acatech COOPERATION

Pathways into the energy future

The transformation of energy systems in an international perspective

acatech/BDI (Eds.)

International cooperation is the only way it will be possible to develop an energy supply which is affordable, reliable and sustainable. Too little account is still being taken of global interdependencies and the effects of national action. This is why there is a need for systematic insights about international strategies and innovative approaches to research.

But which energy system innovations are showing the way forward? Which transformation pathways are already being successfully followed and what examples of best practice in the energy sector provide opportunities for Germany in Europe and in a global context? And what opportunities for cooperation are arising from them?

The joint project "Pathways into the energy future. The transformation of energy systems in an international perspective" between acatech – National Academy of Science and Engineering and The Federation of German Industries (BDI) was established in 2016 with the aim of finding answers to these questions. The project was funded by the Federal Ministry of Education and Research (BMBF).

The central pillars of the project were Fact Finding Missions by delegations of top-ranking representatives from German business, academia and politics to leading energy research institutions and industry in selected G20 countries. April 2017 saw the first delegation of German experts visit the USA while the second mission travelled to China, Japan and South Korea in spring 2018. The third and final mission was to Australia in autumn 2019.

acatech and BDI compiled joint discussion papers on the basis of the conclusions drawn from the findings made during the missions. These papers showed important ways forward for the development of five options for action for German and European energy research policy:

1. Focusing expertise, linking up research: central coordination of the energy transition is necessary.

2. Maintaining breadth of energy research and promoting outcome and technology neutrality, while nevertheless in particular more intensely focusing on integrated energy systems and power-to-X (PtX), CCUS technologies and electrochemical storage systems

3. Introducing continuous energy transition benchmarking of the G20 countries.

4. Fostering international technology alliances and partnerships, in particular a German-Australian green hydrogen partnership.

5. Leading by example: showing that it is possible.

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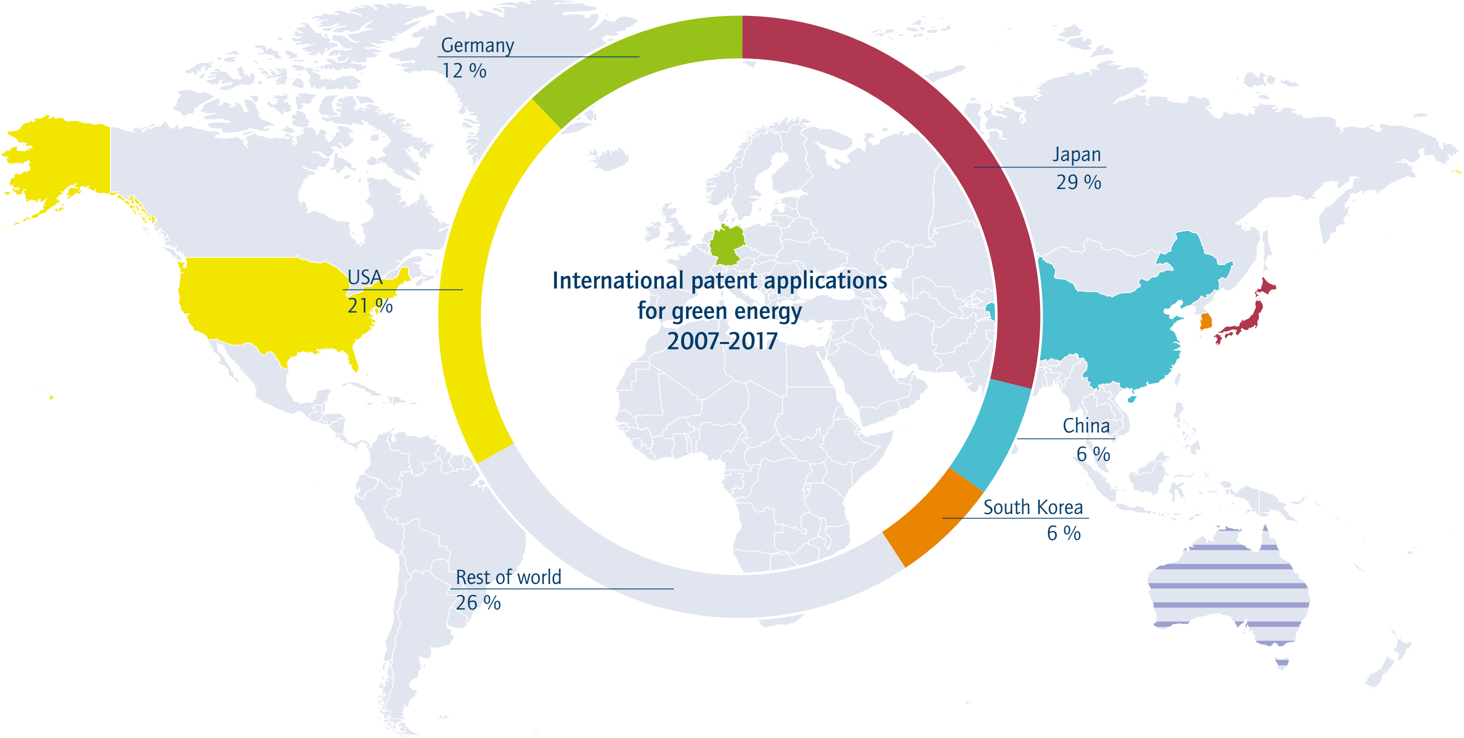

Figure 1: International patent applications for green energy technologies by origin, 2007-2017. According to the World Intellectual Property Organization (WIPO), green energy technologies include alternative energy production, energy saving, green transport technologies and nuclear energy (source: own presentation on the basis of WIPO 2018[1]).

Energy research policy and best practice examples from the G20 countries visited

United States of America

The USA is the world's largest economy and has substantial fossil fuel resources, with oil, natural gas and coal in particular being used for energy generation. Energy independence, security of supply and cost-efficiency are the central aims of the USA's energy strategy.

Best practice example: National Labs

The 17 National Labs are innovation ecosystems which cooperate with both university research institutions and private companies. These are centrally coordinated by the Department of Energy and span the entire innovation process from basic research, via applied research to market launch and mass production, so they provide the basis for a systematic and integrated funding landscape. The close cooperation with companies means that the focus is on rapidly implementing and applying research results.

Energy research in the USA is broad in scope and does not rule out any development pathways in basic research, which means that no individual technology is preferred. As a result, a wide range of energy issues is addressed, in particular by the "National Labs".

Economic interests and a start-up culture ensure that research results are quickly implemented in practical applications. The direction of research is predominantly determined by the political agenda and is accordingly subject to the interests of the currently ruling administration. This in particular has an impact on issues which, in the government's view, are of "national significance".

People's Republic of China

The People's Republic of China, with its continuously rising energy consumption, is the world's biggest emitter of CO_2. Nevertheless, in addition to energy security and energy independence, the focus of China's energy policy is increasingly on improving domestic air quality.

Chinese energy research is aligned with the communist party's strategic aims. Strict state directives mean that funds for priority research areas are provided at short notice and implemented in projects. While there is an aspiration towards technology neutrality, basic research is less broad in scope.

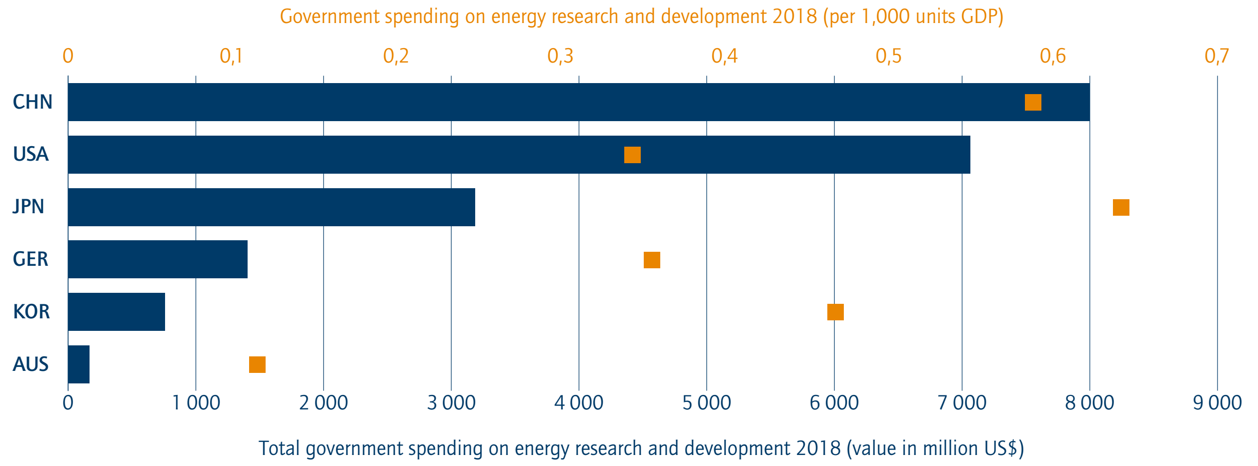

Figure 2: Comparison of government spending on energy research and development in 2018
(source: own presentation on the basis of data from IEA 2019[2] and World Bank 2020[3])

Best practice example: Power grids and grid expansion

The uneven distribution of power generation in the west of the country with load centres on the coast in the east presents China with enormous challenges. In order to reduce the high curtailment rates for photovoltaics and wind power systems, the country is continuously and extremely rapidly building thousands of kilometres of state-of-the-art ultra-high-voltage lines. In addition to nationwide grid expansion, the State Grid Corporation of China is also researching the development of smart grid technologies and grid control and simulation systems. The magnitude of grid expansion and associated research is globally unparalleled.

Chinese research has long built on the results from leading international research, in some cases by compulsory technology and knowledge transfer. The level of research in some application-oriented areas now matches or surpasses western standards.

The state's assumption of investment risks plays a major role in the success of energy research: Chinese research institutions and companies are in the unique position of being able to implement innovative technologies in large-scale projects and to scale innovative energy solutions to market levels in targeted manner.

South Korea

As a resource-poor country, South Korea is dependent on primary energy imports. Security of supply is thus of the highest priority. The current government's "Renewable Energy 3020" plan has set a new political course: instead of nuclear energy and coal-fired power generation, the focus is now increasingly to be on natural gas and renewable energies.

South Korea's energy research has a comparatively narrow focus. Strong cooperation with Korea's internationally active corporate conglomerates means that research efforts concentrate on those innovations with the greatest export potential. Technology corporations are active not only in application-oriented research and development but, in some cases, in basic research too in their specialist areas. Such centralization is an important cornerstone of the market leadership of South Korea's battery manufacturers.

Best practice example: Battery research

The focus on security of supply and technology exports means that stationary and mobile storage technologies are an essential component of Korea's energy research. Many of the world's leading battery producers, each of which have their own research facilities, originate from South Korea. The huge projected demand for electric vehicles from China is leading to great pressure to innovate in the mobile storage system field. The focus is in particular on increasing range and on the recycling of raw materials by means of materials research. Stationary storage systems, on the other hand, are set to assist with smoothing domestic photovoltaic generation peaks and avoiding blackouts. The country is here making use of its leading position in lithium ion technology.

In addition to research into storage technologies, the change in political course means that grids and renewable energy generation are increasingly being investigated. Despite nuclear energy's declining significance in the domestic energy system, research into this field is to be continued primarily for the export market.

Japan

As a country poor in raw materials, Japan's energy policy focuses on economic efficiency and reducing dependency on imports of fossil fuels. To this end, in 2017, the Japanese government set out its technology-neutral hydrogen strategy which is intended to secure the competitiveness of Japanese industry and the potential market for hydrogen technologies. In doing so, Japan positioned itself as first mover in the hydrogen field.

Japanese energy research is systematically structured and oriented to the long term. There is a clear division of labour between academia and business: basic research is primarily concentrated in university institutions, while application-oriented and experimental research and development are predominantly carried out by Japanese technology corporations. The government's "top-down" approach provides support, in particular if the research projects serve to implement the hydrogen strategy and thus added value in Japan itself.

The strong political directives and close interconnection between business and politics mean that Japan's energy research policy is largely homogeneous.

In line with Japan's dominant hydrogen strategy, the research priorities are located along the entire value chain: from production via transport to use of hydrogen. Carbon Capture and Storage (CCS) technologies are also being investigated in this connection.

Best practice example: NEDO

The New Energy and Industrial Technology Development Organization (NEDO) was established in 2003 and is the central interface between academia, business and politics. NEDO's remit is to coordinate energy research policy for practical application. Working together with policy makers, NEDO is creating suitable conditions for technology development and promoting innovation in energy efficiency, renewable energies, "clean coal" technologies and resource conservation. By collaborating closely with project partners, NEDO supports the implementation of research projects and technology transfer. NEDO also carries out pilot and demonstration projects and schemes with international industrial partners, so assisting Japanese companies in gaining a foothold on international markets.

Australia

Australia has huge deposits of fossil resources and is the world's largest coal exporter and second largest exporter of liquefied natural gas (LNG). The country is also the largest producer of lithium ore. At the same time, Australia is one of the sunniest countries and, with thousands of kilometres of windy coastline, has huge potential for generating power from renewable energies.

Australia's energy research is technology-neutral but, due to its vast export potential, is oriented towards export markets. In addition to various research institutions, Australian universities in particular play a decisive role in research. These regularly occupy leading positions in international rankings while their size and huge budgets mean that they are managed like companies. Academia and business work together hand in glove. Nevertheless, it is predominantly foreign companies which are active in the country.

Australia has numerous CCS technology research projects. Low-emission technologies such as battery storage systems and the production and application of hydrogen are, however, also Australian energy research priorities. In contrast with simple fossil energy exports, the intention with these technologies is to retain value creation within Australia itself.

Best practice example: CRCs

The government-funded Cooperative Research Centers (CRCs), which are collaborative projects between academia and business, are a distinctive feature in energy research. The energy sector has two such centres: Future Fuels CRC and Future Battery Industries CRC, the first in particular researching and developing alternative fuels in the gas market and in mobility. The recently founded Future Battery Industries CRC will work on cell fabrication and materials research in a centre of expertise specifically established for this purpose. CO2CRC, whose government funding has come to an end, has been privately funded since 2014, primarily focusing on demonstration systems for the underground storage of CO_2.

Options for action

The insights gained from the Fact Finding Missions have led to five specific options for action for German energy research policy.

1. Focusing expertise, linking up research: central coordination of the energy transition is necessary

Best practice examples from outside Germany demonstrate the effectiveness of linking up existing energy research into centres of expertise like Japan's NEDO or Australia's CRCs in order to become global frontrunners in key technologies such as the hydrogen economy, alternative fuels or battery storage systems.

The regulatory sandboxes, Kopernikus and SINTEG projects funded by federal ministries and the Agency for Breakthrough Innovation are tools which are already in place for designing and trialling innovative technologies. In addition, non-university research in institutions such as the Fraunhofer-Gesellschaft, the Helmholtz Association, Leibniz Association and Max Planck Society is internationally renowned.

While such decentralized research promotes competition and the independence of German energy research, it also leads to a degree of fragmentation of know-how in important key technologies. If innovative fields of research are to be identified at an earlier stage and research topics strategically developed, better links must be created between and targeted funding provided for existing scientific and industrial research in Germany. This could be enabled by central coordination of the energy transition. Improved coordination has the potential to link existing scientific expertise across institutions and to accelerate highly promising projects. Inspiration could also be drawn from foreign energy research. Moreover, centrally boosting important key technologies at both the national and the European level would strengthen collaboration within the EU and provide competitive advantages over the USA or China.

2. Maintaining breadth of energy research and promoting outcome and technology neutrality

The German federal government's 7th energy research programme covers the necessary breadth of topics in the energy technology field: energy efficiency, renewable energies, systems integration by grids, storage and integrated energy systems together with cross-system research topics and nuclear safety research. In the light of the emission reductions which are still to be made to meet national and European climate targets for 2030, any technologies which have the potential to make a contribution must be pursued. Germany should increase the outcome and technology neutrality of energy research in order to enable potential game changers in future. At the same time, if energy research is to be successful and systematic, there is a need for a reliable framework, in particular with regard to potential long research and development timeframes.

From today's perspective, however, it would seem advisable to focus to a greater extent on specific fields of technology in addition to pursuing broad energy research. With a view to international markets and on the basis of experience and impressions gained from the missions, three fields of technology have been identified by way of example:

Integrated energy systems and power-to-X

Germany's national hydrogen strategy is intended to boost and consolidate the significance of hydrogen as a PtX technology and cornerstone of integrated energy systems.

German companies currently still lead the market in water electrolysis, even if the country lacks large, industrial-scale automated manufacturing facilities for such systems. Green hydrogen and its derived products could be put to use in various sectors of the energy system. Account must, however, be taken in particular of levels of efficiency, path dependencies and investment cycles, in particular in industry.

If Germany is not to lose its internationally leading position and is to seize the industrial potential of a growing market for electrolysers, the highest priority must be given to the scalability of raw materials use, material syntheses and processes from basic research. In addition to increased research into PEM electrolysis, this also relates to high-temperature electrolysis. Since other countries will not exclusively back green hydrogen, technology neutrality should be maintained here too and additional effort put into researching alternative methods such as methane pyrolysis. In addition, the regulatory framework for the operation of electrolysers should be adapted in order to encourage domestic commercial adoption.

Another aspect of successful energy systems integration is research into hydrogen transport media, for example liquid organic hydrogen carriers (LOHC), methanol (CH_3OH) or ammonia (NH_3), each of which has its own different advantages and drawbacks.

It may well be that Germany will not by itself be able to meet future demand by domestic production. Efficient supply chains may increase hydrogen volumes and extend transport distance, so also enabling an international energy transition by "grids and tankers". The conversion and recovery of hydrogen will play a decisive role here.

CCUS technologies

The target of climate neutrality presents the EU and Germany with a major challenge: while climate targets in the power sector would appear to be achievable by emission abatement, non-electrifiable processes and unavoidable process emissions, for example from the cement industry, may be obstacles to climate neutrality. CCUS technologies could be used in such cases.

The extension, planned in the climate protection programme, of CCS funding to industrial processes in the European NER300 programme may be a first step in this direction. It is, however, also important to reassess storage sites within Germany and the EU so as to gain a realistic picture of potential and create possible acceptance among policy makers and society at large.

Largely closing the carbon cycle to establish a circular economy should, however, be a long-term focus of such considerations. Methods for making material use of CO_2 (carbon capture and utilization/CCU) should be further investigated and rapidly implemented. The primary chemicals industry in particular will not be able to do without such methods in a climate-neutral economy. CCU should, however, also be an integral part of a national hydrogen strategy for producing further hydrocarbons such as methanol or kerosene. Creating value and know-how in relation to such methods should be part of Germany's industrial and research strategy.

CCUS technologies should not be viewed from a purely technological standpoint but must also be accepted by all societal stakeholders. This will require a broad, unbiased debate within society to accompany the research.

Electrochemical storage systems

Germany and the EU are lagging behind when it comes to developing lithium ion technologies and establishing their own battery cell manufacturing capabilities. However, this competitiveness gap can be closed by a well-thought-out strategy for developing technology and getting it onto the market. The European Battery Alliance for the production of "green batteries" and the federal government's ideas for establishing joint manufacture with European countries are accordingly one possible way of working together to close this gap. Setting up foreign production facilities would also be one possible way for Germany to develop systems expertise.

Cluster solutions like the Australian CRCs are a further way for Germany to develop expertise. In particular, priority should be given to the development of the next generation of batteries for electromobility or grid operation.

In the context of the existing circular economy initiative, Germany can also establish its own competitive lead in battery recycling which has as yet received little attention internationally. Recycling raw materials can reduce the necessary inputs of energy and raw materials and so contribute to climate protection.

3. Introducing continuous energy transition benchmarking of the G20 countries

The experience gained from the Fact Finding Missions has shown how much national energy system transformation pathways can differ from one another. Investigations and personal contact in the various countries have clearly revealed their individual strengths and weaknesses in R&D efforts and in the development of energy innovation. This may give rise to specific opportunities for cooperation which will not only fill potential gaps in German energy research, but also open up substantial industrial policy potential for Germany.

Ongoing energy transition benchmarking of the G20 countries should be established so that such insights continue to be available in future. One focus should here be on identifying best practice examples of energy research and so establishing an international basis for comparison. Energy policy measures, for example relating to CO_2 pricing, should also be surveyed and evaluated. Such benchmarking could complement existing monitoring approaches for Germany's energy transition such as the "Energy of the Future" Expert Commission or the Expert Commission on Research and Innovation (EFI) report.

4. Fostering international technology alliances and partnerships

Despite its broad-based energy research, Germany cannot be a leader in all fields of technology even if research efforts are redoubled. If the complexity of the energy system of the future is to be tackled, technological development cannot be considered solely on a national level.

International alliances in selected fields of technology offer an opportunity to fill potential gaps in Germany's systems expertise and to open up new markets and so provide lasting protection for the value chain in Germany and the EU. Such cooperative opportunities must be win-win situations for all parties in the alliance and should ensure the highest possible levels of transparency.

The experience gained during the Fact Finding Missions is giving rise to concrete opportunities for cooperation which have considerable potential for Germany in terms of industrial and research policy.

Opportunity for cooperation: German-Australian green hydrogen partnership

Australia is an ideal partner for a long-term, large-scale cooperation project spanning the entire green hydrogen value chain: while Australia has huge potential for renewable energies and great expertise in constructing and operating large-scale plants and infrastructure, it lacks technologies, in particular relating to electrolysis and integrated energy systems. Germany, in contrast, is a world leader in electrolysis technologies and will probably have a significant need for hydrogen imports.

Germany will set out its hydrogen strategy in early 2020 and it is to be anticipated that hydrogen imports from Africa or Australia will play a major role in the strategy. Australia published its Australian Hydrogen Strategy in November 2019, so positioning itself as a possible trading partner. Now is thus a favourable opportunity to examine the feasibility of a hydrogen bridge from Australia to Germany and Europe.

Any barriers along the overall value chain from production and transport via recovery to use of green hydrogen could thus be identified and possible options for overcoming them outlined. In particular, estimating demand and production capacity and the costs of transport on an industrial scale is of central significance.

Such a feasibility study would thus provide important insights for projects such as the BMBF's "Green hydrogen potential atlas" with African countries and for other potential import countries. These insights could create the foundations for a supranational trading system for storable renewable energy carriers and help Germany to establish itself as a market leader in green hydrogen technologies.

Opportunities for cooperation with Asia, in particular with Japan and South Korea

The parallels as leading technology suppliers and in demand structure provide Germany with opportunities for reliable supply relationships with Japan and South Korea. For instance, there is technology export potential for both countries, in particular with regard to offshore wind energy and efficient photovoltaics. Japan could also be an important technology development partner for power-to-X and in hydrogen applications. South Korea has a substantial lead in research into mobile and stationary storage technologies, so making it a suitable cooperation partner. There could be potential for cooperation with China in relation to (smart) grids and systems integration.

5. Leading by example: showing that it is possible

Countries' national priorities such as energy security, energy independence or economic efficiency are often at the top of the political agenda, resulting in climate and energy policy which tends towards pragmatism. The transformation of the energy system is not always driven by climate policy and issues of sustainability often play a subordinate role. In addition, it is currently all too rare for global interdependencies and the effects of national action to be taken into account.

Outside Europe in particular, Germany's energy transition and energy research continue to enjoy a good reputation. Trends in integrated energy systems in Germany are in particular being followed with interest. If Germany is to live up to its position as a model and demonstrate that sustainability and economic efficiency can be combined, it must continue to lead by example and show that it is possible.

The described options for action provide German energy research with a comprehensive range of choices which, if implemented, may give rise to synergistic effects both nationally and internationally: (improved) central coordination will focus existing expertise, help to maintain the breadth of energy research and buoy up technology neutrality. It is essential to introduce ongoing energy transition benchmarking of G20 countries in order to maintain the flow of valuable insights into international transformation pathways. This is the only way international alliances can be identified and entered into on an ongoing basis.

Such technology partnerships are of huge symbolic importance and should be communicated as successful case studies in order to convince other countries that the energy supply of the future can combine sustainability and economic efficiency. Only in this way will a positive narrative about the energy transition be able to withstand future political turbulence.

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[1] | World Intellectual Property Organization (WIPO): *Measuring innovation in energy technologies: green patents as captured by WIPO's IPC green inventory*, 2018. URL: https://www.wipo.int/edocs/pubdocs/en/wipo_pub_econstat_wp_44.pdf [accessed: 30.03.2020].

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[3] | World Bank: *GDP (current US$) – United States, China, Australia, Germany, Japan, Korea, Rep.*, 2020. URL: https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=US-CN-AU-DE-JP-KR [accessed: 30.03.2020].

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