention on Climate Change



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Glossary of Terms

Biogas: gas obtained from biomass. Biogas consists mainly of methane and carbon dioxide.

Biomethane: methane obtained from biomass. Biomethane is compatible with natural gas, because their chemical compositions are similar.

Blue hydrogen: hydrogen produced from fossil energy carriers with additional capturing and storing of fossil carbon (CCS). Blue hydrogen has therefore no CO_2 emissions in the atmosphere.

Carbon Capture and Storage (CCS): carbon capture and storage is a technique for trapping carbon dioxide (CO_2) emitted from large point sources such as power plants, compressing it, and transporting it to a suitable storage site where it is injected into the ground.

Carbon Capture and Utilisation (CCU): process of capturing CO_2 to be recycled for further usage. The aim is to convert the captured CO_2 into substances or products. Climate-friendly gas: gas that shows no net carbon footprint from production to end use. Climate-friendly hydrogen: hydrogen that shows no net carbon footprint from production to end use.

Gas: in the context of this document, gas comprises molecules in aggregate gaseous state used as energy carriers.

Grey hydrogen: hydrogen produced from fossil fuels. CO_2 emissions are not captured and are released into the atmosphere.

Natural gas: gas that mainly consists of methane. It is a fossil energy carrier.

Power-to-X (PtX): technologies that convert power surpluses from renewably energy sources into gases, liquids, or heat. P stands for power, while X stands for the type of energy into which the electricity surplus is being converted. These are known as power-to-gas (PtG), power-to-heat (PtH), or power-to-liquid (PtL). PtX technologies make it possible to store large amounts of renewable energy to be used at a later stage.

Renewable gas: gas produced from renewable energy sources.

Steam reforming: method of producing syngas (hydrogen and carbon monoxide) by the reaction of hydrocarbons with vapour. The purpose is the production of hydrogen.

Synthetic Natural Gas (SNG): gas that mainly consists of methane. SNG is the result of chemical processes. In the best case, its chemical precursors are obtained from renewable sources.

Technology Readiness Level/s (TRL/s): the TRL scale was originally defined by NASA in the 1990s as a means of measuring or indicating the maturity of a given technology. Technologies can be classified on the basis of nine TRLs [1].

Turquoise hydrogen: hydrogen from methane pyrolysis, with solid carbon as a byproduct. Unlike other hydrogen production processes from natural gas, no CO_2 is produced. Turquoise hydrogen has no climate impact, if solid carbon is stored or used as a manufacturing feedstock.

Valley of Death: gap between funding and market readiness of new technologies. After research funding, continuous support and precommercial development are crucial until new technologies can be deployed on the market.

1 Management summary

This document, produced by the European Research Institute for Gas and Energy Innovation (ERIG), defines a pathway for the future development of the European energy sector. The overall target is to reach international and European climate goals, which include keeping the global temperature rise below 2°C and preferably 1.5°C.

It gives a short overview of the commitments of the European Union (EU) to reducing greenhouse gas (GHG) emissions and of the status and progress of its energy transition. It introduces the "world of electrons" and the "world of molecules", ERIG basic approach to energy carriers and energy production, which will be the subject of further discussion.

ERIG applies three overarching guiding principles to energy innovation, which support the European Green Deal, pursue the objective of achieving climate neutrality, and ensure a socially acceptable circular economy. These are the principles underlying ERIG theses for a successful energy transition, which are further described in the following paragraphs.

This document represents the core of ERIG holistic approach to energy transition in Europe.

The main statements of this document are as follows:

the global budget for CO_2 emissions is limited, if the Earth's temperature rise is to stay below 2°C and preferably 1.5°C;

ERIG supports the overarching objectives of the European Green Deal and deems it necessary to adopt a more holistic and detailed approach;

the vast majority of primary energy uses in the EU is in the form of "molecules" –efforts must be intensified to make them climate friendly in order not to jeopardise the success of the European energy transition.

To obtain climate neutrality and achieve a socially acceptable circular economy, three principles should be applied:

Quality – suggestions for actions must be based on accountable research and realistic projections of possible developments;

Completeness – time, existing infrastructure, and overall systemic effects must be primary considerations;

Feasibility – disruption must be minimised for social acceptance and feasibility.

A successful energy transition is only possible through a holistic approach in which gas plays a leading role. Therefore, three theses need to be considered:

Gas at the centre – gas is the key factor in achieving an integrated energy system of electron-based and molecule-based energy carriers;

Multi-gas not mono-gas – all types of energy gas should be considered and deployed on the market according to their GHG reduction potential;

Gas is an R&D priority – R&D efforts for gas solutions must be intensified.

2 The international commitment of the European Union to reducing greenhouse gas emissions

At the 21st Conference of the Parties (COP 21) to the United Nations Framework Convention on Climate Change (UNFCCC), held in Paris in 2015, participating countries agreed to combat climate change. The Paris agreement was signed by 196 countries and by the EU in 2016.

The goal of the Paris agreement was to keep global warming well below 2°C compared to preindustrial levels, and to make efforts with a view to further limiting the global temperature, keeping it below 1.5°C.

In November 2016, the EU published its "Clean energy for all Europeans package" [2], a central part of the "Energy Union Strategy". With this package, the EU committed to reducing its GHG emissions by at least 40% by 2030, a further advance on the Paris agreement. The package also sets out a long-term strategy for a climate-neutral Europe by 2050.

In December 2019, the European Commission, under the presidency of Ms Ursula von der Leyen, presented the "European Green Deal" [3]. In January 2020, the European Parliament voted in support of the Green Deal, which is now the leading plan for the transition of the EU economy to sustainability.

The European Union approach in the Green Deal

The European Green Deal aims to transform the EU into a fair and prosperous society, with a modern, resource-efficient, and competitive economy where there will be no net emissions of GHGs in 2050. The European Green Deal lays down three main goals in its approach to make the EU economy sustainable.

1 | There will be no net emissions of greenhouse gases by 2050

First, the Green Deal reiterates the EU commitment to reaching climate neutrality by 2050 under the existing "Clean energy for all Europeans package" [2]. To help ensure the achievement of this target, the EU increased its ambition for reducing GHG emissions by 2030 (intermediate goal) to at least 50%, but striving for 55%, from their 1990 levels.

2 | Economic growth will be decoupled from resource use

The Green Deal also aims to decouple economic growth from resource use, as annual raw material extraction continues to grow worldwide and is responsible for around half of GHG emissions. This additional condition to the climate neutrality target requires the full commitment of the industrial sector. The EU recognises a benefit in the opportunities of a circular economy, both domestically and globally.

3 | No person and no place left behind

To help ensure the success of the Green Deal, the EU also addresses social acceptance as a target in its own right, both in general terms and at the national and regional levels. A clean energy transition requires just and inclusive solutions, and it should involve and benefit consumers, as expressed in the European Pillar of Social Rights, which is intended to guide actions so that this objective is met.

Status and progress of the energy transition

In October 2018, the Intergovernmental Panel on Climate Change (IPCC) published its report “Global Warming of 1.5°C”, in which it estimates a carbon budget of 580 to 770 Gigatonnes of carbon dioxide ($GtCO_2$) for limiting the increase to 1.5°C with a 50% probability. In the last two years, global emissions amounted to 85.2 $GtCO_2$, accounting for 15% of the available budget [4]. Even when considering the less desirable 2°C target, current emission rates correspond to 7% of the available budget. The global community has little time to implement appropriate actions. For industrialised regions, such as the EU, the pressure is even higher, as they need to reduce their emissions more, with a view to enabling less developed regions to expand their economies while still achieving the overall global target.

Cumulative emissions ($GtCO_2$)

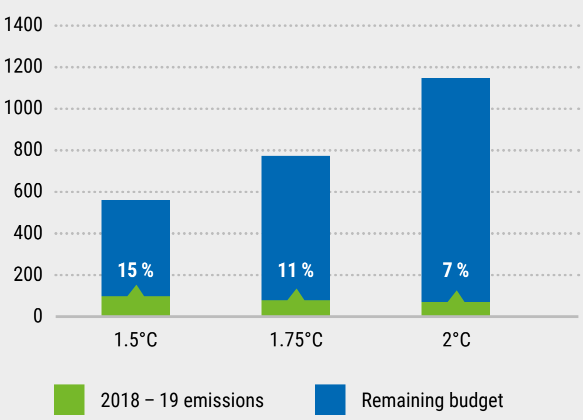


Figure 1: The remaining global CO_2 Budget depends on the targeted temperature increase. In 2018 and 2019, already 15% of the CO_2 Budget for the 1.5°C target was expended [5].

Annual emissions ($GtCO_2$ per year)

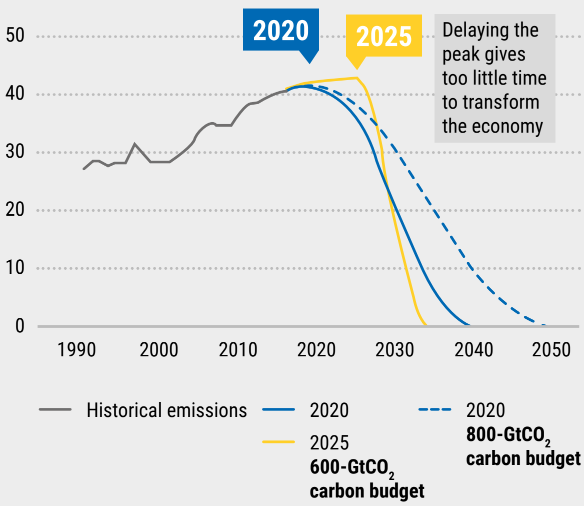


Figure 2: Prospects of global CO_2 emission reduction according to the carbon budget and the year of emission peak [6].

The carbon budget of the EU, based on its share of the world’s population, is 47.7 $GtCO_2$ for the 1.5°C scenario and 61.5 $GtCO_2$ for the 2°C scenario. At the current rate of 3.5 $GtCO_2$ emissions per year (2018 value), the budget would last until 2031 and 2035, respectively [7]. By 2018, the total GHG emissions (including land use, land use change, and forestry – LULUCF), of the EU were reduced by 23.9% from their 1990 levels, with a reduction of 22.2% in the energy sector [8].

Primary energy consumption in TWh

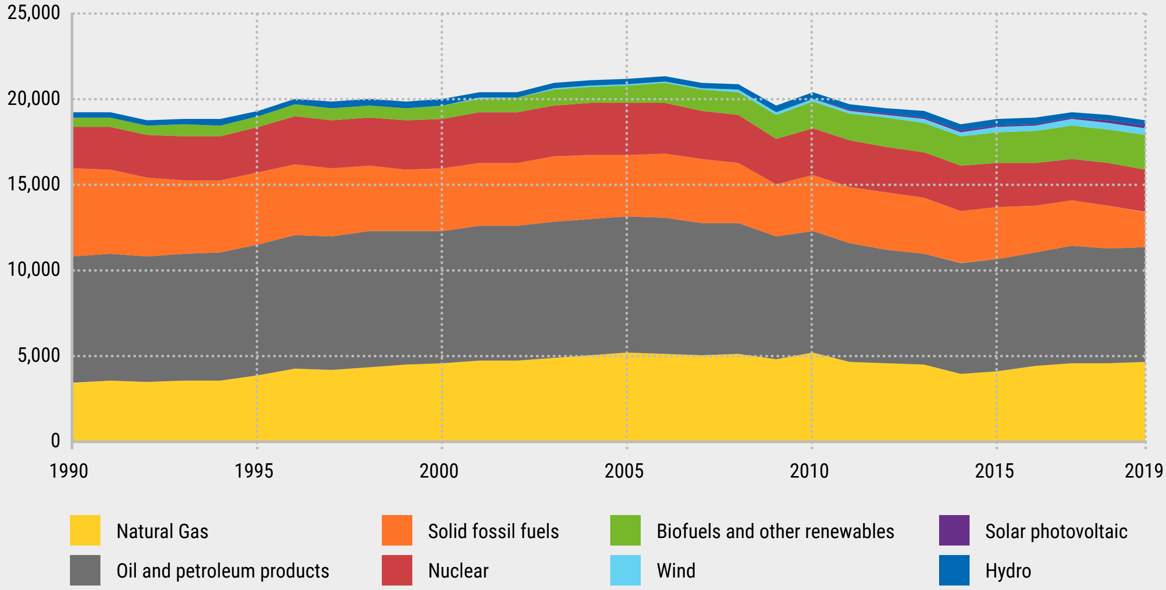


Figure 3: Primary energy consumption change (1990 – 2019) by fuel type in the EU-28 [9], [10].

Total primary energy consumption decreased steadily after 2006, and at some point was back down to 1990 levels. A reduction in GHGs was achieved as a result of increased reliance on renewable energy sources and of the reduction of the use of solid fossil fuels, oil and petroleum products.

In order to target a significant decarbonisation rate in all sectors, priority should be assigned to the transition from high-carbon energy carriers, e.g. coal and oil, to low-carbon energy carriers, e.g. gases, especially climate-friendly gases. This would reduce both GHG emissions and primary energy demand at a faster rate and with lower costs, while maintaining the resilience of the system and social acceptance.

Reduction of annual CO_2-equivalent emissions in the EU-27

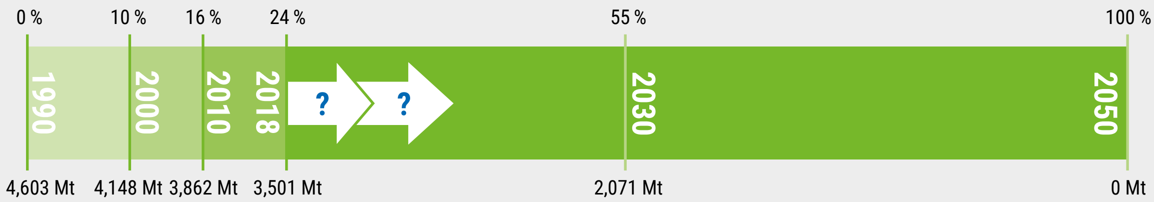


Figure 4: Annual CO_2-equivalent emissions (including LULUCF) in the past in relation to the goals for 2030 and 2050 [8].

3 The world of electrons and the world of molecules – complementary parts of the energy transition

When envisioning options in the transition that we are facing, it is helpful to draw a broad picture of where we are starting from. In ERIG, the connection between the “world of molecules” and the “world of electrons” has been at the core of its approach since the creation of its network in 2015. The understanding is that each of these “worlds” includes all the relevant technologies and infrastructure: “electrons” are the energy carrier for electricity, while “molecules” include energy carriers in solid, liquid, or gaseous form. In the overall perspective, we can make a number of observations. This is the basis for ERIG strategic approach.

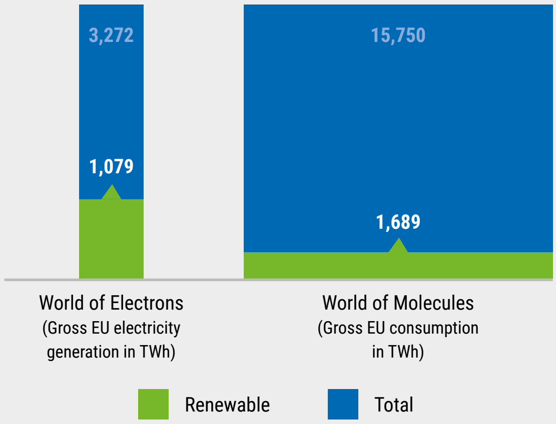


Figure 5: Energy generated and consumed in the world of electrons and the world of molecules and their corresponding renewable share [11]

Electrons and molecules have complementary basic properties

It is worth pointing out that both electrons and molecules serve additional purposes beyond the energy sector. Molecules are needed in the production industry, since a substantial part of the demand for molecules derives from the need for using them as feedstock.

None of the two worlds are per se either “green” or “fossil-based”– both worlds possess means and technologies for renewability and climate neutrality.

In Europe, only 20% of energy uses is in the form of electrons, whereas the remaining 80% is in the form of molecules. Thus, a comprehensive strategy to reach climate neutrality needs to reflect this fact.

Most renewable electrons are produced from wind and solar sources; thus, this production is fluctuating and non-controllable. Renewable electrons need complementary technologies in order to enable the matching of energy supply with energy demand. To a large extent, molecules provide the controllable part of the world of electrons. Renewable electrons are relatively uncomplicated to produce. Reliance on Power-to-X (PtX) technologies opens up new possibilities for renewable molecules that are no longer limited to the availability of biomass.

In a larger perspective, looking also outside Europe, we can observe that, today, 66% of the EU energy is imported. From an economic point of view, it is desirable to develop an international market of and trade in renewable energy. To enable this, an energy carrier in molecule form, such as gas, is needed.

The electricity distribution system needs continuous balancing – the gas distribution system offers stability

There exist well-functioning infrastructure and technologies for storage, transport, and distribution of all energy carriers to meet today's needs.

The electricity system needs continuous balancing and is already reaching its limits in terms of both capacity and storage. The molecules contained in fuels are stored energy per se and their distribution systems are therefore much more robust.

For both electricity and gas, there is a pan-European cross-border transmission and distribution grid. Additionally, gas can also be transported on the road network, either cooled to a liquid state or in pressure vessels. As with electricity in the power grid, which is generated from a variety of sources, the gas flowing through the gas grid could in future be biomethane, synthetic natural gas from renewable sources, or even renewable hydrogen. This existing potential is not yet utilised.

Both worlds have typical energy applications – additionally, molecules are needed as feedstock in the industrial sector

The inherent strengths and weaknesses of both the world of electrons and the world of molecules are reflected in how they are applied today.

Electrons are used for lighting, low-temperature process heat and cooling, smaller-scale operations, and in smaller mobile applications or vehicles, where energy density and range are not as important as in other uses.

Molecules are used for higher temperature applications and heating, in larger-scale operations, and larger mobile applications and vehicles, where energy density, range, and off-grid-capability are of essence. Furthermore, molecules are also needed as feedstock in the industrial sector. [13]

The diversity of energy carriers used in applications makes today's system robust, more so than relying on a single carrier. If applications where molecules are currently used were massively replaced with electricity, the consequences in terms of resilience of the system would be unpredictable.

This summary highlights that a further mutual integration between the world of electrons and the world of molecules could maximise their strengths and minimise their weaknesses. The existing infrastructure and available technologies appear to make gas the perfect partner to the world of electrons with a view to attaining the objectives of climate neutrality.

4 Guiding principles to reach climate neutrality and a socially acceptable circular economy

ERIG supports the overall ambitions of the European Green Deal. To be able to discuss the effectiveness of individual actions in regard to energy transition, it is helpful to have a common understanding of the principles on which they should be measured. ERIG has defined three overarching principles to guide its work that it regards as universally applicable and undeniable if the EU wishes to be successful in its "Man on the Moon" project – the European Green Deal.

Quality – suggestions for actions must be based on accountable research and realistic projections of possible developments;

Completeness – time, existing infrastructure, and overall systemic effects must be primary considerations;

Feasibility – disruption must be minimised for social acceptance and feasibility.

Each guiding principle addresses a given aspect and all the guiding principles should be considered in relation to each other to provide a sound basis for the energy transition.

Quality – suggestions for actions must be based on accountable research and realistic projections of possible developments

As the energy system and climate change are at the heart of the political debate, it is not unusual for researchers in this field to observe how science gets politicised. Results and arguments are taken out of their scientific context and exploited in a misleading debate.

However, the area of energy research is also an extremely challenging one, especially as it becomes increasingly further away from applied technical R&D. System analyses and simulations of future developments and their implications are by necessity complex – as is the energy system that they intend to portray. Furthermore, the world of molecules includes not only the energy system, but also the production industry, and thus, already at this level, when looking only at the energy system, such distortion must be taken into account. Even with the best of intentions, no system analysis can ever mirror the exact conditions of reality. Although fulfilling high scientific requirements, results can still be out of touch with reality, if boundary conditions are too narrow or simplifications too general.

Verifying or determining scientific quality, in the sense of relevance to reality, is therefore not an easy task. Peer-review processes are useful, but by no way a guarantee, as they focus primarily on the scientific state of the art.

ERIG is committed to high quality and accountability and consists of a scientific community largely from the countries represented within its Board of Directors. Furthermore, to become actively cooperating members of ERIG, applicants should be accepted by their peers, and thus the level of commitment and mutual quality control is very high.

Moreover, ERIG Board of Directors has set up a Scientific Advisory Board, which features one leading scientist in energy-related research from each country represented in ERIG membership. The Scientific Advisory Board supports ERIG Board of Directors and Topic Groups, acting as a gate keeper and as an advisor for quality.

ERIG aspires to contribute to correctly reporting scientific results concerning gas and energy research and innovation. Bound to the highest scientific tandards, ERIG views not only scientific correctness, but also adherence to reality as the key points of accountability.

Completeness – time, existing infrastructure, and overall systemic effects must be primary considerations

The basic principle of the three-pronged target of environmental sustainability, resilience and security of supply, and economic efficiency is undisputed, both in regard to climate neutrality and economic growth decoupled from resource use. The implications, however, are often a matter of debate.

By refining and translating these terms into practical principles, we can express the deeper common understanding within ERIG.

We know that the time pressure for GHG reduction is high. ERIG regards approaches that immediately and substantially reduce GHG emissions at low costs as preferable over more uncertain approaches that might – or might not – honour their promising potentials.

By ranking and deploying the measures to be taken in order of cheapest costs for maximal emission reduction ("merit order of measures"), fast reductions can be achieved at a minimal cost.

However, to be credible, the merit order of measures needs also to take into account local conditions. Although energy transition in Europe is a country-level overarching challenge, generic approaches to implement the same solutions at individual or household level can never be the right answer for every case, everywhere. For example, we must assess solutions with combined heat and power differently in places where district heating grids already exist. Where no such grids are available, other approaches, i.e. increasing the use of climate-friendly gas and modernising water heaters, are more cost efficient.

Furthermore, we cannot assess the suitability of measures for reducing GHGs based on a single criterion, e.g. energy efficiency. These measures might have a seemingly positive effect in a local perspective, but when looking at their total effects over the entire value chain, they might have opposite implications. Hence, it is necessary to evaluate the merit order of measures along the entire value chain, based on the overall systemic efficiency (to maintain a resilient energy system) and the overall cost efficiency.

Therefore, ERIG regards the consideration of regional conditions and the existing infrastructure, in combination with overall systemic and cost efficiency, as a major guiding principle for GHG reduction.

Feasibility – disruption must be minimised for social acceptance and feasibility

The best way to ensure a high acceptance of the required measures is to take, from the start, the overall cheapest and most efficient approach. It is worth mentioning that the current development in the EU and especially in some member countries does not fulfil this basic criterion.

To be feasible, the approach must also be socially acceptable. Disruption, in itself, is an inevitable part of the implementation of the objectives of the European Green Deal, and its social consequences are also addressed in part in the expression "no person or place left behind". ERIG regards a more detailed approach minimising disruption of industry, people, and places as a key guiding principle in this respect

The phasing out and/or transformation of entire industries always put a lot of social stress on regions, as well as on employees facing unemployment. The greening of already existing industries is a legitimate priority and must be evaluated according to a principle of "completeness". New industries should not only be located in the proximity of existing ones, but also be consistent as far as possible with the former qualification profiles of employees. This is what we mean by minimising disruption of industry.

Additionally, in the energy transition, there should be a social balance between people who are more advantaged and those who are not. If people who are already wealthy become more advantaged thanks to subsidies for their investments, while those who are less wealthy (and therefore are more sensitive to increased costs) are faced with only those increased costs, we cannot expect wide support. Solutions should be affordable and not excessively benefit persons with wealth, such as property or funds to invest. This is what we mean by minimising disruption of people.

Furthermore, the "not in my backyard" phenomenon is well known. Indeed, the energy infrastructure often disturbs rural areas and landscapes and causes harm to the local ecosystem. Thus, the energy system should not only consider the overarching climate neutrality, but also promote solutions in which the already existing infrastructure is utilised and the visual and environmental impact is mitigated. This is what we mean by minimising disruption of places.

5 Three theses for a successful energy transition

In the previous Chapter 4 we have defined the overarching guiding principles to achieve climate neutrality and a socially acceptable circular economy. To fulfil these requirements, ERIG considers gas as the single most important energy carrier in the years to come. Gas is the molecule-based energy carrier that has the "lowest barrier" to the world of electrons. Amongst molecule-based carriers, it is the one featuring the cleanest combustion and the lowest emissions. Considering this, the existing infrastructure, and potential further developments with gas solutions, ERIG regards three theses dedicated to gas as crucial to a successful energy transition:

Gas at the centre – gas is the key factor in achieving an integrated energy system of electron- and mole cule-based energy carriers;

Multi-gas not mono-gas – all types of energy gas should be considered and deployed on the market based on their GHG reduction potential;

Gas is an R&D priority – R&D efforts for gas solutions must be intensified.

Gas at the centre – gas is the key factor in achieving an integrated energy system of electron- and molecule-based energy carriers

Looking only at Europe, the existing gas grid has about 70 million (industrial and private) customers and a total length of 2.2 million kilometres, including a storage capacity of almost 1100 TWh. This means that the gas grid is already equipped to respond to seasonal variations in energy demand.[13]

The EU gas infrastructure extends far beyond its immediate neighbouring countries. With Liquefied Natural Gas (LNG), trade in energy gas is truly international and not limited to countries connected to the grid. Norway has been showcasing how imported gas from outside the EU can help the EU become climate neutral. It has deployed Carbon Capture and Storage (CCS) for over 10 years, has a strategy in place to produce renewable hydrogen from hydro power on a large scale, and could thus rise to the challenge to supply Europe with its share of climate-friendly gases – further countries could follow this lead.

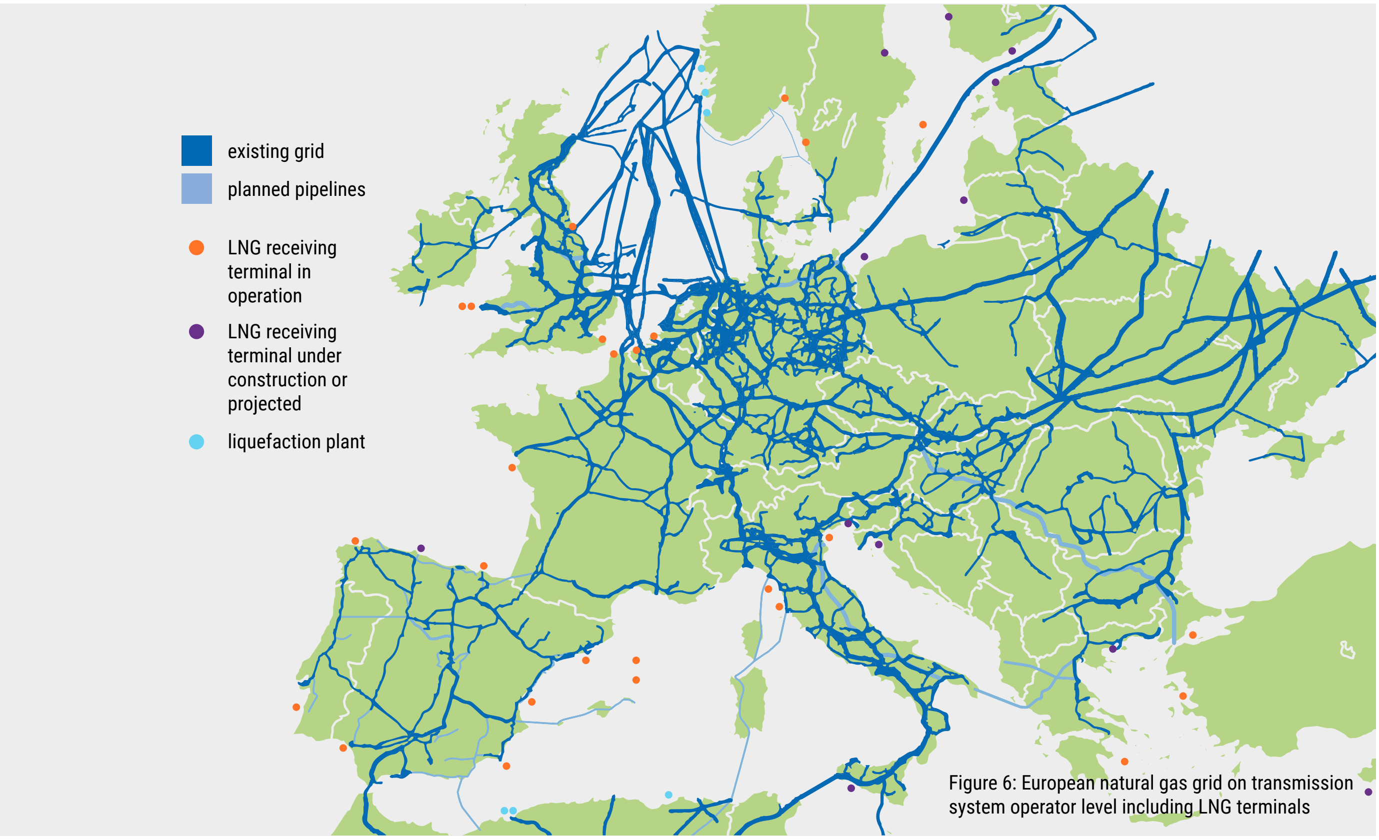


Figure 6: European natural gas grid on transmission system operator level including LNG terminals

Within the world of molecules, gas has an exceptional potential to reduce GHG emissions in a speedy way. Considering that, even on far-reaching electrification scenarios, 40–60% of energy demand in 2050 is expected to be in the form of molecules [12], it is clear that the EU needs a serious strategy to make molecules climate neutral.

Shifting from coal and oil to gas applications can reduce both the amount of emissions and the demand for primary energy, while paving the way for the next step, i.e. gradually making gas even more climate friendly. This applies to all sectors: industry, heating, mobility/transport – and to electricity. Thus, coal and oil replacement with gas, by retrofitting industrial applications and power generation, should be prioritised – shifting to gas in mobility and in the heavy transport sector can also yield positive effects at low costs.

Modernising heating appliances would be a further step in the right direction. Likewise, admixing a share of climate-friendly gases to the natural gas grid could provide enormous total effects with widespread financial implications.

In the world of electrons, gas already plays a substantial role in power generation. Thus, a strategy to make gas climate neutral would also have a direct proportional effect on the climate neutrality of the world of electrons. Furthermore, gas would make it possible to control power generation and bring stability in the form of a "rotating mass" to the electricity system. It also provides storage options and flexibility where and when it is needed.

Another reason why the introduction of large volumes of carbon-neutral gas is absolutely necessary for the EU to reach 2050 mitigation targets is the future need for energy storage for balancing supply and demand (typically in the longer term/on a seasonal basis) and balancing the grid itself (typically in the short term). Already, the EU natural gas system relies on seasonal balancing thanks to underground gas storages facilities, which have a total capacity equal to about 15–20% of the annual gas uptake. As the use of intermittent renewable sources (fluctuating power supply) and the role of electricity (more difficult grid balancing than with gases) are expected to grow considerably, both in absolute and relative terms, the need for large-scale gas storage is expected to increase beyond current capacities. Since large-scale storage and the subsequent transport of gases are much cheaper and easier than they are for electrons under almost all conditions, the demand for hydrogen will also grow for this reason. Studies show that combining the existing gas grid with power-to-gas technologies can save more than € 200 billion per year by 2050 [13].

Considering the growing volatility in the electricity system and the inherent robustness of the gas system, an increased share of gas from the world of molecule-based energy carriers could be beneficial, so that electricity and gas can become the two leading partners of the energy transition. The resulting integrated energy system should be founded on a truly systemic multienergy approach with flowing transitions for a perfect collaboration. Important factors for this European system are reliable data harvesting, structuring, standardisation, and monitoring of energy demand and supply. These factors are important to ensure a smooth operation of the system and an efficient use of the data for its optimisation.

It is clear that gas is a binding component to turn the EU climate ambitions into reality in a speedy way, at low cost, and with minimal disruption. Therefore, in the world of electrons and molecules, gas has an exceptional potential to become the key point of an integrated energy system.

Multi-gas not mono-gas – all types of energy gas should be considered and deployed on the market based on their GHG reduction potential

In the ERIG vision, all the different types of gas must be considered at the same time. Given the overarching guiding principles set out in this paper, a strategy considering each individual gas on its own is inadequate. A renewable hydrogen strategy alone is too slow and not extensive enough. For fast progress and to minimise costs, the gas system should also be an integrated one.

There is an array of gases of different origin with varying GHG emission reduction potential. 95% of the hydrogen used today in the EU is grey hydrogen. Just as a switch from oil and coal to natural gas would achieve substantial CO_2 emission reductions, a switch from grey to blue hydrogen by adding CCU/S can lower CO_2 emissions by 65% on average and up to 90% [14]. If the pyrolysis of biogas is considered, it is possible that even negative CO_2 emissions could be achieved.

Europe also has a good availability of resources for producing renewable gas from biomaterials and waste. The utilisation of these resources is still at its initial stage; however, production could be ramped up substantially with conventional scaling methods. If biogas production is combined with methanation of hydrogen from renewable electricity, the production of the potential renewable methane (as synthetic natural gas – SNG) could be ramped up even more and almost doubled. One advantage of this type of climate-friendly gas is that it is renewable methane and is thus fully compatible with today's existing infrastructure and appliances.

Family of renewable and climate-neutral gases

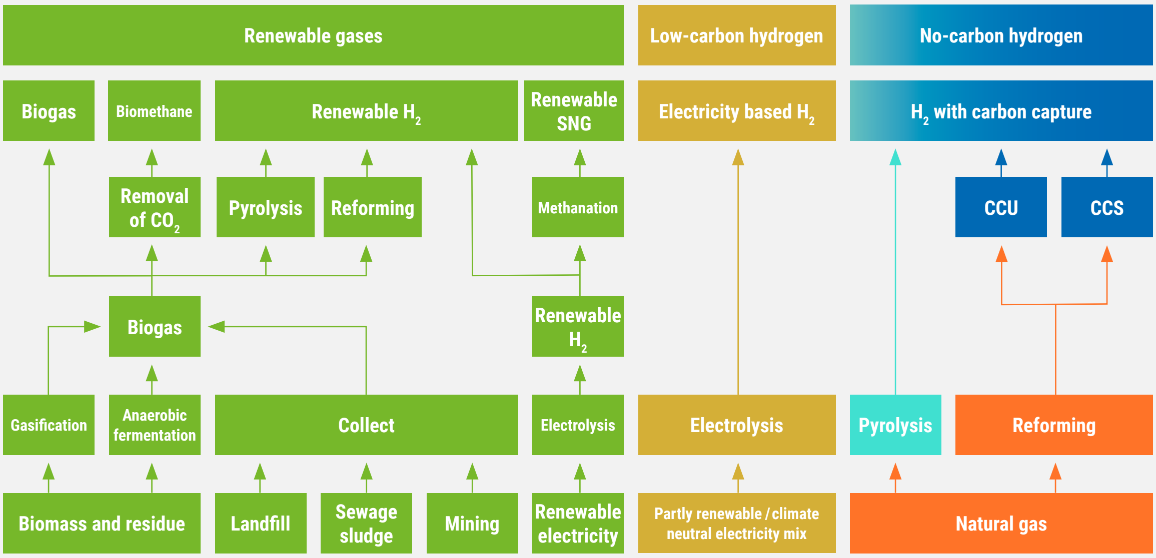


Figure 7: A variety of renewable and climate-neutral gases can be obtained by several production technolgies and energy sources.

As the physical properties of hydrogen differ from those of natural gas (methane), ERIG recognises that special attention is needed for a Europe-wide deployment of hydrogen. To enable the success of hydrogen applications, climate-friendly hydrogen should be accessible evenly throughout Europe. This process would be too long or be unnecessarily expensive by adopting a strategy that is based on only pure hydrogen transport solutions and only renewable hydrogen.

Therefore, all types of hydrogen are to be considered and combined with a strategy of hydrogen admixture to the natural gas grid. This would permit cheap and efficient long-distance transport and distribution of hydrogen. This strategy would have a twofold effect. Studies in Germany indicate that an admixture of up to 20% by volume of hydrogen to natural gas would be possible for the large majority of appliances – for heating and many industrial uses. The resulting immediate GHG emission reduction would be significant. With complementary separation technologies and methanation, hydrogen-sensitive installations could be protected, while simultaneously allowing for the development of local clusters for hydrogen throughout Europe – a second benefit of this approach.

ERIG recommends starting right away with hydrogen readiness of grids and applications in local sections of natural gas distribution grids. Regions where renewable hydrogen is produced could be the first movers in the transition to pure hydrogen supply. These clusters of pure hydrogen will grow and multiply over the years, while pure hydrogen readiness and admixing in both transport and distribution grids are further extended. Some European transport lines should be prioritised to create a pure hydrogen backbone for large-scale hydrogen supply and to connect the regional clusters. This would allow for a seamless supply of pure hydrogen from the source to the designated place of use in all of Europe.

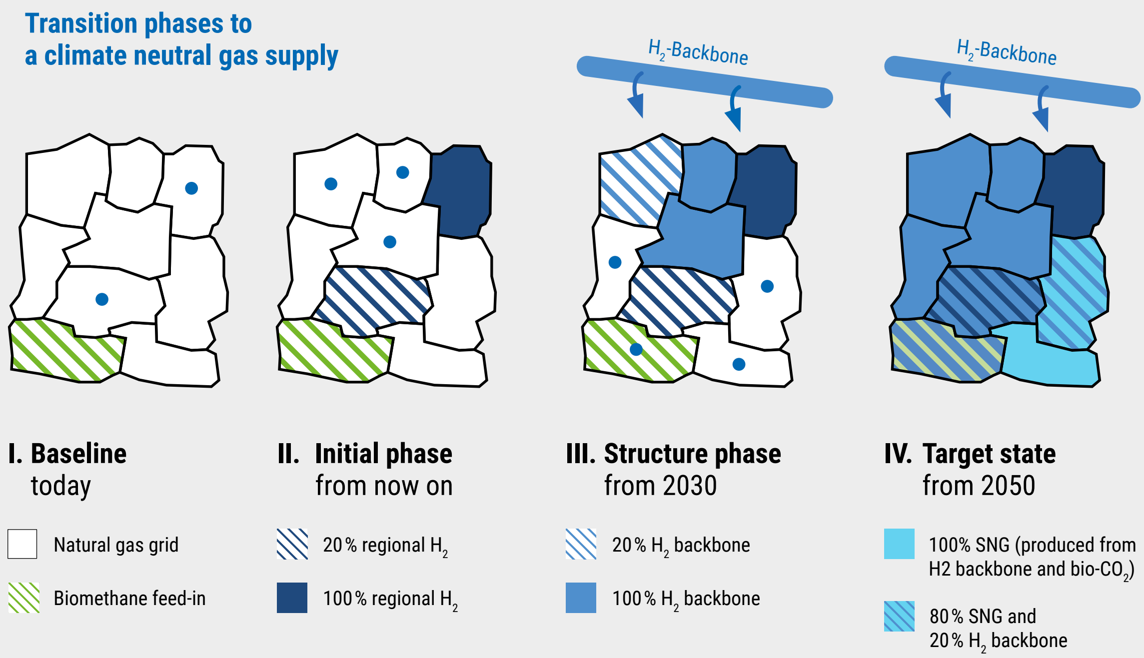


Figure 8: Regional clusters for gradual switch to climate-neutral gases based on an H_2 admixing and backbone strategy [15].

In summary, ERIG recognises that all the resourc-es necessary to reach climate neutrality under its guiding principles should be utilised. The need arises for clear full-range definitions for all gases to permit basic access to these resources for all applications, together with a harmonised system of guarantees of origin. This is necessary to enable a fair domestic and cross-border trade of all gases. ERIG supports a market system for gas that does not discriminate between different gases, but only considers their individual GHG emission reduction rates in a fair and transparent way, as well as an integrated multi-gas strategy instead of individual mono-gas regulations.

Gas is an R&D priority – R&D efforts for gas solutions must be intensified

Innovation is crucial to attaining climate neutrality and technological advances provide the EU with a competitive edge. Thus, continuous support to research on all energy-related technologies is desirable and needed. The focus of development should not only be purely technical, but also address the connection with the energy economy and the requirements of different market situations.

Achieving high rates of high-quality research under our guiding principles and developing innovation efficiently requires adequate funding resources. Considering the size of the challenges existing in each of the two worlds, ERIG deems it reasonable that the allocation of research funding reflects the size of the world of electrons and that of the world of molecules.

Today, 80% of the European energy system relies on molecule-based energy carriers. Projections towards 2050 indicate that this share will remain substantial. Even on high electrification rate scenarios, 40–60% of final energy consumption will have to be covered by molecule-based energy carriers. Therefore, decarbonisation efforts are not only needed in the electricity sector, but they are even more crucial for molecule-based energy carriers.

In the world of molecules, gas is the most versatile and efficient energy carrier, having the greatest potential to cut down emissions with small effort and on short notice. New gas technologies should be rolled out rapidly. By so doing, we will be able to utilise the advantages of technologies as soon as possible, while the advantage of scale will have the effect of reducing the overall costs to be incurred. Market-ready technologies need further attention and can help overcome "the valley of death".

Deploying renewable gas technologies in today's energy system still needs a clear political commitment as well as good financing. The higher the Technology Readiness Level (TRL), the more important are a good support strategy and the right adaptation of the policy framework. Only the combination of both aspects can make it possible to tap the full potential of technologies to the greatest benefit of society. The policy framework should focus in particular on legal harmonisation efforts in parallel with technical innovations. In this way, a consistent framework of laws, regulations, standards, and practices will facilitate the use and the combination of European gas technologies.

Special emphasis should be placed on gas technologies with a low TRL, such as pyrolysis of methane. The funding of promising technologies in the early development state is important in putting in place an integrated energy system. In other words, it is imperative not to neglect new technologies, even if they are less advanced.

It is also important to take into account the geographical scales of the different gas projects and developments. There should be a linkage between "macro-studies" and local dynamics, to "bridge the gap" between them, because all R&D actions should work together, to ensure the fastest and most efficient development. This calls for robust decision-support tools also for smaller entities, e.g. local authorities, utilities, and cooperatives.

Bridging the valley of death for new technologies

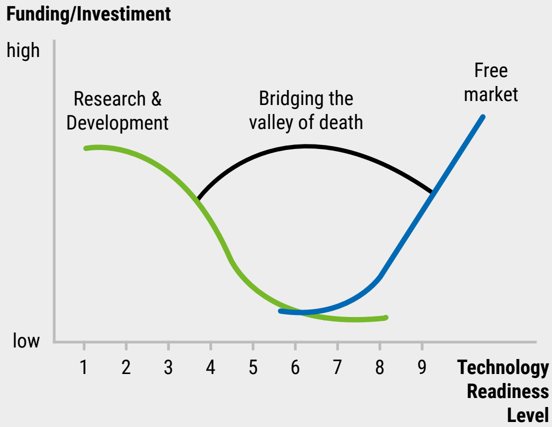


Figure 9: Overcoming the valley of death is crucial for the market start of new technologies

ERIG proposes to evaluate present and future energy technologies – especially in view of their actual deployment at local level – on the basis of a systemic, multi-energy approach. Under the latter approach, energy supply grids are expected to work in a synergistic fashion to bring the required energy services to society at large, while maximising energy supply and energy efficiency, and creating a backbone infrastructure to support the penetration of renewable energy sources.

In today's energy system, molecules represent the greater proportion of energy carriers. However, projections in line with ERIG guiding principles of quality, completeness, and feasibility unanimously show that their share should remain substantial even in a climate-neutral energy system. Progress in making the world of molecules climate neutral should be prioritised, otherwise the goals of the energy transition would be at risk. Gas is the central energy carrier for successful energy transition to both worlds. It is crucial that there is investment in R&D in gas innovation, especially in hydrogen blending and deblending in the gas grid, and in the role of gas in an integrated energy system. Studies confirm that an integrated approach with gas would result in a cheaper energy system in 2050, with savings of several hundreds of billions of euro per year. It is therefore of paramount importance to increase the budget allocated for consolidating gas technologies and applying them in the integrated energy system on their way to market readiness. This budget should at least match that of the world of electrons.

6 Conclusions

ERIG Theses for the European Energy Future show a possible pathway to achieve international and European climate goals. The document presents a holistic approach considering not only the energy sector itself, but also social acceptance and economic feasibility. Since the time and the CO_2 budget are limited, the need arises for starting a realistic process immediately.

The main guiding principles to reach climate neutrality and a socially acceptable circular economy are:

Quality – suggestions for actions must be based on accountable research and realistic projections of possible developments

ERIG views the application of actions to reality – and not only scientific state-of-the-art suggestions and studies concerning the energy transition – as the main point of accountability. With a scientific community of renowned research institutes, country members representing technical scientific associations rooted in industry, as well as an organisation promoting quality control, this commitment is the living culture of ERIG.

Completeness – time, existing infrastructure, and overall systemic effects must be primary considerations

ERIG regards the consideration of regional conditions and the existing infrastructure, in combination with overall systemic and cost efficiency, as a major guiding principle for GHG reduction. This would allow for an optimal achievement of the three-pronged target of environmental sustainability, resilience and security of supply, and economic efficiency that should guide our efforts to reach both climate neutrality and a circular economy.

Feasibility – Disruption must be minimised for social acceptance and feasibility

To be applicable, our approach must be socially acceptable. Disruption is an inevitable part of the implementation of the European Green Deal objectives, and its social consequences are in part addressed in the expression "no person or place left behind". ERIG regards a more detailed approach minimising disruption of industry, people, and places as the leading guiding principle in this respect.

These guiding principles are considered and expressed in three theses for a successful energy transition:

Gas at the centre – gas is the key factor in achieving an integrated energy system of electron- and molecule-based energy carriers

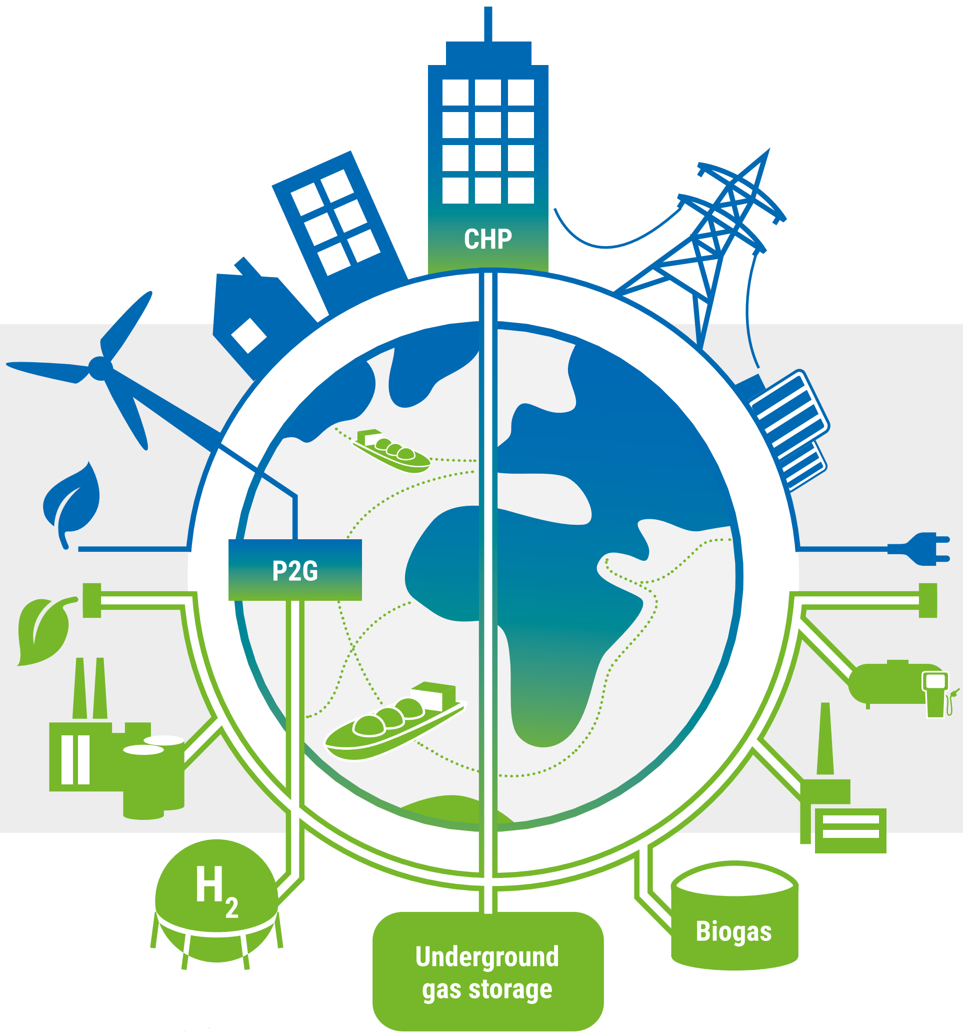
Gas is the molecule-based energy carrier that is closest to the world of electrons and the cleanest one within the world of molecules. Europe has an extensive gas infrastructure, which is already being used for transporting and storing energy throughout the Union. Its storage infrastructure is designed for seasonal shifting and is interconnected to enable energy exchange with neighbouring countries and the world. There is an array of options for well-developed technologies to produce climate-friendly gas. Therefore, ERIG deems it necessary to put gas at the centre of considerations for a decarbonisation and emission reduction strategy.

Multi-gas not mono-gas – All types of energy gas should be considered and deployed on the market based on their GHG reduction potential

All types of gas should be considered at the same time and all the resources necessary to reach climate neutrality under our guiding principles should be utilised. The need arises for clear fullrange definitions for all gases to permit basic access to these resources for all applications, together with a harmonised system of guarantees of origin. ERIG envisages a market system for gas that does not discriminate between different gases, but simply considers their GHG emission reduction rates in a fair and transparent way, as well as an integrated multi-gas strategy instead of individual mono-gas regulations.

Gas is an R&D priority – R&D efforts for gas solutions must be intensified

Gas is the central energy carrier for a successful energy transition to both worlds of electrons and molecules. In order not to risk failure of this energy transition, it is crucial that there is investment in R&D in gas innovation, as well as in the role of gas in an integrated energy system. We should increase the budget allocated for consolidation of gas technologies and their application in the integrated energy system on their way to market readiness. This budget should at least match that for efforts in the electricity sector.



7 References

[1] **NASA, "Technology Readiness Level", 2012.** https://www.nasa.gov/directorates/heo/scan/engineering/technology/txt_accordion1.html

[2] **European Commission, "Clean energy for all Europeans", 2019.** https://ec.europa.eu/energy/topics/energy-strategy/clean-energy-all-europeans_en

[3] **European Commission," The European Green Deal COM (2019) 640 final", Brussels, 2019.** https://ec.europa.eu/info/sites/default/files/european-green-deal-communication_en.pdf

[4] **IPCC, V. Masson-Delmotte, P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea and P. Shukla, "Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels", 2018.** https://www.ipcc.ch/sr15/

[5] **A. Dalman, "Carbon Tracker," 2020.** https://carbontracker.org/carbon-budgets-where-are-we-now/

[6] **mega., "It's the economy, stupid: winning the sustainability debate", 2017.** https://mega.online/en/articles/climate-economy/

[7] **Öko-Institut e.V., "The Vision Scenario for the European Union", Öko-Institut e.V.,** https://www.oeko.de/publikationen/p-details/the-vision-scenario-for-the-european-union

[8] **European Environment Agency, "EEA greenhouse gas – data viewer", 2020.** https://www.eea.europa.eu/data-and-maps/data/data-viewers/greenhouse-gases-viewer

[9] **European Commission, "Data Browser", 2021.** https://ec.europa.eu/eurostat/databrowser/view/NRG_BAL_C__custom_520198/settings_1/table?lang=en

[10] **European Environment Agency, "Primary energy consumption by fuel in Europe", 2020.** https://www.eea.europa.eu/data-and-maps/indicators/primary-energy-consumption-by-fuel-7/assessment

[11] **European Commission, "Energy statistical country datasheets", 2020.** https://ec.europa.eu/energy/data-analysis/energy-statistical-pocketbook_en

[12] **Eurelectric, "Decarbonization Pathways", 2018.** https://www.eurelectric.org/decarbonisation-pathways/

[13] **STORE&GO, "Innovative large-scale energy storage technologies and Power-to-Gas concepts after optimisation", 2020.** https://www.storeandgo.info/publications

[14] **Greenpeace Energy EG, "Blauer Wasserstoff", Greenpeace Energy EG, 2020.** https://www.greenpeace-energy.de/fileadmin/user_upload/broschuere-wasserstoff.pdf

[15] **DVGW e. V., "H2vorOrt", 2020.** https://www.dvgw.de/themen/energiewende/wasserstoff-und-energiewende/h2vorort/

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