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# STAYING WITHIN THE GLOBAL CARBON BUDGET

# Imprint

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# STAYING WITHIN THE GLOBAL CARBON BUDGET

## A technical scientific statement from the German Gas and Water Association

## THE CHALLENGE

### GLOBALLY INCREASING PROSPERITY, WORLDWIDE GROWTH AND THE ACHIEVEMENT OF CLIMATE PROTECTION TARGETS ARE NOT MUTUALLY EXCLUSIVE: THE CLIMATE PROTECTION MEASURES CONSISTING OF THE FUEL SWITCH, CONTENT SWITCH AND MODAL SWITCH ENABLES SECURE, AFFORDABLE AND CLIMATE-NEUTRAL ENERGY SUPPLY WORLDWIDE

**The COP21 resolutions require the world to make fast and extensive investments in climate-friendly technologies: the climate protection measures can be implemented worldwide and provides an orientation framework for this transformation and for establishing climate-neutral energy systems.**

At the end of 2015, participants at the COP21 UN climate change conference in Paris signed a multilateral agreement by which the international community undertook to reduce greenhouse gas emissions substantially and thereby limit the increase in global warming to a maximum of 2 degrees but if possible no more than 1.5 degrees by the year 2050. Within a few months, this agreement was ratified by a large majority of UN member states, i.e. the emitters of greenhouse gases, and therefore formally came into force. More and more countries recognise the necessity of implementing ambitious and effective climate protection measures and are directing their efforts towards achieving this aim. One of the key challenges in this context lies in enabling the global economic growth processes that will lead to an increase in the general level of prosperity over the coming decades up to 2050, and linking these to a significant reduction in global greenhouse gas emissions. This requires a rapid changeover from the use of emissions-intensive energy sources and technologies to climate-friendly energy sources and their extensive use in all sectors which cause greenhouse emissions to a significant degree.

At the same time, this process must not overstretch the performance capacity of global regions and individual countries, nor should it obstruct economic momentum or the ability of as many sections as possible of the global population to participate. Otherwise the transformation process towards the urgently needed climate-neutral global energy production and supply may suffer a gradual erosion of acceptance. In addition, those countries with highperforming economies such as the G7 and G20 groups of leading industrial nations will be required to take on a particularly pioneering role model function.

The current distribution of greenhouse gas emissions shows clearly that the COP 21 targets can only be achieved by means of extensive transformation processes in the energy systems of numerous countries around the globe: in 2016, for example, US emissions amounted to 5.17 billion tons of $CO_2$, while the figure for China was 10.64 billion and for India 2.46 billion. These three countries are thus currently responsible for generating about half of global $CO_2$ emissions, amounting to 36.1 billion tons of $CO_2$ in 2015 (China: 30 per cent, USA 14 per cent, India 7 per cent).[1] The energy-related emissions of the G20 states increased by more than a half from 1990 to 2013. South Africa increased its $CO_2$ emissions from 1995 to 2015 by 39 per cent, for example, while in India $CO_2$ emissions increased in the same period by 185 per cent and in Indonesia by 114 per cent.[2] The causes of this are clear and obvious: over recent decades, massive investments have been made in expanding energy systems based on coal-powered electricity. Today, coal-fired power generation accounts for 39 per cent of worldwide electricity production, which totals 24 billion MWh; renewable energies currently account for 24 per cent and natural gas 22 per cent.[3] All in all, the G20 states are responsible for more than three quarters of the world‘s ener-

[1] cf. Olivier, Jos G.J.: Trends in Global CO2 Emissions. 2016 Report. (2016) PBL Netherlands Environmental Assessment Agency, The Hague (p.12-14).
[2] cf. Olivier, Jos G.J.: Trends in Global CO2 Emissions. 2016 Report. (2016) PBL Netherlands Environmental Assessment Agency, The Hague (p.12-14).
[3] cf. World Energy Council.

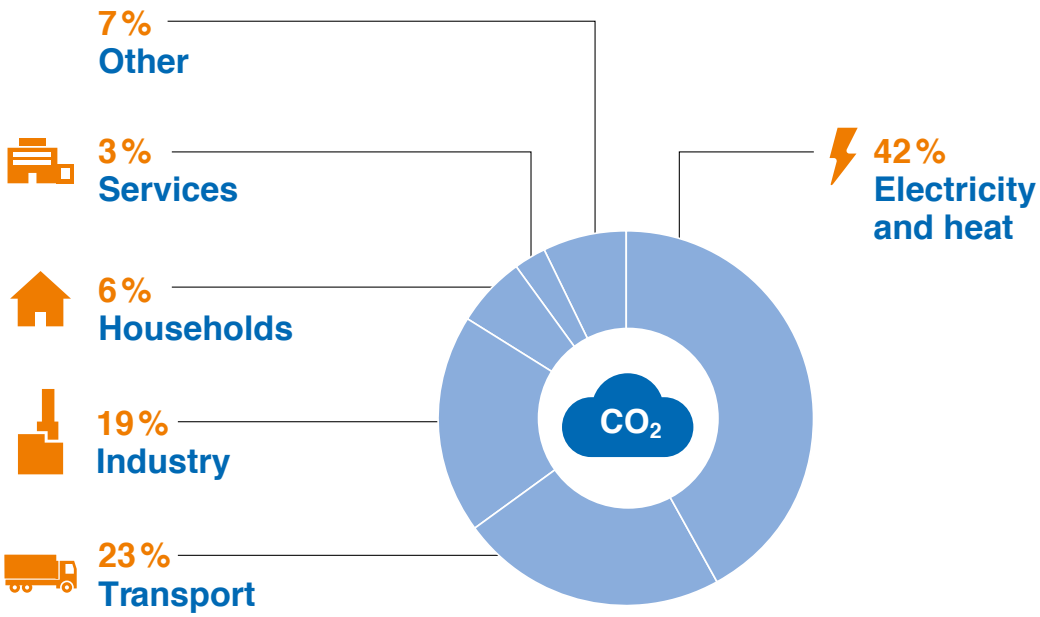


Figure 1: Distribution of energy-related $CO_2$ emissions worldwide by sectors in 2016 [4]

gy consumption and greenhouse gas emissions.[5] Energy policy in these countries thus has a significant impact on whether and how the Paris climate protection targets can be met.

One particularly sensitive area in terms of the necessity to reduce GHG emissions quickly and extensively is the transportation sector. Globalisation and global dynamic economic momentum have already resulted in a sharp increase in traffic volume and continuously increasing traffic density, so emissions are rising substantially in the transportation sector in particular: international shipping traffic alone was responsible for emissions of approx. 640 million tons of $CO_2$ in 2015, while international air traffic emitted some 500 million tons of $CO_2$, damaging the climate with harmful greenhouse gases.[6] All in all, worldwide $CO_2$ emissions in the transportation sector account for approximately 23 per cent of total emissions,[7] the largest share of this being borne by motorised land traffic with a figure of 7,163 billion tons of $CO_2$. The International Energy Agency is forecasting a further dynamic increase in GHG emissions for heavy motorised traffic in particular. However, energy and heat generation is responsible for the largest share (some 42 per cent) of $CO_2$ emissions worldwide.[8]

**If coal and petroleum products continue to be used so intensely, climate protection targets for 2050 will not be met. However, the global climate protection measures of Fuel Switch, Content Switch and Modal Switch will enable the COP21 targets to be met in all regions and countries of the world.**

According to IMF forecasts, for example, economic growth in the coming decades will result in China tripling its GDP by 2050 as compared to 2015.[9] Continued application of emissions-intensive methods and structures in economic activity will inevitably lead to failure in terms of achieving the 2050 climate protection targets set out in the Paris agreement.

In order to be able to meet the ambitious greenhouse gas reduction targets to which the international community aspires, it will in some cases be necessary to substantially re-adapt worldwide energy and climate protection policy and the associated investments in the use of energy sources and infrastructure as pursued in recent years. Within the short term, all countries must continuously decarbonise their energy generation and supply and continue to pursue this path consistently.

**The global climate protection measures consisting of the Fuel Switch, Content Switch and Modal Switch will enable the COP21 targets to be met.**

[4] cf. Olivier, Jos G.J.: Trends in Global $CO_2$ Emissions. 2016 Report. (2016) PBL Netherlands Environmental Assessment Agency, The Hague (p.35).
[5] cf. Burck, Jan: Brown to Green. Assessing the G20 transition to a low-carbon economy. (2016) Climate Transparency, Berlin. (p.13).
[6] cf. Olivier, Jos G.J.: Trends in Global CO2 Emissions. 2016 Report. (2016) PBL Netherlands Environmental Assessment Agency, The Hague (p.12-14).
[7] cf. Olivier, Jos G.J.: Trends in Global CO2 Emissions. 2016 Report. (2016) PBL Netherlands Environmental Assessment Agency, The Hague (p.34-35).
[8] cf. Olivier, Jos G.J.: Trends in Global $CO_2$ Emissions. 2016 Report. (2016) PBL Netherlands Environmental Assessment Agency, The Hague (p.34-35).
[9] IMF World Economic Outlook Database.

# THE COMPELLING STRATEGY: STAYING WITHIN THE GLOBAL CARBON BUDGET

In 2017, the German Gas and Water Association (DVGW) has developed a strategy on how to stay within the national carbon budget by utilising more and more natural gas and renewable gases and by bringing power grids and gas grids to convergence: a coupling of both sectors.

Since then, this strategy has been verified by various scientific studies and findings from first demonstration projects. It consists of three steps: It consists of three steps and it is applicable to all relevant segments: Power generation, heat generation and transport.

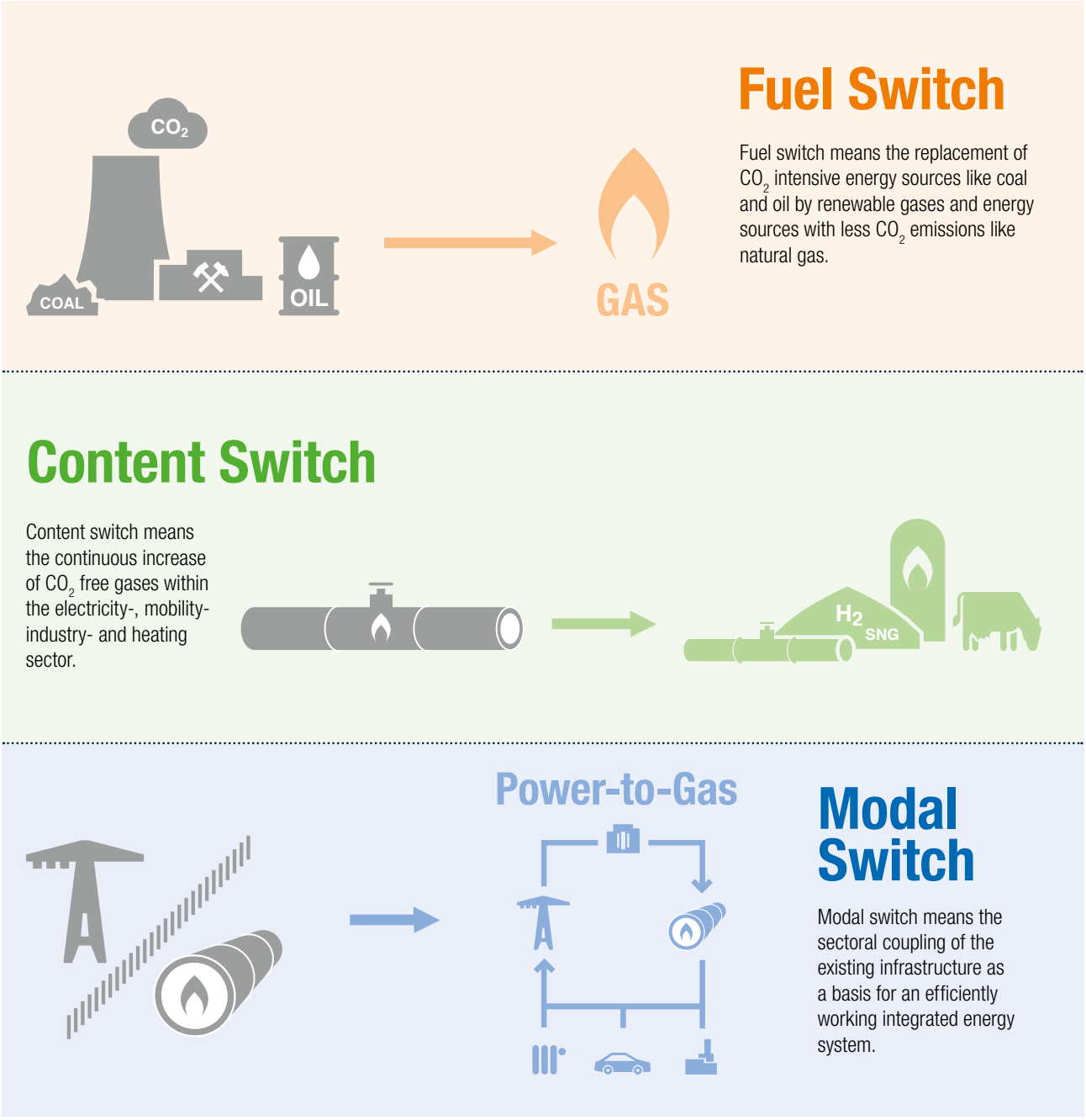


Figure 2: The global climate protection measures: Fuel Switch, Content Switch and Modal Switch

# THE STRATEGY IN DETAIL:

The first stage, the so-called **Fuel Switch**, involves the emissions-intensive energy sources of coal and oil to be replaced by natural gas and the establishment and expansion of gas infrastructures in all sectors of energy generation and consumption. This will make achievement of the 2050 climate protection targets possible while at the same time enabling the ongoing expansion of renewable energies. The Fuel Switch enables the cost of the transformation processes necessary in national economies to be limited, thereby underpinning acceptance of extensive climate-neutrality in as many countries in the world as possible.

The consistent implementation of this Fuel Switch would significantly increase the intensity and speed of greenhouse gas reduction worldwide, and numerous countries would be able to catch up on the greenhouse gas reduction roadmap as agreed on in Kyoto in 1997. This would put the Paris global climate protection and greenhouse gas targets well within reach.

The aim is to largely stop the use of coal and petroleum products as energy sources in the medium term and to initiate more widespread use of a **combination of renewable energies and gas-based technologies**. At the same time, countries with a fast-increasing demand for energy and power due to dynamic economic growth should refrain from investing in new coal-firedpower stations and expanding transportation infrastructure geared towards the use of oil and petroleum products: instead they should invest directly in establishing a climate-friendly energy system based on natural gas, green gases and renewable energies.

The **Content Switch** is a process which starts parallel to the Fuel Switch and involves a continuous increase in the share of gases from renewable energy sources in the gas infrastructures. This process of increasing the share of green gases produced from renewable sources will mean that, in the long term, the gases flowing through the natural gas grids will become increasingly climate-neutral – and this will then also apply to the sectors in which gases are used. In addition to the absolutely imperative Fuel Switch, this process is the second substantial component of the climate protection measures required by the international community in order to meet climate protection targets by 2050.

According to the current state of technology, there are four renewable gas types or green gases that can be produced:

- **Biogas** is generated by fermenting biomass from agriculture, commercial waste, food waste or other organic material.

- **Biomethane** can be produced by means of biomass gasification via synthesis gas. Here biogas is enhanced to “natural gas quality” in the compound with carbon dioxide and its fuel value is adapted to that of natural gas.

- **Green hydrogen** is produced by means of renewable electricity in power-to-gas facilities. Here, electrolysers split water into its components hydrogen and oxygen.

- **Synthetic methane** is produced from green hydrogen by means of the socalled methanisation process. In order to create methane, hydrogen has to bond with carbon. It is possible to recycle the $CO_2$ required for this process from emissions sources such as power plants or industry so as to establish a closed $CO_2$ cycle and avoid greenhouse gas emissions.

In this way, green gases from renewable sources can be produced in substantial quantities using known, market-ready and tested technologies and put to decentralised use or transported via the gas grid infrastructures.

In order to be able to use a growing volume of green gases from renewable sources, energy system infrastructures have to be interlinked. Climate protection targets and the transformation of energy systems is most effectively planned and implemented by interlinking infrastructures – especially by making use of the gas grid and gas infrastructures.


Figure 3: The Fuel, Content and Modal Switch offer enormous climate protection potential in all relevant sectors

By way of this **Modal Switch**, therefore, gas infrastructures are used as a link and platform for enabling extensive sectoral interconnection of largely climateneutral energy sources across all sectors.

The Modal Switch is the third element in the climate protection measures, enabling ever larger quantities of renewably produced gases to be used as energy sources that can flow freely across sectoral boundaries, with the capacity for seasonal and long-term storage and for deployment in the areas of electric power, heat, mobility and industry. Power-to-gas technology will have a hugely important global role to play when it comes to making renewable energies available to all energy consumption sectors via gas infrastructures. Power-to-gas refers to the conversion of renewable power to hydrogen by means of electrolysis or its further processing to create synthetic methane. This allows surplus power from renewable energy sources such as wind power and solar energy to be saved and transported in large quantities. In the foreseeable future it will be possible to use renewable power to generate green hydrogen, either at a low cost or – in the case of negative electricity rates – even free of charge. The production costs of green hydrogen will drop as electrolysis technology evelops further, economies of scale will increase due to the continuous addition of plants and capacity utilisation of power-to-gas facilities will grow.

For the power sector, the combination of renewable energies, gas infrastructures and sectoral linkage elements in all regions of the world will lead to lowcost, comprehensive supply reliability.

- After all, gas power plants are the ideal partners for renewable energies in terms of providing assured capacity,
- Thereby perfectly supplementing and securing fluctuating power generation from wind and solar energy.
- What is more, gas power plants are able to provide large quantities of power so as to meet the growing demand in dynamically developing economic regions in a climate-friendly and flexible manner.
- Natural gas and renewably produced gases are also energy sources that can be stored on a seasonal and long-term basis,
- Retrieved as required at any time and used flexibly in the power, heat and mobility sectors as a base or raw material for industrial applications.
- The use of power-to-gas technologies and gases in all technologies also enables the cost of expanding power grids to be reduced since additional expansion is often no longer necessary.

# EXAMPLES

If instead of the coal-fired power stations currently under construction in China, modern gas power plants were to be installed with the same output, it would be possible to achieve total savings of 350 million tons of $CO_2$ per year.[10] This would be equivalent to the entire annual $CO_2$ emissions of the national economy of the G20 state [11] of Turkey.

The great potential of the Fuel Switch in terms of global climate protection is demonstrated even more clearly by the following model: replacing five per cent of the coal-fired power stations currently on the grid in China with modern gas-fired power plants every year over the next ten years. Once again assuming 5,000 hours at full capacity per power station and the above-mentioned average emissions levels, this would enable savings of some 3.2 billion tons of $CO_2$ within the ten-year period. By comparison: this would relieve the world climate of a quantity of GHG emissions equivalent to what the entire economy of India emits within approx. one and a half years.[12]

[10] Assumptions: Coal fired and gas fired plant with 700g and 350g per kWh respectively. Requested output: 200 GW over 5,000 hours.[11] Cf. Carbonbrief: Emissions Giants (2015).
[12] Cf. Carbonbrief: Emissions Giants (2015).
[13] Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2015.
[14] Cf. Carbonbrief: Emissions Giants (2015).

In the transportation sector, a consistent Fuel Switch is clearly the way to implement affordable, global climate protection both smoothly and simply. If 30 per cent of the vehicles used on the roads in the USA today – which caused total $CO_2$ emissions of approx. two billion tons in 2016 – [13] were to be fitted with gas power, this would save approx. 300 million tons of $CO_2$ due to the 15 per cent reduction in $CO_2$ emissions of CNG and LNG as compared to diesel and petrol. This would be equivalent to the annual $CO_2$ emissions produced by the transportation sectors in the G7 states of the UK, Italy and France [14].

If just 20 per cent of the total of 80 TWh of wind power produced in Germany in 2016 [15] (i.e. 16 TWh) were converted to hydrogen using power-to-gas technology and fed into the gas grid (= 11 TWh, assuming that the degree of efficiency of electrolysis is 70 per cent), this amount of energy would have been sufficient to switch off a major German lignite-fired power plant generating 11 TWh of electricity per year. This would have saved a climate-friendly 12.4 million tons of $CO_2$, 8,200 tons of sulphur dioxides, 4,900 tons of nitrogen oxide and 169 tons of particulate matter. This example can be applied globally: after all, the expansion of renewable energies in more and more countries means that, for the moment, power grids are not capable of taking on additional quantities of renewable power. In China, for example, the power grid will not be capable of taking on the total volume of wind power produced per year (2016: 241 TWh) in the medium term. For this reason, an average of up to 15 per cent of wind power is cut off (= 36.15 TWh).16 If this amount of power were to be converted into hydrogen using power-to-gas technology and fed into the gas grid (at an assumed degree of efficiency of 70 per cent = 25.3 TWh), this would be sufficient to replace an entire power plant park of non-climate-friendly lignite-fired power stations in China.

# CONCLUSION

A **Fuel Switch** carried out soon, i.e. mainly replacing coal and oil with gases and gas-based technologies, is especially important in view of the forecast of a major worldwide increase in economic growth and the significant increase in transportation this will entail. At the present time there are (as of January 2017) 2,753 coal-fired power plants in China with 914,619 megawatts of installed output in operation, emitting some 3,968 billion tons of $CO_2$ per year. Further coal-fired power plants with a rating of 200,000 megawatts are currently under construction. [10]

To appreciate the enormous climate protection potential of a comprehensive worldwide Fuel Switch in the transportation sector alone, especially in the area of heavy traffic, one simply needs to consider that about one third of all new heavy commercial vehicles were sold to China in 2016. These trucks run almost 100 per cent on diesel. While a move towards alternative drive forms such as battery-powered vehicles has started in China in the area of passenger cars, the fast-growing increase in heavy traffic in Asia is based virtually entirely on diesel. This is due to a simple necessity: where heavy loads have to be transported over long distances on a daily basis, gaseous or liquid fuels are required. However, three key positive effects would be derived from a changeover from diesel to natural gas and in the medium term to LNG with an increasing addition of synthetically produced green gases from renewable sources:

- Greenhouse gas emissions in the transportation sector would see a fast and substantial reduction in this fast-growing economic region

- Environmental pollution caused by pollutants such as particulate matter, NOx, SOx and noise would be significantly reduced

- There would be no negative impact on economic momentum

The combination of a **Fuel Switch** and **Content Switch** can enable the climate protection targets for 2050 to be met almost fully if the share of renewably produced gases in the energy systems and gas infrastructures is systematically and continuously increased worldwide.

The use of renewable gases enables substantial additional reduction of greenhouse gas emissions in all sectors, thereby further increasing the speed of climate protection and achieving the required further greenhouse gas emission reductions by 2050 in an efficient, low-cost manner. As Figure 3 shows, for example, $CO_2$ reduction potential based on gases and fuels produced by power-to-gas technologies in the transportation sector is estimated at at least 95 per cent in the area of automobiles, by comparison with conventional fuels such as petrol, diesel and natural gas. [17]

The climate protection measures of Fuel, Content and Modal Switch enables an effective transformation of all national energysystems in all global regions, allowing climate-friendly energy to be used in all sectors as well as satisfying increasing energy needs for ongoing economic growth in a cost-effective, climate-friendly and ecologically compatible way. Many energy systems are already engaged in a transformation process at the present time: numerous countries are investing hugely in the development of renewable energies.[18] In order to ensure climate protection remains affordable in the medium to long term, to provide consumers and industry with an assured capacity – even allowing for volatile supply from renewable energy sources – and to retain the ability to store surplus energy from renewable sources between seasons and on a long-term basis, natural gas, green gases and gas infrastructures provide the ideal supplement to renewable energies. Together they are capable of forming the backbone of energy systems in terms of the energy sources used. Gas infrastructures in particular with their diverse range of potential uses can provide the platform and foundation for comprehensive sectoral linkage and therefore the use of climate-friendly energy sources in all sectors. In order to tap into these advantages, investment in natural gas and gas technologies, gas infrastructures and renewable energies has to be significantly promoted right away, while at the same time putting a stop to new investment in coal and petroleum-based technologies and facilities.

In view of ongoing climate change, meeting the Paris climate protection targets is not simply a matter of preference, it is a necessity. It is no longer possible to use the atmosphere as a dumping site for more and more greenhouse gas emissions. Achieving the 2050 climate protection targets is the most important directive at the present time. The climate protection measures consisting of the Fuel Switch, Content Switch and Modal Switch offers a globally feasible option that enables not just effective climate protection but also economic growth and increasing general prosperity in all regions of the world.

[15] cf. Endcoal: Global Coal Plant Tracker. Summary Statistics (January 2017).
[16] Erneuerbare Energien in Deutschland. Daten zur Entwicklung im Jahr 2016. (Data on the development of renewable energies in Germany in 2016) Arbeitsgruppe Erneuerbare Energien-Statistik (AGEE-Stat).
[17] Cf. OECD/IEA (2016) Next Generation Wind and Solar Power - From Cost to Value, p. 34. 19 cf. Olivier, Jos G.J.: Trends in Global $CO_2$ Emissions. 2016 Report. (2016) PBL Netherlands Environmental Assessment Agency, The Hague (p.12-14).
[18] Cf. Dena (2016): Potenzialatlas Power to Gas.
[19] cf. Olivier, Jos G.J.: Trends in Global CO2 Emissions. 2016 Report. (2016) PBL Netherlands Environmental Assessment Agency, The Hague (p.12-14).

# SUMMARY

**Implementing the global climate protection measures consisting of the Fuel Switch, Content Switch and Modal Switch enables COP21 targets to be met: Fuel, Content and Modal Switch results in affordable climate protection and lasting economic growth in all national economies.**

The three transformation stages and processes of the Fuel, Content and Modal Switch enable efficient climate protection in all sectors in addition to lasting economic growth – regardless of the individual state of development of the national economy or the current structure of the national energy system.

The economies of further developed countries in particular will require extensive transformation of their energy systems and their energy sources if they are to meet the COP21 targets securely and within the stipulated period. They must initiate the Fuel Switch without delay and push ahead with the Content and Modal Switch in the medium term.

Those national economies with energy systems that are still not fully established or are undergoing further expansion must avoid any additional lock-in effects due to investment in non-climate-friendly energy sources such as coal and oil in all sectors while at the same time implementing the Fuel Switch and the Content Switch.

National economies with increased energy needs and growing transportation due to intense economic momentum should meet their energy demand in the various sectors not by increasing their use of non-climate-friendly coal or petroleum products but by investing directly in the combination of renewable energies, natural gas and green gases, thereby enabling the Content and Modal Switch right away; in other words, they must promote more intense use of gas mobility in the transportation sector, for example.

**The Fuel, Content and Modal Switch offer enormous climate protection potential, enabling the large GHG emitters in particular to reduce greenhouse gas emissions in the short term.**

**“Gas is the key to success for the energy transition! Within the framework of the energy policy system defined by climate protection, security of supplies and economics, gas can play a key role in reshaping energy supplies in Germany – and worldwide.”**

Gerald Linke, Managing Director of DVGW The German Technical and Scientific Association for Gas and Water


DVGW (Deutscher Verein des Gas- und Wasserfaches e.V = DVGW German Technical and Scientific Association for Gas and Water) has worked successfully in the gas and water industry for more than 150 years. Safety, hygiene and environmental protection are the main focuses of all the association's activities. DVGW is an association with more than 13,600 members which establishes the generally accepted rules of technology for gas and water systems, initiates research projects and provides training on a full range of gas and water industry topics. Moreover DVGW provides an inspection and certification unit for products, individuals and companies. DVGW codes of practice lay the foundation for technical self-regulation and for the responsibility of the gas and water industry in Germany. They ensure safe gas and water supplies to the highest international standards. The not-for-profit organization was established in Frankfurt am Main in 1859. DVGW is economically independent and politically impartial. www.dvgw.de