Energy Security in a Digitalised World and its Geostrategic Implications

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Foreword

Global energy systems are currently undergoing tremendous and multi-fold challenges. This 'energy transition' towards a non-fossil fuel energy system can be best described along three, mutually reinforcing strategic trends: decarbonisation, digitalisation and decentralisation ('3 Ds'). To come to grip with this increasingly dynamic development, Germany as a leading industrial and export-oriented country has to redefine its business model as well as its role as an influential geopolitical actor. Regional and international cooperation is very much in need to set reliable political and legal frameworks and speed up innovation.

In 2015 Konrad-Adenauer-Stiftung launched a new "Regional Project Energy Security and Climate Change Asia-Pacific (RECAP)", based in Hong Kong SAR/PR China. It provides a cross-regional platform for the exchange of strategic challenges and innovation concepts both in Asia-Pacific and Europe – and beyond.

As part of this endeavour the following analysis by Dr. Frank Umbach, Research Director at the European Centre for Energy and Resource Security (EUCERS) London and Adjunct Senior Fellow in RSIS at S. Rajaratnam School of International Studies (RSIS) Singapore, provides a comprehensive view on the impacts of digitalisation on the global energy system. Against the background of a massive and accelerating digitalisation – and other newly emerging disruptive technologies – it analyses the 'energy trilemma', the impacts of the transition from 'peak oil' to 'peak oil demand' and the geopolitical implications of expanding renewables. In particular with the forced electrification and ‚datarisation' of the energy sector, the vulnerability of complex networks has dramatically increased; cybersecurity – not surprisingly – now ranks top among national security strategies.

Beyond the energy sector, Konrad-Adenauer-Stiftung has identified digitalisation as a strategic and cross-sectoral topic in its domestic and global work – fundamentally changing concepts of communication, information and value creation. Digitalisation is among the most powerful forces of transformation in economics, politics and society. And it comes in parallel with a second revolution: the „Energiewende" (energy transformation). These two revolutions in information and energy production/consumption will widely shape the geopolitical landscape of the 21st century.

I hope that this study will serve as a rich and thought-provoking contribution to a deeper understanding of these ground-breaking transformations and how to cope with in global business, politics and society.

Dr Peter Hefele

Director RECAP

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Abbreviations

3 Ds	Decarbonisation, Digitalisation, Decentralisation
4 As	Availability, Accessibility, Affordability, Acceptability
AI	Artificial intelligence
APERC	The Asia Pacific Energy Research Centre
APT	Advanced Persistent Threat
ASEAN	Association of Southeast Asian Nations
bb	billion barrels
bcm	billion cubic meters
BfV	Germany's Domestic Intelligence Agency
bn	billion
BSI	Federal Office for Information and Security
CBM	Confidence Building Measure
CEIs	Critical Energy Infrastructures
CIs	Critical Infrastructures
CRM	Critical Raw Material
DRC	Democratic Republic of Congo
DUCs	Drilled but uncompleted wells
EEZ	Exclusive Economic Zone
EIA	Energy Information Administration
EV	Electric Vehicle
EVs	Electric Vehicles
FBI	Federal Bureau of Investigation
FSRU	Floating Storage Regasification Units
GHG	Greenhouse gas
GHGE	Green House Gas Emissions
GWh	Gigawatt hours
HREEs	Heavy Rare Earths Elements
ICE	Internal Combustion Engine
ICS	Industrial Control Systems
ICT	Information and Communication Technology
IEA	International Energy Agency
INESS	Integrated National Energy Strategy
IoTs	Internet of Things
IRENA	International Renewable Energy Agency
IT	Information Technology
kWh	Kilowatt per hour
LNG	Liquefied Natural Gas

m	million
mb/d	million barrels per day
mt	million tons
MENA-region	Middle East and North Africa
NDCs	Nationally Determined Contributions
NMC	Nickel-Manganese-Cobalt
NOCs	National Oil Companies
NPS	New Policy Scenario
NSA	National Security Agency
OECD	Organisation for Co-operation and Development
OPEC	Organisation of Petroleum Exporting Countries
PPP	Public Private Partnership
R&D	Research and Development
REE	Raw Earth Element
REEs	Rare Earth Elements
RES	Renewable Energy Sources
SDS	Sustainable Development Scenario
SCADA	Supervisory Control and Data Acquisition
tcf	trillion cubic feet
tcm	trillion cubic meters
VEP	Vulnerability Equities Process
WEC	World's Energy Council
WTO	World Trade Organisation

Executive Summary

The worldwide energy sector stands at the crossroads by coping with unprecedented changes and challenges of the digitalisation, new forms of mobility, autonomous driving and the introduction of Artificial Intelligence (AI) technologies. In contrast to the past, most of the new technologies are developed outside of the energy sector itself but might have unprecedented impacts on energy markets and traditional energy industries. For the incumbent energy industry, these changes offer both new benefits as well as operational and strategic risks.

In Europe, the loss of jobs rather than any benefits have dominated most of the perceptions of AI. But the EU needs to expand its own AI capabilities in the global competition. It also needs to balance its growing data protectionism with the potential benefits as hinder Europe to compete successfully with the U.S. and China. Moreover, the restrictions of the international transfer of data could even hamper global businesses on all sides.

The global 'energy transition' to a non-fossil fuel energy system is based on three reinforcing strategic trends: decarbonization, digitalization and decentralization ('3 Ds'). It transforms, in particular, the global electricity sector and is largely based on the integration of Renewable Energy Sources (RES) and other distributed energy resources. The energy transition is also dependent on fundamental reforms of current regulatory frameworks to accommodate the shifting energy supply structure. These megatrends will affect not only the industries but also the daily life of every citizen and public order as it will become ever more dependent on the stable functioning of critical (energy) infrastructures. The dramatic changes of the global energy sector are also linked to the rising worldwide energy demand (i.e. electricity), greater energy efficiency, disinvestment in carbon-intensive industries as well as the U.S. shale oil and gas revolution (together with the rapidly expanding worldwide LNG trade), which have far-reaching impacts on the global oil and gas markets.

In contrast to the years before 2010, the world is no longer confronted with any scarcity of fossil fuels, which had sparked debates of a near 'peak oil'-era with ever increasing fossil fuel prices. Instead, the present world now has to cope with fossil fuel oversupplies and rapidly decreasing fossil fuel prices, which have changed the overall geo-economic and geopolitical balance of power between consumer and producer countries, leading to new 'buyers' markets'.

The energy sector has always been at the forefront of adapting technological innovations. Power utilities have proved to be 'digital pioneers' since the 1970s by using technologies to improve grid management and operations, while oil and gas companies used digital technologies for modelling exploration and production assets. The fastening digitalisation with the widespread use of 'Information and Communication Technology (ICT)' is changing the established energy sector and the traditional energy business models by creating new consumption patterns, providers and platforms (also from outside of the energy sector). The digitalisation and electrification have also led to rising competition among energy companies which face at the same time new competitors from outside (i.e. IT companies).

This is even true for the oil and gas companies, which have created strategic alliances and partnerships with IT companies. It signals that a new digital era in energy has arrived and even more radical changes lay ahead, which will encompass all energy sectors. Renewables, as well as energy storage solutions, have become much cheaper and competitive. This also offers oil and gas companies new options to diversify their energy sources and businesses and has led to a new class of hybrid energy enterprises, reconciling fossil fuels with renewables. In Europe, Royal Dutch Shell and Total have also begun to invest in the further expansion into the electricity supply chain and building a retail energy business in Europe for an integrated power supply chain from generation to retail supply, challenging traditional power companies.

So far only a few analyses of the impacts of digitalisation of the energy sector have focused on energy companies, their business models and strategies. This comprehensive net study is one of the first which offers a detailed and holistic analysis focusing on the wider international impacts and implications for regional and global energy security as well as geo-economic and geopolitical risks; it hopes to fill an analytical research gap and to stimulate new thinking and discussions on future energy security concepts.

The study has addressed and discussed the evolving energy security concepts of the 21st century in the light of the digitalization and new emerging disruptive technologies and their impacts. It analyses the 'energy trilemma', the impacts of the transition from 'peak oil' to 'peak oil demand' and the wider geopolitical implications of expanding RES. It pays particular attention to the fastening electrification of the entire energy sector and related cybersecurity requirements as part of new energy security concepts. Furthermore, the analysis has explored the global energy megatrends and examined the strategic implications of the global transition from traditional energy scarcity to energy abundance. In more detail, it has examined the impacts of the expansion of RES and the decentralization of energy supply, the U.S. shale oil and shale gas revolution, and the geo-economic and geopolitical implications of expanding natural gas and LNG for the global oil and gas markets and energy supply security. In this wider context of global energy security developments, the study focuses on the global dimensions of the digitalization of the energy and electricity sectors. It has examined the related new cybersecurity challenges, the prospects of the electrification of the transport sector and the digitalization on energy supply security, in the traditional oil and gas industry as well as in the rapidly changing electricity sector with the expanding technologies of smart meters, smart grids, and smart home appliances. The study has identified five geostrategic challenges of digitalization.

Impacts of the Digitalisation, Electrification and Connectivity

Oil and gas companies already operate some of the world's most powerful supercomputers. The new U.S. shale revolution 2.0 includes cloud computing services, which store and analyse an unprecedented amount of data of seismic information, drilling and production much more precisely. Digitalization and automation, as well as new alliances between oil and IT companies, will make future operations of oil and gas drilling even safer, cleaner, and more efficient by maximising output.

Moreover, the industry is already coupling AI with new advanced sensors, sophisticated seismic data processes and management as well as automated drilling rigs to maximise production of tight oil and shale gas with only a few engineers and technicians. But the barriers and challenges to implement the full specter are of the new digital technologies - range from adequate timing of capital intensive large projects, the existing infrastructures, the traditional inward focus, risk-averse management perspectives to introduce new disruptive technologies, its high fragmentation along the supply chains, long-term demand trends, dependence on a up-to-date Information Technology (IT) support infrastructure – might slow their fast implementation and full exploitation of the new disruptive technologies.

But the electricity sector is expected to undergo the greatest digital transformation as it will break down the traditional boundaries between the various energy sectors, increase flexibility, blur the distinction between generation and consumption as well as fasten the integration across entire systems. Since 2014, global investments in digital (electricity) infrastructure and software have jumped by 20% per year up to US$47 bn in 2016. Around 90% of the world data has been created just over the past two years! While the digitalization is at first glance primarily a technology revolution, its impacts for companies and governments will be far outreaching and change markets, business models, organisational structures and companies' cultures substantially in the forthcoming years. The potential of saving costs and investments in the worldwide power sector due to digitalization has been estimated at around US$80 bn between 2016 and 2040 by reducing operation and maintenance costs, improving the efficiency of the power plants and networks, decreasing unplanned outages and downtime, and extending operational lifetimes of assets. The current electricity model is increasingly disrupted and undergoing major changes. Even fundamentals are increasingly questioned: (1) electricity prices are no longer always based on usage-based prices (i.e. negative electricity prices); (2) and only energy companies will generate and sell electricity; (3) not all private and industrial customers need an electricity and wider grid connection as well as regional system operator; and (4) local distribution companies will not necessarily functioning as a stable and profitable source of funds to local governments owning them.

In consequence, the whole electricity industry needs to adopt radical changes in its business models. Many won't survive and/or be able to compete in fundamentally different future markets. The greatest potential for the digitalization in the energy sector might be the breaking down of traditional segmentation and boundaries between various energy sectors themselves as well as with other sectors and industries. They will enforce the integration of entire systems and the creation of new ones. In this context, connectivity becomes the most important factor driving the digitalization of the industrial and the electricity sector.

Geopolitical Implications

These strategic developments have wider geo-economic and geopolitical impacts and will transform international energy relations between countries and regions. In traditional energy security analyses, geopolitical risks and vulnerabilities (in particular supply disruptions) have been considered exclusively linked with fossil fuels as renewables are considered as immaterial and available almost everywhere. Their expansion also promotes the overall decentralisation of energy supplies, which has also been widely perceived as enhancing national and regional energy security. They may not just reduce the dependence on politically unstable fossil fuel suppliers (both state and corporate), but also decrease their political and (geo-) economic power in international relations. The loss of the previous geopolitical influence of those fossil fuel suppliers as well as the shale oil and gas revolution in the U.S. have already translated into the creation of global 'buyers' markets'.

The new era of energy abundance creates different new geo-economic and geopolitical challenges. In addition, the technology transformation could also lead to a new 'securitization' of raw materials and strengthen the monopolization of political and economic power as well as autocratization of political systems inside countries as well as internationally. In this context, China's world views and geopolitical strategies - such as the 'Belt and Road-Initiative (BRI'), formerly also known as 'One Belt and Road'-Strategy ('OBOR') -, and its nationalist tendencies in its domestic policies under President Xi Jinping are of utmost strategic importance for the West and global stability.

Those strategic developments demand a new comprehensive understanding and holistic strategies for analysing and stabilising international energy security. The global changes and energy megatrends are fuelled by global climate mitigation decarbonization efforts and the digitalization of the worldwide energy sector. Over time, they might increasingly depoliticize the world's energy markets. But at the same time, grid developments and other new technologies (smart meter, smart home, Internet of Things/IoTs etc.) make future energy policies and relations between countries as well as global regions even more complex and may replace traditional 'pipeline politics and diplomacies'. But electrification of the transport and heating sectors could in the mid- and longer-term perspective de-diversify those sectors as they will become exclusively reliant on stable electricity supply.

By 2040, energy geopolitics will still be dominated by fossil fuels despite the expansion of renewables and a broadening of national energy mixes. The decarbonization of the worldwide energy sector and fastening clean energy developments will also be shaped by a different kind of new geopolitical dependencies, risks and vulnerabilities, creating 'winners' and 'losers' of global decarbonization.

The current energy megatrends of expanding renewables and the production of unconventional oil and gas resources have caused a redistribution of political and economic power at the expense of fossil fuel producers and exporters. The digitalization of the energy sector as well as technologies offer new investment opportunities for companies and might transfer some strategic control to them (i.e. internet giants such as Facebook, Amazon). New players on the local level might evolve as a result of more decentralised energy supplies. Worldwide energy sector and critical (energy) infrastructures) are becoming increasingly dependent on "new, unfamiliar supply chains from unfamiliar sources", in particular, raw materials, and on a stable internet (access) and electricity supply.

Against this background, the following five geostrategic challenges of the international digitalisation are addressed in more detail:

(1) Rising cyber security threats and the need for critical (energy) infrastructure protection;

(2) The impacts of decarbonisation and digitalisation on the political-economic stability of traditional oil and gas producer countries;

(3) A higher increase of the regional and global worldwide electricity demand;

(4) The need for advanced battery storage technologies; and

(5) Rising dependencies on raw material supply security.

Rising New Cyber Security Threats and the Need for Critical (Energy) Infrastructure Protection

During the last years, the worldwide increase of sophisticated cyber attacks on industrial control centres has alarmed industries, governments and cybersecurity experts. As long as the identification (or attribution) of the sources of cyberattacks remains very difficult and offensive cyber tools are becoming commonplace and available for rogue nations, jihadists and cyber-criminalists throughout the world, sophisticated cyber attacks on critical information and control systems (ICS)-networks might further increase. Disruptive and destructive attacks against Critical (Energy) Infrastructures (CIs/CEIs) have already exceeded previous forecasts.

The rapidly expanding introduction of new technologies will multiply already existing cybersecurity risks and vulnerabilities, not best due to billions of internet-connected Internet of Things (IoT) items of networks of smart-sensor-enabled devices that communicate and cooperate with each other. The rapid and often premature adoption of digital technologies and IoT devices has already created new vulnerabilities and data breaches (i.e. the worldwide 'WannaCry'-ransomware attack in May 2017).

During the last years, international consciousness, awareness and preparedness and the exchange of information, as well as expertise between Western countries, have increased. National law enforcement and intelligence agencies have also enhanced their cooperation both nationally and internationally. Despite the progress being made at the cyber fronts, the overall preparedness and defence capabilities have not yet lived up to the worldwide offensive cyberattack capabilities of transnational crime and governmental-supported hacking groups.

While warnings of 'Digital Pearl Harbor'-attacks on critical infrastructures (CIs) are not new, the present situation might become even more precarious, particularly for highly industrialized countries such as the U.S., the EU, Japan and others. Global cyberattacks might further increase due to new technologies of digitalization, electrification, robotics and AI, which will revolutionize the energy sectors and other industries. Although artificial intelligence might also significantly improve the worldwide cyber defence capabilities, the new disruptive technologies might also create numerous new risks and vulnerabilities, particularly for the CIs/CEIs and their Industrial Control Systems (ICS). More efficient, resilient cybersecurity strategies need to be based on layered 'defense-in-depth'-concepts, which give much more attention to mitigating and disrupting cyberattacks and restoring the operational functioning of CIs to prevent any wider cascading impacts.

Ultimately, governments, industries as well as businesses and the public need to be aware that any new technology can be used for offensive crime-related purposes as well as for strengthening defence and resilience in the cyberspace in an ever escalating cyber arms race.

Toward a Higher Regional and Worldwide Electricity Demand?

Electrification and digitalization of the transport and heating as well as the forthcoming 'industry 4.0'-revolution, based on robotics and artificial intelligence systems, will significantly increase the role of electricity in final energy consumption. It might also result in a higher demand for electricity and energy than currently projected. The IEA (International Energy Agency) has forecasted in its latest 'WEO-2017'-report that by 2040 global electricity demand will increase by 60% according to its major New Policy Scenario (NPS) - twice the estimated total demand growth. 85% of it will come from developing countries, when the growing world population and the further rise in living standards are taken into account. The share of electricity in the final energy consumption might grow from 20% up to 23% in the NPS and 27% in the Sustainable Development Scenario (SDS) by 2040.

But the electrification of the worldwide transport sector might need more time and may not decrease the oil demand as many supporters of electric vehicles (EVs) currently expect. For the international car industry, it is not yet clear that the time for petrol and diesel cars has already ended due to various factors and challenges: (1) The environmental balance of battery-driven EVs is currently questionable as long as high energy-intensive battery production is based largely on fossil fuels. The problem might even get worse, if a higher electricity demand is not based on an expansion of renewables but on fossil fuels at least in the short- and mid-term future; (2) the manifold problems of insufficient infrastructures (such as expensive battery charging stations), particularly in less densely populated countries, cannot be solved just in a few years. (3) The international car and oil industries also place their hopes on widespread commercialised new biofuels and synfuels (based on algae or another basis), which could provide another environmental friendly solution to internal combustion engine (ICE) vehicles by decreasing CO2 emission. If these alternative fuels become commercially viable and offer a future for ICEs, the demand for batteries (and their raw materials) might decrease for at least some time.

Technology innovations and their implementation in other sectors might be fuelled by digitalization. The worldwide spread of cryptocurrencies, Blockchain, cloud systems and other disruptive technologies, for instance, have proven to be very energy intensive and threaten many energy forecasts. The EU's and IEA's projected electricity demand growth appears to still overlook or at least marginalise those combined impacts of various technological developments. Thus the EU's targets of its integrated energy and climate policies for 2030/2040 might be too optimistic if not unrealistic. While electrification and digitalization also promise substantial prospects for energy conservation and enhancing energy efficiency, many new technological developments and the electrification of all energy and industrial sectors do not take energy efficiency sufficiently into account. As a result, underestimating the increase of electricity demand could have wide-ranging implications for the future energy mix, climate targets and the agreed and defined energy conservation as well as efficiency targets on the national, regional (i.e. EU) and global level.

In the short- and mid-term perspective, the worldwide energy transition to a global decarbonised energy system may offer a diversification of the energy mix by adding various RES to the energy mix. In the longer-term perspective, an electrified energy system will rely rather on a single transport modality and a less diversified energy system with all the subsystems being dependent on a stable supply of electricity, the internet and a stable cybersecurity environment.

The Need for Advanced Battery Storage Technologies

The development of a new generation of batteries does not just matter for the electrification of the worldwide transport sector, but also offers new storage perspectives, including in other sectors (such as power plants/electricity sector and heating). Further improvements of lithium batteries will also allow them to be used in trucks, busses, and increasingly also for air and sea transport. Energy utilities have already begun to use utility grade lithium-ion batteries for large industry storage systems and grid-scale energy storage applications. Declining battery costs are both a challenge as well as an opportunity for energy utilities. Since 2008, battery costs have declined by 73% to US$230 per kilowatt hour (kWh) in 2016. Some industry forecasts suggest that the cost of EVs will fall to match those powered by ICEs by 2022 when battery costs will have further fallen to US$100/kWh. The costs of stationary use could fall by another 66% by 2030. A new generation of batteries with a much longer range and shorter charging times is expected to become commercialised in the early 2020s.

If batteries are becoming a cheap storage option for private and industrial consumers and are built into intermittent solar and wind power stations of the electricity system - as an integrated part build-in retrofitted storage option - countries and utilities no longer need conventional backup capacity by traditional coal and gas power plants.

China not only matters as the world's largest EV market but is also as the globally largest battery producer with 59% in 2018 (projected to rise to 73% by 2021). It would create new critical dependencies for the European carmakers for years if not decades due to the unwillingness to create its own battery production in Europe. In addition, as metal prices for years have been determined by China's industrial demand, the world stocks of industrial metals have become very dependent on China's future industrial and technological developments as well as their raw material demand.. The rising dependence on the development of China's EV and battery markets is aggravated by an equally rising dependence on Critical Raw Materials (CRMs) such as rare earth and other CRMs, which are mainly under Chinese control. China is also acquiring strategic control over global lithium, cobalt and CRM markets.

As China has scaled back its car subsidies, it has become unclear how fast the worldwide electric mobility – and, in addition to that, the production of batteries and their CRM demand - will further grow in the forthcoming years. Even if the electrification of China's transport sector may slow down for some years, the digitalisation and the battery development might fasten in other industry sectors, and, therewith, the demand for CRMs will grow.

The future chosen locations of the battery gigafactories will considerably shape the geography and geo-economics of the auto industry for the next decades. They have numerous advantages over car construction plants that have no gigafactory in their direct neighbourhood and rely on long-distance imports from Asia. The extended supply chain of those gigafactories also guarantees a large number of skilled jobs in the future. Hence, for European governments it is very alarming when its carmakers invest seven times more in EV production in China than in their home markets. A European car battery value chain alone has been estimated to be worth approximately 250 billion Euros by 2025. The European Commission has launched a 'European Battery Alliance' in October 2017 to stimulate European and Asian companies to build battery factories in Europe.

Rising Dependencies on Raw Material Supply Security

The worldwide electrification of the transport and other industry sectors, the development of a new generation of batteries for electricity storage as well as the digitalization of the industries, including the spread of robotics and artificial intelligence systems in the industry ('industry 4.0') will further boost the worldwide demand for CRMs such as lithium, cobalt and others. As a result, it might create new and unprecedented challenges, including bottlenecks and supply shortages, for the global supply chains of the CRMs on each stage ranging from mining to processing, refining and manufacturing.

The production of CRMs is geopolitically - compared with the concentration of conventional oil and gas resources - more challenging and problematic as currently 50% of CRMs are located in fragile states or politically unstable regions. Moreover, security of supply risks are not just constrained to primary natural resources and CRMs but also to the import of semi-manufactured and refined goods as well as finished products. Manipulated prices, restricted supplies and attempts at cartelization of CRM markets with wide-ranging negative economic consequences are not restricted just to producing and exporting countries. Powerful states and private companies have also been responsible for non-transparent pricing mechanisms for many precious CRMs. Global supply chains have become ever more complex due to the blurring of boundaries between physical and financial markets and weakly governed market platforms. These market imperfections lead to the manipulation of prices and threaten the stability of the future security of supply of CRMs.

Given China's status as the world's largest battery producer, and as the leading nation in the electrification of the national transport sector, it may increase the dependencies of the European and U.S. carmakers on China. The dependence on CRMs such as lithium, cobalt, graphite, rare earth and others will equally rise. Those geopolitical impacts have already been highlighted in 2010–2011, when China in the midst of escalating diplomatic conflict with Japan stopped all exports of Rare Earth Elements (REEs) to the world's biggest importer and blackmailed Tokyo diplomatically by instrumentalising its status as the world's largest producer and exporter of REEs. It has sent a troubling message to the world that the new rising Asian economic and military power might not respect international law, the existing global rules of the WTO and that Beijing may not politically be willing to accept the regional and global responsibilities that grow with its emerging superpower status. Over the last months, China has further strengthened its efforts to control the entire global supply chain of lithium, from owning international mines to the production of lithium up to manufacturing of batteries and EVs.

Their future supply security depends largely on timely investments, depending on adequate investment conditions, and alternative strategies such as (1) the re-use; (2) a reduced use; (3) substitution; and (4) recycling of CRMs. Using these strategies for reducing the rising imports of CRMs might allow a reduction of imported CRM in the longer-term perspective. These options need also to be an integral part of the development of 'circular economies' as a response strategy, which will use CRMs more economically, efficiently and environmentally friendly by reducing their mining demand in order to strengthen their security of supply.

But recycling options are often constrained due to poor data on both current and future recycling rates and an insufficient profitability for industry businesses. While substitutes are available for many applications, they are often generally less efficient and/or demand more energy in return. Western diversification strategies for diversifying production and imports of REEs have often been not really be successful and profitable during the last years.

Alternative strategies such as a diversification of future supplies (by opening new mines around the world), recycling and substitution also face various limitations and constraints: opening new mines, for instance, often requires lead times of at least 7 years, in Western countries up to 20 years with 10 years to build political and industrial consent on the infrastructure to make the mine operational. In today's world of mounting public acceptance challenges in many OECD countries, it has become ever more challenging to find investors for those long-term projects due to rising political risks of those commercial projects.

While the U.S. will be able to compete at least to some extent with China, albeit also remain dependent on Chinese battery supplies and sales, it can rely on increasing own lithium reserves on its continent. The EU, by contrast, has neither own larger lithium reserves nor established any battery manufacturing capacity up to now.

Given the EU's, the U.S. and the world's increasing dependence on CRMs in the context of their global demand rise as well as China's role as the world's largest REEs producer exporter as well as leading global role of investor, mining operator and controlling market force, it will become almost impossible to sidestep China in the global technological-industrial arms race as its combined strength is unique in the world. Furthermore, its strength does not lie just in the mining process itself, but also in its industrial policy to develop its downstream processing, technology innovation and domestic energy transformation as well as its long-term plan for acquiring strategic control of the most important CRMs. China is the only superpower (in contrast to the U.S. and the EU), which has positioned itself strongly throughout the entire clean tech supply chain, involving the most important critical raw materials and minerals. China seeks to acquire the strategic control of worldwide available REEs and other CRMs by buying into international mines and receiving majority shares. Even Greenland with its large CRMs, including REEs, has been in the strategic investment focus of China for some years. While most studies do not predict a major long-term supply-side problem of CRMs for the global markets, they mostly agree that the supply needs to be closely monitored for avoiding any short- and mid-term supply shortcomings and other problems.

While CRM producers in Africa, Latin America and the Eurasian landmass will benefit economically and financially from the global rise of CRMs, the producers and exporters of CRMs are confronted as 'rentier states' with traditional challenges of a 'resource curse' and an unprecedented international attention to the mining practices and conditions. The more the world will expand 'green technologies' and become dependent on a rising and stable supply of CRMs, the more the international focus will be directed towards their environmental standards and energy efficient production methods. Mining companies, already fearing for their international reputation, are already increasing the share of renewables in their energy mix of production and trying to reduce the accompanying negative environmental impacts.

In developed countries, the environment may become cleaner with EVs and an expanded battery use for EVs and RES. But the opposite might be true in the developing countries producing the raw materials for the rich world due to environmental and social costs. These countries may face even more water shortages, rising emissions and toxic pollution and other environmental problems, and have to cope with human rights abuses and international labour standards. Supply chains from mining to end products are often not fully transparent, despite many efforts to improve industry practice for responsible and ethical sourcing. But international certification schemes such as the 'OECD Due Diligence Guidance' and conflict-free sourcing initiatives offer instruments for more transparency and international collaboration.

Decarbonisation Efforts and Digitalisation Threatening Traditional Oil and Gas Producer Countries: Political Stability versus Decarbonisation

Present decarbonization efforts are mostly of economic, technical and technocratic-theoretical nature. They focus on demand-side management as well as on the 'greening' of the energy mix of developed countries. They mostly overlook and disregard the strategic interests of the major oil and gas producing countries as 'rentier states'. As long as their strategic interests and heavy dependence on oil and gas export revenues are not taken into account, the worldwide decarbonization will hardly fasten and implemented. The target of keeping global warming below 2°C will become more unrealistic. Overambitious decarbonization efforts may have the unintended consequence of destabilizing those 'rentier states' without offering them a realistic economic diversification and an alternative economic development.

Any major reform and change of energy policies on national, regional or global level produce winners and losers, depending on the transition period and its pace, scope and duration. In mid-term perspective, most of the world's largest oil and gas producers are still not prepared for a decarbonised world as their economies have not been diversified in times when huge revenue flows based on high oil and gas prices were available. This is, in particular, true for the 'Greater Middle East' and Gulf region, which still contains the greatest concentration of giant and super-giant oil and gas fields in the world with the most attractive oil and gas geology. While Saudi Arabia and some other Gulf states are promoting and expanding RES, those efforts are determined by their primary interest to decrease domestic oil as well as gas resources to export them - and not by an interest to support the global climate mitigation policies and any real decarbonization strategies.

With the exception of Saudi Arabia and some of the smaller Gulf states, which have both at least a strategic vision and the funds available for diversifying their economies, many other countries (i.e. Venezuela, Iraq, Iran, African producers, but also Russia) are not prepared and do not have the political will to cope with a longer period of dramatically lower oil and gas prices – and even less for a more rapid decarbonization of the world's energy mix. In this wider political context, four major conclusions can be made:

(1) The more investors will recognise fossil fuel facilities and projects as '*stranded assets*' and '*stranded investments'* , the more rapidly oil, gas and coal producing countries might expand their production and export their remaining coal, oil and gas reserves in the short-and medium-term. It will make fossil fuels ever cheaper for a longer transition period, and it could become even more difficult to achieve deeper cuts in greenhouse gas emissions (GHGE).

(2) As climate and security experts have warned for years, climate change can fuel already existing conflicts inside and between countries. But another truth is rather overlooked: More rapid decarbonisation of the world's energy supply might produce unintended regional-wide, large-scale socio-economic and political instabilities in many oil and gas producing countries, which could result in new, unprecedented refugee flows of their rapidly expanding populations (particularly from the MENA-region to Europe).

(3) Until the richer developed countries, promoting and benefitting economically from a '*global Energiewende'*, do not pro-actively offer advice and alternative economic development models and, simultaneously, engage much more in regional peace-building and political sustainability, any decarbonisation efforts might also produce much stronger political resistance and counterstrategies to the global climate policies.

(4) As long as such a broader political-economic Western assistance for many oil and gas producing countries (such as Iran, Iraq and many African states) appears hardly realistic, overambitious Western pro-climate mitigation policies may contradict their own geopolitical interests of maintaining peace and stability in their neighbourhood such as Russia and the already unstable regions of the '*Greater Middle East*' and Africa. Any larger repercussion in these regions will not only have an impact on global economic stability but also directly on Europe as its neighbouring region.

In this light, the Western developed countries need a more balanced climate policy, which also takes into account the strategic interests of the oil and gas producing countries, the present dependence of their hydrocarbon sectors as well as the challenge of oil and gas producing countries to transition to a new economic development model.

Conceptual Implications for Future Energy Security Concepts

New holistic strategies need to systematically incorporate these five new dimensions, rather than address and conceptualise them just individually and in isolation to each other. Thus challenges and supply strategies for CRMs, disruptive technologies and their wide-ranging impacts, new cybersecurity dimensions, impacts of the decarbonization on traditional oil and gas producing countries, new geopolitical dependencies as the result of the expansion of RES, and a potential higher increase of the worldwide electricity consumption need to be an integral part of those new holistic concepts in order to preserve the EU's future international leverage seeking new forms of international cooperation to avoid any new technology arms races with wide-ranging geopolitical impacts at the expense of global stability.

Despite a growing attention and general awareness of the EU about the manifold global implications of the digitalization and the adoption of disruptive technologies, the EU is being threatened to fall behind the two economic and technological superpowers of China and the U.S. Simultaneously, these geo-economic and geopolitical megatrends are also impacted by the global ascendancy of a rising number of autocratic states with a (combined) unprecedented economic power (i.e. China) and the political will to use their economic-financial soft power (i.e. Russia) to divide and weaken Western democracies. In this regard, the EU needs to define and adopt new holistic energy security concepts, and energy foreign policies that take the five analysed geo-economic and geopolitical trends in global energy security into account and formulate new comprehensive as well as sustainable energy security strategies.

1 Introduction: Digitalisation of the Energy Sector Beyond Business Models and Company Strategies

"We are moving from a world where the value of energy is embedded in the resource to where the technology is the resource."
Francis O'Sullivan, MIT Energy[1]

1.1 The Fastening Digitalisation of the Energy Industry

The fastening digitalisation, describing the widespread use of '*information and communication technology (ICT)*', new consumption patterns, providers and platforms (also coming from outside of the energy sector) are aggressively attacking and changing established industries. These changes come along at a time, when the energy sector is already undergoing dramatic changes not least due to increasing deployment of renewable energy resources (RES), rising energy demand, greater energy efficiency, disinvestment in carbon-intensive industries and the U.S. shale oil and gas revolution (together with the rapidly expanding worldwide LNG trade) with far-reaching impacts on the global oil and gas markets. The '*energy transition'* affects in particular the global electricity sector, which is transformed by the three reinforcing strategic trends of the '*3 Ds*': *decarbonisation, digitalisation* and *decentralisation*. This energy transition based on the integration of renewables and other distributed energy resources is highly dependent on fundamental reforms of current regulatory frameworks to accommodate the shifting energy supply structure at a time when daily life and public order will become ever more dependent on the stable functioning of critical (energy) infrastructures. But political decision-making and regulators are often unable to adapt quickly enough to these disruptive technology innovations in order to benefit from the new technological options such as enhancing safety, accessibility, connectivity, productivity, efficiency and sustainability of the energy transition: "*Digitalised energy systems in the future may be able to identify who needs energy and deliver it at the right time, in the right place and at the lowest cost.*"[2]

But to implement these promises will be extremely challenging as the implementation of the digitalisation and automation are already experiencing heightened energy security risks, privacy (data) questions, potential infrastructure redundancies, investment challenges and the need for new resilience concepts as well as strategies for maintaining the ever more complex system reliability of security of energy supply.[3] Increasing internet interconnectivity and a vast amount of sensitive data, as well as asymmetric conflict patterns in international

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1 Quoted following 'Clean Power is Shaking up the Global Geopolitics of Energy', Economist, 15 March 2018, here p. 4.

2 IEA, 'Digitalisation & Energy', (Paris: IEA/OECD, 2017), p. 15.

3 See Francois Austin, 'How to Solve the Energy 'Trilemma', 27 November 2017 (https://www.greenbiz.com/article/how-solve-energy-trilemma; accessed on 30 January 2018).

relations, have dramatically increased the risks and vulnerability of national and global energy infrastructures regarding sophisticated cyberattacks by services.[4] Those threats can even multiply with the next digitalisation wave in the energy sector (i.e. electricity generation and distribution), the further global expansion of RES and the electrification of the transport (i.e. rapid expansion of electric vehicles) and heating sectors. It is not least due to this development of unprecedented changes, opportunities and risks that the International Energy Agency (IEA) stated in 2017,

> "[That] every unit of the IEA – from efficiency to investment, from electricity to transportation, from renewables to modelling, from sustainability to statistics – is examining the implications of digitalisation on the energy sector. [...] The interest in this topic is strong, but the world's current understanding of the scale and scope of its potential remains limited, particularly when it comes to analytically-rigorous assessments."[5]

The EU has declared the full development of the '*Digital Single Market'* as one of the top ten priorities during President Juncker's mandate. It will also facilitate the clean energy transition in the EU and make the EU energy sector more stable, competitive and sustainable for the 21st century. Without expanded and effective digitalisation, the energy sector will not be able to achieve its ambitious objectives for enhancing energy efficiency, reducing Greenhouse Gas Emissions (GHGE), improving quality, decarbonizing the energy mix of production and consumption as well as reducing the overall energy costs for private and industrial consumers. Digitalisation and other technology developments allow better decentralisation and distribution, the use of access to renewables; and to link them with smart grids (i.e. 'microgrids') and smart metering technologies ('*smart meter data hubs*') as well as new battery storage solutions. German utilities, for example, are striving to become consumer-centred and service-based organisations, but their actual market share in the digitalised retail market is still very small. New business models need to be developed to the '*3 Ds'*. For those energy utilities, the major challenge is not just the digitalisation itself, but the interlinkage with the other two '*Ds*' and its impacts on the markets, and smart home market and implications for their own future business models and business development strategies. Furthermore, expanded robotics and AI promise that half of the activities (not jobs), carried out traditionally by workers, can be automated. '*Deep learning*

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4 Vgl. F. Umbach, 'Critical Energy Infrastructure and Risk of Cyber Attack', in: KAS-International Reports, September 2012, pp. 35-66; idem, 'Cyber Security – Dossier', Geopolitical Information Service (GIS - www.geopolitical-info.com), August 2013; idem, 'The Fog of Cybersecurity", Geopolitical Intelligence Service (GIS), 10 July 2017; and idem, 'Schutz kritischer Infrastrukturen im Zeitalter von Cybersecurity' ('Protection of Critical Infrastructures in the Age of Cybersecurity'), Mittler-Brief 2/2017.

5 Vgl. IEA: https://www.iea.org/newsroom/news/2017/april/iea-examines-critical-interplay-between-digital-and-energy-systems.html

systems' are using artificial neural networks and real-time data can predict demand trends on a hyper-regional basis.[6] The loss of jobs rather than any benefits dominate most of the perceptions of AI in Europe, albeit the EU knows it needs to expand its own AI capabilities in the global competition. The need for constant learning and training the workforce has been recognised as a pre-condition for adapting AI, but companies are still struggling with the challenges and their changing structures as well as business strategies.[7] Moreover, the growing data protectionism may not only hinder Europe to compete successfully with the U.S. and China. The restrictions of the international transfer of data it might also hamper global businesses on all sides.[8]

The introduction of the blockchain-technology is another example being symptomatic for the perceived contradicting implications for the energy and other sectors (i.e. financial one).The blockchain technology is a digital ledger system that records online transactions and is based on decentralised, commonly used databanks, in which sender and receiver of a transaction are directly interlinked and intermediary actors as '*trusted third parties'* are no longer needed. Thus the blockchain-technology would allow producers to sell their oil, gas and electricity to consumers directly, which threaten traditional midstream companies and other intermediaries with their survival. The perceived disruptive technology also promises massive changes in the energy sector[9] particularly in the value chains of trade, distribution, retail and grid as well as decentralised markets of production and consumption ('*prosumer*') to streamline financial processes and to cut back-office costs by removing middlemen and invoicing from many transactions. It might even threaten the existence and important role of distribution of network operators.[10] But instead of perceiving the blockchain technology as a threat to their role and overall importance, network operators should become an integral part and play an active role in the)se digital projects. The blockchain technology may even threaten principles of political and corporate governance as they are a decentralised (distribution) functional rather than hierarchical mechanism.[11]

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6 See also Richard Waters, ''Deep Learning' - the Hot Topic in AI', Financial Times (FT), 14 May 2018.

7 See also Patrick McGee, 'Auto Bosses Accused of Failing to Train Workers for AI Revolution', FT, 17 June 2018.

8 See Alan Beattie, 'Data Protectionism: The Growing Menace to Global Business', FT, 13 May 2018; McKinsey Global Institute, 'AI, Automation, and the Future of Work: Ten Things to Solve for, Briefing Note Prepared for the Tech Good Summit, Organized by the French Presidency, June 2018, and McKinsey&Company, 'The Real-World Potential and Limitations of Artificial Intelligence', Mc Kinsey Quarterly, April 2018..

9 BP together with the Italian oil major Eni and Wien Energie of Austria are experimenting in a pilot programme with trading systems to explore the practical implications of the technology in the energy sector – see Andrew Ward, 'BP Experiments with Blockchain for Oil and Gas Trading', Financial Times (FT), 3 October 2017.

10 See Marius Buchmann, 'Blockchain Technology – a Threat to Distribution Network Operators', Energpost.eu, 28 June 2018.

11 See Henrique Schneider, 'Blockchain as a Principle of Governance', GIS, 11 May 2018.

The technology has even been considered as a safe alternative mechanism to weak state institutions, particularly in emerging and developing countries as they promise security and transparency without any subordinate authority.[12] But the blockchain developing companies are still struggling to solve the three critical issues of scalability (as a single piece of software risks bottlenecks and slow calculations), privacy (versus commercial interests) and standardisation in addition to the technical implementation into the energy sector.[13]

1.2 Geopolitical Implications

The energy transition to a low carbon energy system and ultimately to a non-fossil fuel age as well as the digitalisation of the energy sectors are linked to the introduction of other disruptive technologies (i.e. robotics and artificial intelligence[14]). The present energy transition and the digitalisation have fuelled a global race for the best and most disruptive technologies and competition about access as well as strategic control to critical raw materials (CRMs), such as rare earth, lithium, cobalt and others. These strategic developments have wider geo-economic and geopolitical impacts and may transform international energy relations between countries and regions. For some years, China already accused acquiring worldwide (legally and illegally with all kind of instruments, including cyber espionage) the world's forthcoming technologies to transform its own economy and rival the U.S. as the world's future technology superpower.[15] The heightened competition for the global technology-industrial leadership has already led to a growing technology race between the U.S. and China, which is shaping the present and will determine future geopolitical competition between the two superpowers of the 21st century.[16] Those technology transformation could also lead to a new '*securitisation*' of raw materials alongside of the monopolisation of political *and* economic power, strengthening

[12] See Christian Hübner, 'More than Just Bitcoin. The Potential of Blockchain Technology, Using the Example of Latin America', KAS-International Reports 1/2018, pp. 64-77.

[13] See also Silvia Favasuli, 'Blockchain Developers Strive to Crack Oil and Gas Sector', www.interfaxenergy.com, Natural Gas Daily (NGD), 2 May 2018, pp. 1-2.

[14] To AI see Richard Waters, 'Why We are in Dangers of Overestimating AI', FT, 5 February 2018; 'Limiting the Downsides of Artificial Intelligence', FT, 22 February 2018; Rana Foroohar, 'How We Can Protect Workers from AI? FT Readers Respond', FT, 21 February 2018; 'The Global Policy Response to AI', FTI Consulting Inc., February 2018;

[15] See also Richard B. Freeman/Wei Huang, 'China's 'Great Leap Forward' in Science and Engineering'. NBER Working Paper, Nr. 21081, 2015; The Tech Giants Growing Behind China's Great Firewall', Stratfor.com, 6 February 2018, Philipp Staab/Florian Butollo, 'Digitaler Kapitalismus – Wie China das Silicon Valley herausfordert', Friedrich Ebert Stiftung (FES), Wiso-Direkt 3/2018; Andreas Shalal, 'Germany Risks Losing Key Technology Takeovers-Spy Chief', Reuters, 11 April 2018, and Kai-Fu Lee/Paul Trioto, 'China's Artificial Intelligence Revolution. Understanding Beijing's Structural Advantages', Eurasia Group, Sinovation Ventures, 2017.

[16] See also 'The Coming War Tech War with China', Stratfor.com, 6 February 2018; Holger Steltzner, 'Chinas Weg zur Weltherrschaft', Frankfurter Allgemeine Sonntagszeitung (FAS), 7 January 2018, pp. 19-20; Hendrik Ankenbrand, 'Ehrgeiz vernetzt Berge', ibid., 4 February 2018, p. 5.

the autocratisation of political systems inside countries as well as internationally.[17] In this context, China's world views and geopolitical strategies - such as the '*Belt and Road-Initiative (BRI')*, formerly also known as '*One Belt and Road'-Strategy ('OBOR')* -, and its nationalist tendencies in its domestic policies under President Xi Jinping are of utmost strategic importance for the West and global stability.[18]

While the EU is being threatened to fall behind these two economic-technological super-powers[19], the geo-economic and geopolitical megatrends are impacted by the global ascendancy of a rising number of autocratic states with a (combined) unprecedented economic power and the political will to use their economic-financial soft power to divide and weaken Western democracies. The share of "*not free*" and "*partially free*" countries has grown from 12% of global income to 33% nowadays – a level not seen since the early 1930s and the rise of fascism in Europe.[20]

Although not all implications for and impacts on the worldwide, regional and national energy sectors can already be identified and analysed in detail or even are fully understood, it becomes already clear that those unprecedented technological changes of the worldwide energy sectors will also have wide-ranging geo-economic and geopolitical implications. Thereby, many geopolitical implications are still overlooked as the discussions of the digitalisation alongside the other developments still centre on the economic changes, the management of the perceived short-term challenges of the energy transition to a non-fossil fuel age and the risks for traditional business models and strategies as well as company cultures.[21]

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17 See also Peter Hefele, 'Of Streams of Data, Thought, and other Things', KAS-International Report 1/2018, pp. 56-63 (58).

18 See also Martin Wolf, 'How Beijing Elite Sees the World', FT, 1 May 2018.

19 See also Matthew Bey, 'A Test of Europe's Artificial Intelligence', Stratfor.com, 12 April 2018.

20 See alsoYascha Mounk/Roberto Stefan Foa, 'The End of the Democratic Century', Foreign Affairs, 16 April 2018, here p. 2.

21 See also Diane Coyle, 'The Digital Economy Is Disrupting our Old Models', FT, 25 April 2018; Michael Pooler, 'Robot Army Is Transforming the Global Workplace', FT, 20 November 2017; Helmut Edelmann/Robert Jung/Dominic Nailis, 'Das Veränderungspotenzial digitaler Technologien in der Energiewirtschaft', Studie von Ernst & Young GmbH/BET, 2018; David G. Victor/Kassia Yanosek, 'The Next Energy Revolution. The Promise and Peril of High-Tech Innovation', Foreign Affairs, July-August 2017; Jacques Bughin et.al., 'Why Digital Strategies Fail', McKinsey Quarterly, January 2018; idem/Laura LaBerge/Anette Mellbye, 'The Case for Digital Reinvention', ibid., February 2017; Theo Schmidtner, 'Digitalisierung von Unternehmen als Road map', Energiewirtschaftliche Tagesfragen (ET), 8/2017, pp. 44-47; Gerd Pischetsrieder, 'Die digitale Transformation: Mehr als ein Technologiewandel', ET 4/2017, pp. 39-42; Matthias Wissner et.al., 'Strategien in der Zusammenarbeit zwischen Energie- und TK-Unternehmen', ET 1-2/2017, pp. 85-87; Megan Richards, 'What Does Digital Mean for the Future of the Energy Sector', CEEP-Newsletter 3/2017, p. 2; Peter Stewart, 'Companies Need to Get Wise to Smart Power Systems', www.interfaxenergy.com, NGD, 1 June 2017,p. 6, Eniz Gezgin et.al., 'Digital Transformation: Raising Supply-Chain Performance to New Levels', McKinsey & Company, November 2017, and Robin Wiggesworth, 'Can Big Data Revolutionise Policymaking by Governments', FT, 31 January 2018.

Figure 1: Recent and Forthcoming Changes of the Global Energy Sector

Energy market changes and impacts

Recent changes in global energy markets	*Forthcoming changes due to:*	*Impacts*
• Expansion of renewables	• Electrification of the transport and heating sectors	• Energy prices and competition between fossil fuels and renewables
• Energy efficiency technologies and strategies	• Digitalization – Energy utilities and electricity/power sectors (smart grids, smart metering, internet of things/smart home etc.) – Fossil fuel production	• Additional rise of worldwide and European electricity demand (already growing much faster than global primary energy consumption)
• Decarbonization/disinvestment in fossil fuels	• Blockchain technology	• Increasing need for battery or other storage solutions
• U.S. shale oil and gas revolution	• Decentralization	• Rising cyber risks and vulnerabilities of critical energy infrastructures due to internet linkages and digitalization
• LNG revolution	• Battery storage solutions	• Socioeconomic and political stability of oil and gas producers
• Rising cyberattacks on critical energy infrastructures	• Quickening decarbonization	• Risks and vulnerabilities of the rising critical raw material demand for supply security
• Decreasing public acceptance of energy infrastructure investments (i.e. in fossil fuels)		

Source: Dr. Frank Umbach

GIS GEOPOLITICAL INTELLIGENCE SERVICES www.GISreportsonline.com

Source: Dr. F. Umbach/GIS 2018

As the clean energy developments and the other new technology trends of '*industry 4.0*', big data and smart cities (alongside of the worldwide urbanisation) all need more than ever an increasing stable supply of CRMs (i.e. rare earth, lithium, cobalt, palladium, platinum etc.), challenges of raw material supply security and its current dependency on only a few extracting and producing countries and companies (also compared with conventional oil and gas producers) will become increasingly interlinked with the future concepts of clean energy supply security.[22] In this context, it matters that China has very strategically planned all kind of up- and downstream clean energy projects by taking various supply chains from R&D to the raw material basis, production capabilities to the consuming markets in foreign countries into account.[23]

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22 Daniel Scholten and Rick Bosman in their analysis of 'Geopolitics of Renewables' stated in regard to rare earths and those CRMs: *„While these minerals might form a bottleneck, it should be noted that it concerns input for a piece of technology, which when installed produces energy for several decades. As such, it is a very different challenge than securing a constant flow of energy commodities, which is the case in a fossil fuel dominated energy system"* – idem, 'The Strategic Realities of the Emerging Energy Game – Conclusions and Reflections', in: Daniel Scholten (Ed.), 'Geopolitics of Renewables'. Lectures Notes in Energy, Vol. 61 (Cham: Springer, 2018), pp. 307-328 (313 f.). While I basically agree with both authors, one needs not to overlook that windmills and solar cells have rather short life-cycles and are being replaced with successor models every 5-10 years. Furthermore, those CRMs and minerals are also increasingly been used for all kind of digitalisation, robotics and artificial technologies being introduced in the clean energy and other industrial sectors of the EU, the U.S. and other leading technology leaders.

23 See also the example of Chinese investments in rare earth mining in Greenland – Jesper Zeuthen, 'Part of the Master Plan? Chinese Investment in Rare Earth Mining in Greenland', in: Heather Exner-Pirot, H./, Lassi Heininen, L./Plouffe, J., 'Arctic Yearbook 2017', pp. 1-14 (https://www.arcticyearbook.com/images/Articles_2017/scholarly-

In contrast to many mainstream articles and discussions of the digitalisation of the energy and other industrial sectors focusing on internal business strategies, models and companies' cultures, the following study will focus on the analysis of the geo-economic and geostrategic impacts and implications and to which extent risks, costs and benefits of the worldwide digitalisation and technology revolutions are balanced or unevenly distributed.

Against the background of these dramatic forthcoming changes, at least five geopolitical implications of the digitalisation of the energy sector - alongside the other already impacting strategic energy developments - can be identified on the global and regional levels:

(1) A further rising electricity demand, which has already been forecasted to grow much faster than the overall primary energy demand on national, regional and global levels. While the digitalisation might also promise new energy efficiency gains and energy conservation, many newly introduced and identified new technologies have proved to be very energy intensive and might lead to even higher electricity demand.

(2) As electricity supply, alongside expanding volatile renewables and advancements of battery storage technologies, becomes ever more important for the future energy supply security as much as traditional energy supply security of oil and gas resources, the need for storing electricity for a stable electricity supply will become ever more important. Advancing technologies for battery storage may cause one of the most disruptive changes and a major game changer in the power and renewable industries.

(3) Despite of a more decentralised energy production and distribution, the more the energy sectors will be interconnected by renewable-based electricity generation, smart meters and smart grids, the electrification of the transport and heating sectors, the internet of things (and applications) and critical (energy) infrastructures (CEIs), the more vulnerable the energy sectors become towards sophisticated cyber-attacks and blackmail attempts to disrupt a stable supply of electricity and sensitive communication flows to operate and maintain the functioning of CEIs.

(4) Renewables are often considered as indigenous energy resources, which – in contrast to fossil fuels - do not need to be imported from other producing countries, often being politically unstable. The myth suggests that renewables do not cause any inherent risks and vulnerabilities, but rather decreases import dependencies from politically unstable producers and, thereby, increases supply security. However,

articles/17_Part_of_the_Master_Plan.pdf), and Anna-Katarina Gravgaard, 'Greenland's Rare Earths Gold Rush', Foreign Affairs, 28 October 2013.

renewables, batteries and other '*green technologies*', including further digitalisation, artificial intelligence (AI) systems and robotics, need many CRMs (i.e. rare earth, lithium, cobalt, platinum and others). Their production is often concentrated in few countries (i.e. China has a 90% production and export monopoly of rare earth) and huge mining companies.[24] A stable supply and rise of global demand may have wide-ranging geo-economic and geopolitical implications – particularly when future economic and military superpowers such as China will have the combined capability of being one of the future technology and R&D leaders of AI having available the much needed CRMs as well as the production capabilities to dominate the worldwide demand and value chains of their supply.[25]

Hence, non-energy resource security will become a major dimension in global energy security in the future. These challenges not only require a comprehensive discussion of national energy systems but also more multilateral cooperation on regional and global levels to avoid new antagonistic conflict patterns and geopolitical rivalries.

(5) While a dramatic collapse of prices for solar and wind power as well as the electrification allow faster decarbonisation of the energy sectors worldwide, fossil fuels will still have to play an important role to play for stable energy supply. However, as the world no longer may have to cope with any shortages of oil, gas and coal resources in regard to a declining global fossil fuel demand, a rapid decarbonisation may challenge the social-economic, and political stability of many oil cut gas producing countries as their economies and economic development strategies are dependent on stable, if not rising exports of oil and gas for their state budgets and economic developments.[26]

Purpose and Structure of the Study

While almost all analyses of the digitalisation of the energy sector have focused on the impacts on energy companies and their business models as well as strategies, this comprehensive study is one of the first one which aims at a detailed and holistic analysis on the wider international impacts and implications of benefits, costs and risks for regional and global energy security as well as geo-economic and geopolitical challenges:

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24 To the interlinkage between these new disruptive technologies and the raw material supply dependency see also Federation of the German Industry (BDI), 'Rohstoffversorgung 4.0. Handlungsempfehlungen für eine nachhaltige Rohstoffpolitik im Zeichen der Digitalisierung', Berlin, October 2017.

25 See the example of electric vehicles and electric mobility and its implications – F. Umbach, 'Four Implications of Electric Mobility', Geopolitical Intelligence Service (GIS), 2 November 2017.

26 See also F. Umbach, 'Decarbonisation and Global Instability', Geopolitical Intelligence Service (GIS), 5 September 2017.

- *Chapter 2* will address and discuss the evolving energy security concepts of the 21st century in the light of the digitalisation and new emerging disruptive technologies and their impacts. It will include analyses of the '*energy trilemma*', the impacts of the transition from '*peak oil*' to '*peak oil demand*' and the wider geopolitical implications of expanding RES. The latter also considers electrification and cybersecurity requirements as part of new energy security concepts in the light of newly emerging disruptive technologies.
- *Chapter 3* will explore the global energy megatrends and examine the strategic implications of the global transition from traditional energy scarcity to energy abundance. In more detail, it will look closer to the expansion of renewables and the decentralisation of energy supply, the impact of the U.S. shale oil and shale gas revolution as well as the geo-economic and geopolitical implications of expanding natural gas and LNG for the global oil and gas markets and worldwide energy supply security.
- *Chapter 4* will analyse and debate more in depth the manifold global dimensions of the digitalisation of the energy and electricity sectors and its global impacts. It will examine the new cybersecurity challenges, the prospects of the electrification of the transport sector and the digitalisation and its impacts on energy supply security, both in the traditional oil and gas industry as well as in the rapidly changing electricity sector (including the emergence of new players) with the expanding technologies of smart meters, smart grids, and smart home appliances.
- Chapter 5 then will further focus and explore five identified geostrategic challenges of the international digitalisation in a more detailed analysis such as (1) a potential higher increase of the regional and global worldwide electricity demand, (2) rising cyber security threats and the need for critical (energy) infrastructure protection, (3) the need for advanced battery storage technologies, (4) the rising dependencies on raw material supply security, and (5) the often overlooked worldwide impacts of decarbonisation and digitalisation on the political-economic stability of traditional oil and gas producer countries.
- *Chapter 6* will shortly summarise some major findings of the study (more details will be offered in chapter 2 of summary and political recommendations) and offer some strategic perspectives for the future.

2 Energy Security in the 21 Century – Evolving Concepts and Disruptive Technologies and Their Impacts

2.1 The Concept of the '*Energy Trilemma*'

During the last decade, a number of geopolitical developments ranging from to the Arab spring revolutions and the nuclear catastrophe in Fukushima in spring 2011 as well as Russia's annexation of Crimea and the occupation of Ukraine's eastern region by Russian-supported separatists in 2014 have all highlighted how important energy supply security is to the global economy, and how vulnerable individual states, as well as consumers, can be to supply disruptions and energy price shocks. At first glance, this appears simply as a function of the growing imbalance in the supply of and demand for energy world-wide. But energy supply challenges also reflect the dependence of OECD countries on politically unstable suppliers like the Middle East or perceived unreliable exporters like Russia.

Traditionally, energy security had been defined as "*the availability of energy at all times in various forms, in sufficient quantities, and at affordable prices*" in the 1980s and 1990s. But with the rising importance environmental and climate protection, the IEA had redefined energy security after 2001 as "*the uninterrupted physical availability at a price which is affordable, while respecting environment concerns*".[27] But '*sufficient quantities*' and '*reasonable*' or '*affordable prices*' have remained rather vague terms and thus 'energy security' has still not precisely been defined. For measuring '*energy security'*, more and more indicators have been created and framed in new complex energy security concepts.[28] In the light of the recent economic-financial crisis since 2008 and the need for timely and sufficient investments in new energy sources and infrastructures to cope with the dual challenge of global energy supply security as well as climate change, the IEA, for instance, has also differentiated between short-and long-term energy security.[29]

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27 So the definition of 'energy security' by the International Energy Agency (IEA): http://www.iea.org/subjectqueries/keyresult.asp?KEYWORD_ID=4103.

28 See also Löschel, A./Moslener, U./ Rübbelke, D.T.G, 'Indicators of Energy Security in Industrial Countries'. Energy Policy 38, 2010, pp. 1665-1671, and idem, 'Editorial: Energy Security – Concepts and Indicators', ibid., pp. 1607-1608; Marilyn A. Brown/Yu Wang/Benjamin K. Sovacool/Anthony Louis D'Agostino , 'Forty Years of Energy Security Trends: A Comparative Assessment of 22 Industrialized Countries', Energy Research & Social Science 4/2014, pp. 64-77, and F.Umbach, 'The Intersection of Climate Protection Policies and Energy Security", Journal of Transatlantic Studies, Vol. 10, N. 4, December 2012, pp. 374-387.

29 See the present definition of 'energy security' by the IEA: "*long-term energy security mainly deals with timely investments to supply energy in line with economic developments and environmental needs. On the other hand, short-term energy security focuses on the ability of the energy system to react promptly to sudden changes in the supply-demand balance*" - http://www.iea.org/topics/energysecurity/ (downloaded on 30 March 2018).

Moreover, '*energy security*' has always had a different meaning depending on the perspectives from producer, consumer and transit states. Whereas consumer nations like EU countries are primarily interested in the security of supply, producer countries like Russia are more focused on 'security of demand' from foreign markets. Transit states like Ukraine and Turkey are often interested both in their own national security of supply from *and* demand security of neighbouring markets in order to benefit from stable and higher transit fees. The concept of 'national energy security' also depends on the individual countries' geographical location, domestic policies and the traditional state, economic and business ties it maintains with foreign partners.[30]

Since the end of the 1990s, international energy experts have stressed the increasing strategic importance of energy supply security as part and within the 'energy triangle' with its three major objectives: economic competitiveness, environmental/ climate sustainability and energy supply security. The Asia Pacific Energy Research Centre (APERC) has introduced in 2007 the concept of *"four As of energy security"*: *availability, accessibility, affordability and acceptability*.[31] But the concept has not solved the different interpretation of the '*4 As*' as energy security "*means different things in different situations and to different people*" nor can a general concept of energy security list all possible risks and vulnerabilities.[32] The complex multi-dimensional nature of energy security goes beyond often oversimplified concepts of '*energy self-sufficiency*' and '*energy independence*'.[33] A more workable specification may at least answer the following three questions: (a) Security for whom?; (b) security for which values?, and (c) security from what threats?[34]

Many energy security experts see the biggest challenge in maintaining the balance between the three or four objectives of the '*energy triangle*' or '*energy trilemma*' instead of favouring one at the expense of the other two or three. Otherwise, neither national nor regional or global energy security can be guaranteed.[35] Due to the interrelationship of improving energy (supply) security and mitigating climate change, for instance, both policy objectives can conflict with each other: on one side, the expanded use of domestic coal as the

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30 See F. Umbach, 'Energy Security in Eurasia: Clashing Interests', in: Dellecker, A./Gomart, T. (Eds.). Russian Energy Security and Foreign Policy (Abingdon-New York 2011: Routledge 2011, pp. 23-38 (25 f.).

31 See APERC, 'A Quest for Energy Security in the 21st Century: Resources and Constraints, Institute of Energy Economics, Japan, 2007.

32 Aleh Cherp/Jessica Jewell, 'The Concept of Energy Security: Beyond the four As', Energy Policy 75/2014, pp. 415-421.

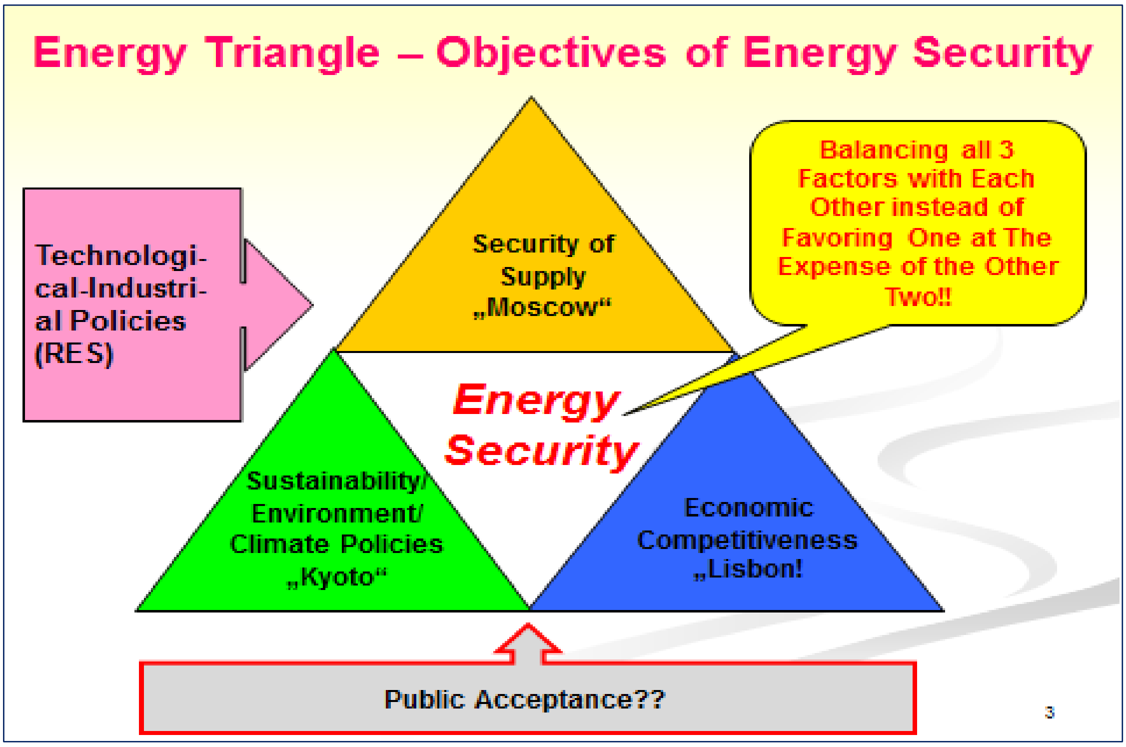
33 See Evan Hillebrand, 'What Is Energy Security? Definitions and Scenarios', 3 March 2016 (https://judithcurry.com/2016/03/03/what-is-energy-security-definitions-and-scenarios/; accessed: 20 March 2018).

34 See Aleh Cherp/Jessica Jewell, 'The Concept of Energy Security'.

35 See F. Umbach, 'The Intersection of Climate Protection Policies and Energy Security', and idem, 'The Future Role of Coal: International Market Realities vs. Climate Protection?', EUCERS-Strategy Paper Six, King's College, London, May 2015.

worldwide biggest emitter can strengthen energy supply security and bolster economic competitiveness as the cheapest fossil fuel, but will increase CO_2 emissions and fasten climate change. On the other side, reducing national emissions by 5% through a switch from coal to gas (in particular pipe-based) can have negative impacts on energy supply security and economic competitiveness of economies and national enterprises.[36] Thus the EU's common energy policies have been criticised of paying not sufficient attention to the global energy supply challenges and those of preserving the economic competitiveness.[37]

Figure 2: Energy Triangle and Objectives of Energy Security



Source: Dr. Frank Umbach

In addition, maintaining the balance between all three objectives of the '*energy triangle*' has become even more difficult by new industrial policies subsidizing RES like in Europe (i.e. Germany) or promoting unconventional oil and gas exploration in the U.S. But the biggest challenge for European and other governments today is public acceptance in the light of increasing NIMBY-attitudes, ideological positioning and new vested interests. In the political reality on both sides of the transatlantic, the three objectives very often compete with or even contradict each other, creating an unstable 'energy trilemma' instead of a balanced 'energy triangle.[38]

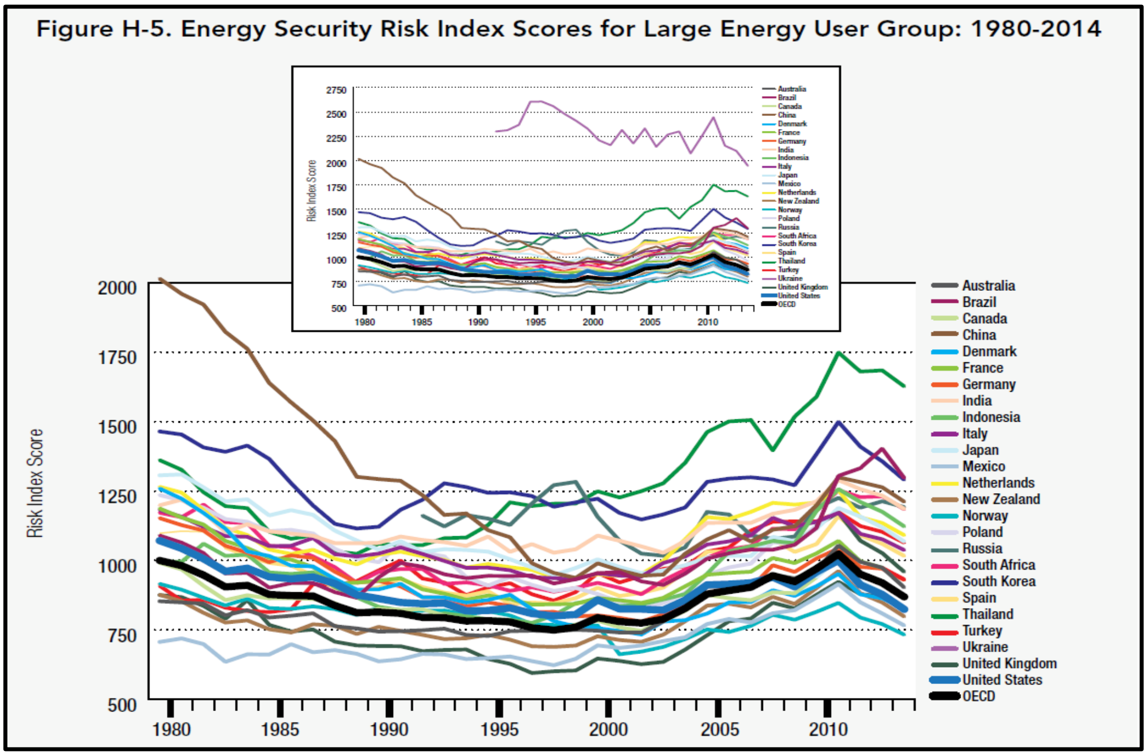
36 See International Energy Agency (IEA), 'Energy Security and Climate Policy. Assessing Interactions' (Paris: IEA, 2007), pp. 18, 102 ff.

37 See also F. Umbach, 'Global Energy Security and the Implications for the EU', Energy Policy, Vol. 38, Issue 3, March 2010, pp. 1229-1240.

38 See also World Energy Council (WEC)/Oliver Wyman, 'World Energy Trilemma Index 2017', London 2017.

Due to the U.S. '*shale oil and gas revolution*' and its global impacts on oil and gas markets, the energy security risks of at least 25 analysed large energy consuming countries have overall decreased, and their energy supply security has improved from 2010 of 2014. However, a closer look also highlights that the situation is still different between and within regions as well as in each energy security categories (oil, gas, coal, electricity). Natural gas import risks have remained very high in Europe (i.e. Ukraine), Japan and South Korea in this period. No country scored well in every energy risk category but did poorly in every category either.[39]

Figure 3: Energy Security Risk Index for 25 Large Energy User Countries 1980–2014



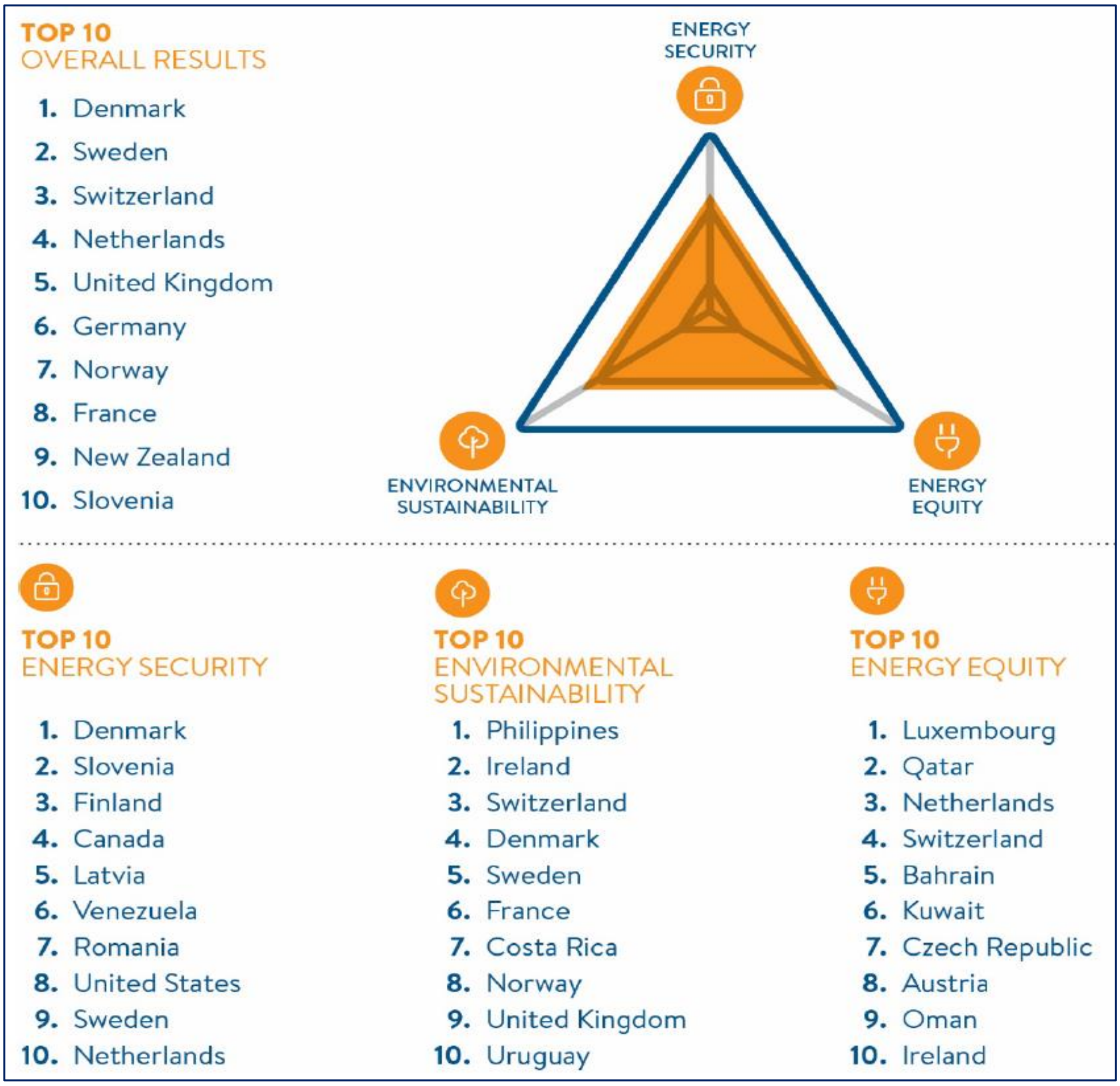
Source: Institute for 21st Century Energy/U.S. Chamber of Commerce 2016.

The World's Energy Council's (WEC) annual '*World Energy Trilemma Index 2017*' report, profiling 94 WEC member countries, also confirm some basic positive trends. Access to electricity and clean cooking have both significantly increased from 7% to 87% and 75% respectively, while renewables have increased their share up to 19.3% of final global energy consumption worldwide in 2015.[40]

39 See Institute for 21st Century Energy/U.S. Chamber of Commerce, 'International Index of Energy Security Risk - 2016 Edition, Washington D.C. 2016. To the background also see Spanish Institute for Strategic Studies, 'Energy and Geostrategy 2016. Spanish Committee of the World Energy Council/Spanish Energy Club/Ministry of Defence, Madrid 2016.

40 See again WEC, 'World Energy Trilemma Index 2017', pp. 5 ff.

Figure 4: TOP 10 Energy Trilemma Index Performers Overall and Per Dimension



Source: WEC/Oliver Wyman 2017.

In contrast to these rather objective analyses, the perceptions of political leaders and industrial executives can differ. An opinion poll of '*McKinsey's Global Survey on Globalisation*' of May 2016 concluded a perceived rise of numerous geopolitical risks and instabilities in the forthcoming years.[41]

In this context of an already rapidly changing global environment with perceived rising geopolitical risks, the digitalisation of the worldwide energy sector offers both new opportunities and challenges.

41 See McKinsey&Company,'Geostrategic Risks on the Rise', May 2016.

2.2 From '*Peak Oil*' to '*Peak Oil Demand*'

"The Stone Age came to an end, not because we had a lack of stones, and the oil age will not end because of the lack of oil"
Sheikh Ahmed Zaki *Yamani*, former Saudi Oil Minister in 2000[42]

The old oil era was characterised by a continuously rising global oil demand due to emerging markets (i.e. China) and a conventional oil production rise with new investments in ultra-deep offshore fields (i.e. Brazil's sub-salt fields), remote areas (i.e. Arctic, Siberia) and Canadian oil sands. Those projects have all been high-cost oil production options. But within few years, the combined conventional and unconventional U.S. oil production almost doubled from slightly over 5 million barrels per day (mb/d) in 2010 to 9.4 mb/d in 2015 almost half of Saudi Arabia's production at a cost range between US$40-80 per barrel, depending on the various reservoirs and regions. Since 2015, more than half of the total U.S. crude oil production has come from tight shale oil.[43] Since the lift of a 40-year old export ban in December 2015, the U.S. has exported its shale oil to 33 countries – with Asia becoming a major buying market - despite it is still a net oil importer. U.S. oil exports climbed up to a record of 7.3 mb/d in December 2017.[44] Around 12% of the U.S. crude oil exports are already shipped to Europe.[45]

While the old conventional oil era was based on an oil price above US$100 and with OPEC and Saudi Arabia being the global oil price setter, the U.S. shale oil production has become a new global price setter, translating into a new oil era.[46] While much lower oil prices are benefiting consumers and importing nations, they are hurting high-cost producer companies and countries – in particular, those, whose state budgets are highly dependent on oil export revenues and which have a less diversified economy.

In addition and in a mid-term perspective, the decarbonisation of the world's fossil-fuel-based energy system, the electrification of the transport and the heating sectors as well as the digitalisation, automatisation, big data, artificial intelligence and other technology innovation such as '*digital oil fields*' could further destabilise many oil as well as gas

42 Quoted following 'Clean Power is Shaking up the Global Geopolitics of Energy', Economist, 15 March 2018, here p. 4.

43 See also F. Umbach, 'Does OPEC Have a Future? OPEC versus US Shale Oil Revolution', in: European Security & Defence (ES&D), August 2017, pp. 22-25, and idem, 'The Future of OPEC', in: Geopolitical Intelligence Service (GIS), 29 November 2016.

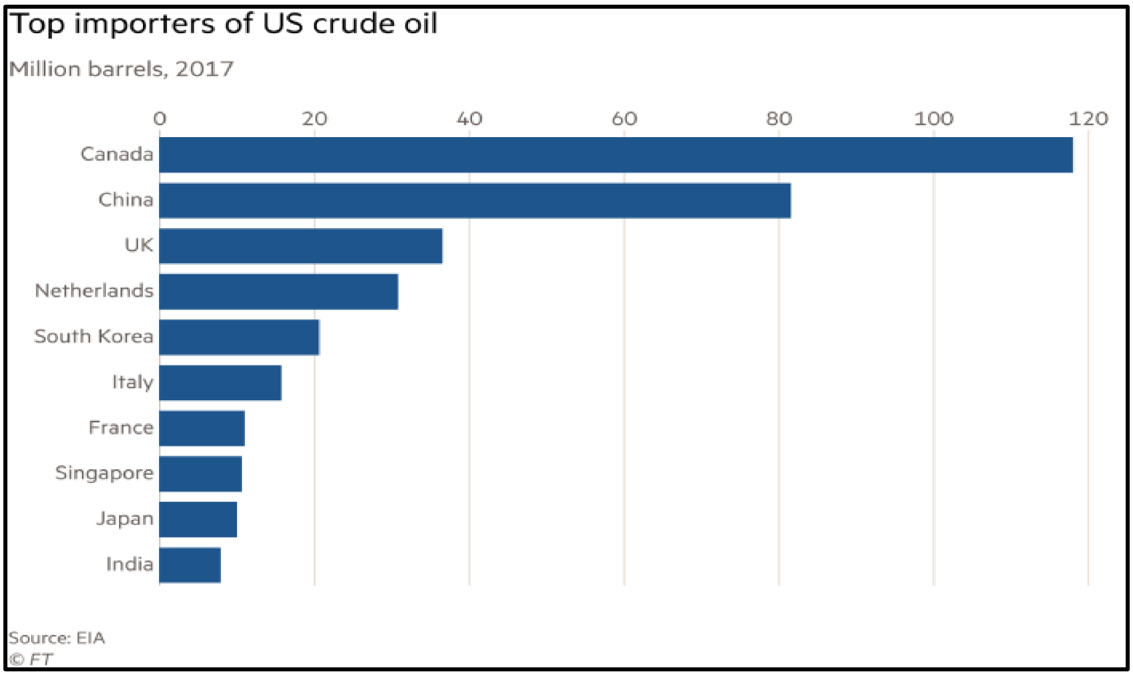
44 See also Carole Nakhle, 'Increasing Oil Competition in Asia', GIS, 27 March 2018 and Gregory Meyer, 'US Oil Pipelines Pivot South as Shale Surges', FT, 6 March 2018.

45 See Olga Yagova, 'Trump's Revenge: U.S. Oil Floods Europe, Hurting OPEC and Russia', Reuters, 23 April 2018.

46 See also Ed Crooks/Anjli Raval, 'Energy: The Indispensable Country', Financial Times (FT), 15 July 2014; Robert Rapier, 'Peak Oil and Peak Demand Have Entirely Different Outcomes', Forbes, 15 August 2017, and Ed Crooks, 'The US Shale Revolution. How It Changed the World (and Why Nothing Will Ever be the Same)', FT, 24 April 2015.

producing countries and regions if the oil demand and prices will fall once again.[47] While Arab countries can produce oil for just US$10-12 per barrel, they need more than US$60 per barrel to balance their state budgets.[48]

Figure 5: U.S. Oil Export Destinations in 2017 (in million barrels)



Source: FT 2018

Experts meanwhile are discussing a future '*peak oil demand*'-scenario; the projected future decline of the worldwide oil consumption is not so much the result of a declining oil production due to geological conditions of an increasingly scarce resource, but rather due to a declining demand and new technological factors leading to the expansion of alternative energy resources, in particular in renewables).[49] The U.S. shale industry has remarkably improved further its overall production efficiency during the last years and could constantly produce more barrels and gas out of the same investment.[50]

While the oil prices have increased to more than US$75 per barrel in the early summer of 2018, the volatile oil price development is expected to continue in the years and decades ahead. But even in the short term, the global oil price development could also fall again to US$30-40 per barrel in the next years as the U.S. oil production (not affected by any negotiated OPEC oil production cuts) will further increase, when OPEC will be unable to

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47 See also Ed Crooks, 'Boom Times for US Shale Oil Producers', FT, 4 March 2018.

48 See also F. Umbach, 'Geopolitische Auswirkungen des Ölpreisverfalls – Gewinner und Verlierer', in: Europäische Sicherheit und Technik (ES&T), December 2017, pp. 21-24, and idem, 'Decarbonisation and Global Instability', GIS, 5 September 2017.

49 See also Robert Rapier, 'Peak Oil and Peak Demand Have Entirely Different Outcomes', Forbes, 15 August 2017.

50 See Ed Crooks, 'Boom Times for US Shale Oil Producers'.

agree on a sufficient oil production cut and geopolitical conflicts decrease (U.S.-Iran, Iran-Saudi Arabia, Syria, Libya etc.) as well as Venezuela can increase its oil production.[51] For OPEC – due to its competing national interests within the cartel – it might become even more difficult to implement any new production cuts. Furthermore, if geopolitical conditions will improve, other oil producing countries such as Iran, Iraq, Nigeria and Iraq are able to boost their oil production significantly. In the mid-term perspective, OPEC and the other non-OPEC oil producers will produce as much as they can before climate change concerns and the energy transition to a non-fossil fuel age will lead to a peak of oil consumption, making the 'lower-for longer'-thesis irreversible.[52]

OPEC operates as a price cartel to coordinate the member states' oil policies to ensure steady income and oil market stabilisation. But it has always been Saudi Arabia as the dominate producer, that had the most geo-economic influence on world oil markets. So far the Saudi oil price strategy for collapsing the US shale oil production has largely failed. In the old oil era, Saudi Arabia was not just the worldwide biggest producer and exporter; it also held the largest spare capacity as '*the nuclear weapon in the global oil market*'.[53] It gave Riad - as the world's largest exporter with a global oil market share of 15% - an unrivalled influence in the old world oil order.[54] But in June 2018, the global spare capacity has been melting down to just 3.4 mb/d and is being considered as insufficient in regard to the rising global oil demand of more than 99 mb/d in 2018 (which demands a spare capacity of at least 5 mb/d). With almost two-third (2.02 mb/d) of the total OPEC spare capacity held by Saudi Arabia, the presently increased OPEC production of 1 mb/d and confronted with an escalating US-Iran conflict and new U.S. sanctions towards Teheran, it might leave the global market with less than 1 mb/d of total spare capacity to meet all other contingencies. Moreover, any maximum production needs some preparation in advance, questioning any quick production increases when new geopolitical conflicts will arise and escalate.[55]

Furthermore, Riad's role of an oil producer acting unilaterally within OPEC and the world's traditional '*swing producer*' and '*central bank*' of global oil supply has increasingly undermined OPEC's role as a price cartel. Since 2014, Riad has been less willing to

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51 See also 'Oil at $30/b Oil next Year if OPEC Fails to Deepen Cuts, IAEE Conference Hears', S&P Global Platts, 19 June 2017.

52 See also Christyan Malek, 'Lower for Longer' for the Oil Price Is Just Taking a Pause', FT, 11 June 2018 and David Sheppard/Anjli Raval, 'Oil Producers Face Their 'Life or Death' Question', FT, 19 June 2018.

53 See also F. Umbach, 'Globale Energiesicherheit. Strategische Herausforderungen für die europäische und deutsche Außenpolitik', Berlin 2003, pp. 256 ff.

54 See Matthew R. Simmons, 'Twilight in the Desert. The Coming Saudi Oil Shock and the World Economy', Hoboken-New Jersey 2005.

55 See John Kemp, 'Could Saudi Arabia Replace all the Barrels lost from Iran Sanctions', Reuters, 9 July 2018; Ayenat Mersie, 'Oil Prices Gain on Supply Concerns in Iran, Libya, Canada', Reuters, 9 July 2018.

maintain that role due to both economic and geopolitical factors as the U.S has reduced its regional engagement and Saudi Arabia facing in Iran a geopolitical rival in the Middle East (i.e. Yemen, Syria). Given the disagreements even between the monarchies of the Gulf Cooperation Council about the conflicts in Yemen and Syria, the diverging geopolitical interests of OPEC's individual member countries have eroded trust within the cartel. It makes it more difficult to enforce collective decisions that are mutually beneficial in their short- and long-term interests. In March the oil cartel has revised its forecast for supply growth this year as its rivals outside the cartel adding oil supplies to the global market faster than the worldwide oil demand will increase.[56] Despite its recent collective decision to increase OPEC's oil production, Saudi Arabia has become increasingly dependent on the non-OPEC member Russia ("*OPEC+*") to stabilise the world's oil supplies as well as global oil prices. At present, Russia is still the world's largest oil producer with more than 11 mb/d ahead of Saudi Arabia, and the U.S.[57], but might lose its first place to Saudi Arabia's much larger spare capacity and the further expansion of the U.S. tight oil production.

2.3 RES and Geopolitics: Redrawing the Map of Geopolitical Power

A major argument for expanding renewables is the hope that they will substantially reduce Europe's and the world's import dependency on fossil fuels from politically unstable or unreliable producer countries (i.e. the Middle East, Africa, Russia etc.). Geopolitical risks and vulnerabilities supply disruptions have been considered as exclusively linked with fossil fuels as renewables are immaterial ("*none one can ever embargo the sun*") and available almost everywhere.[58] Their expansion has also promoted the overall decentralisation of energy supplies – widely perceived as enhancing energy security. They may not just reduce the dependence on politically unstable fossil fuel suppliers (both state and corporate), but also their political and geo-economic power in international relations. The loss of their previous geo-economic and geopolitical influence translates this into the emergence of global *'buyers' markets'* instead of the traditional *'sellers' markets.* The creation of 'prosumers' (energy consumers becoming simultaneously energy/electricity producers) and the redistribution of economic as well as political power offers new participation, investment and strategic influence to new centralised powers (i.e. internet giants such as Facebook, Amazon, Netflix, Google and others) as well as to new players on the local level as the result of the decentralised energy supplies. But it comes along with "*new, unfamiliar*

56 See David Sheppard, 'OPEC Forecasts Faster Crude Output Growth from Rivals', FT, 14 April 2018.

57 See also Tsvetana Paraskova, 'Russia Gears up to Boost Oil Production in July', Oilprice.com, 20 June 2018.

58 See also Iana Dreyer, 'Renewables: Do They Matter for Foreign Policy?', European Union Institute for Security Studies, Brief Issue, No. 23, June 2013, and Andreas de Vries/Salman Ghouri, 'Should Energy Security Go Green?', Energy Intelligence, March 2017.

supply chains from unfamiliar sources" (i.e. CRMs).[59] According to this logic, expanding RES and '*energy abundance*' will '*depoliticise markets*' by decreasing traditional geopolitical risks of supply disruptions and, therewith, enhancing national, regional and global energy supply security in our traditional understanding and defined concepts.

Hence, some new geopolitical risks of expanding renewables in a broader context are still too much overlooked or underestimated in public and political discussions:

(1) The expansion of renewables is linked with other disruptive technologies (such as smart meters, smart grids), the further digitalisation of the energy sector, the electrification of the transport and heating sectors as well as with robotics and artificial intelligence. As the future energy sector in general and the electricity generation, supply and distribution networks in particular will be linked to the internet, cybersecurity challenges in the energy sector will dramatically increase the risks of national or transnational electricity blackouts, threatening the overall functioning of all critical infrastructures, as on a stable electricity supply and a functioning access to a reliable Internet.

(2) It is indeed true that a more diversified energy mix increases energy supply security and renewables decrease those traditional geopolitical risks of supply disruptions. But it has largely been overlooked that the expansion of renewables also creates new geopolitical dependencies, risks and vulnerabilities as these resources and technologies (i.e. batteries, robotics, artificial intelligence systems etc.) are rely on a stable supply of CRMs. The challenge again is not so much a physical scarcity of those materials, but rather their concentration in production in even fewer producer countries and companies. Compared with the conventional oil and gas resources, the production of CRMs is geopolitically even more challenging and problematic – particularly when the future rise of the global demand is taken into consideration.

Geopolitical risks do not just end with decarbonisation and the end of the fossil fuel age.[60] The '*energy transition*' to a non-fossil fuel age, determined by the interplay between the geopolitics of fossil fuels and renewables in the forthcoming decades, is in particular a challenging, risky and vulnerable process.[61] In particular, a rapid energy transition is

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59 See also Walt Patterson, 'How Renewables Will Change the Geopolitical Map of the World', www.energypost.eu, 9 February 2018.

60 See also Megan O'Sullivan/Indra Overland/David Sandalow, 'The Geopolitics of Renewable Energy', Columbia/SIPA, Belfer Center/Harvard and Norwegian Institute of International Affairs (NPI) 2017; Daniel Scholten, 'Renewable Energy Security', EUCERS-Newsletter, Issue 64, April 2017, pp. 2-4; Daniel Scholten/Rick Bosman, 'The Geopolitics of Renewables: Exploring the Political Implications of Renewable Energy Systems', Technological Forecasting & Social change, 103/2016, pp. 273-283; Meghan L. O'Sullivan, 'Renewables Won't End Geopolitics of Energy', Japan Times, 24 August 2017, and Ian Morris, 'Imagining a World after Fossil Fuels', Stratfor.com, 22 March 2017.

61 See also Danuiel Reimi/Alan J. Krupnick, 'Decarbonisation: It ain't that Easy', Resources for the Future (http://www.rff.org/blog/2018/decarbonisation-it-ain-t-easy; accessed 10 April).

accompanied with a high degree of unpredictability and non-anticipated disruptive developments and implications. Thus the U.S, expert David G. Victor has noted that the present global energy transition as the result of “*tsunamis of innovation*” is challenging “*as almost every aspect of the energy system is changing simultaneously, and when complex systems change in complex ways, predictability goes down*”.[62]

While traditional supply risks such as supply disruptions due to political instabilities in producer countries or attempts for political blackmail (i.e. Russia) indeed will decrease and be marginalised in the mid- an long-term future, new geopolitical risks and vulnerabilities will arise with the expansion of renewables and the rapid introduction of new disruptive technologies (including smart meters, smart and super- as well as micro-grids etc.) in context of the digitalisation, electrification of the transport and heating sectors, robotics and artificial intelligence systems. Up to now, supporters of RES have hoped that power generation becomes more dispersed and decentralised, while regions may become more self-sufficient in energy supply, triggering a process of ‘energy democratisation’, in contrast to the traditional centralised energy systems. Enhanced energy access via mini-grids and rooftop solar panels in Africa, South Asia and other regions, has offered new energy options for reducing ‘energy poverty’ alongside of the further growth of the global population. But the changing energy systems from the traditional one coping with scarcity challenges to abundant RES will inevitably produce losers such as the leading oil and gas producer superpowers. As the Economist has concluded: “*It seems that the geopolitics of energy will develop into a contest to see which country can produce the most energy of its own, and which has the best technology.*”[63]

A US study in 2017 has identified seven major geopolitical implications of the worldwide expansion of RES, cleaner energy mixes and low-carbon energy systems:

(3) Rising dependence on critical raw materials and their supply chains as the result of the global energy transition and the worldwide race for the best technologies;

(4) New technologies and options of financing them;

(5) A new resource curse as oil and gas producing countries lose their hard currency revenues, which may lead to internal instabilities. On the other side new renewable powers and those being major raw material producing countries may also be confronted with implications of the resource curse too;

(6) A decreasing global oil and gas demand, which may either lead to growing domestic instabilities or can be a driver for economic reforms and a more diversified economies;

(7) Transnational grid networks and increasing electricity import dependencies;

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62 Quoted following Quinn Connelly, ‘Energy Transitions? Not so Fast’, RealClear Energy, 18 April 2018.

63 ‘Clean Power Is Shaking up the Global Geopolitics of Energy’, Economist, 15 March 2018, p. 3.

(8) Prevention or reduction of climate change as result of more successful global climate change mitigation efforts which can reduce conflicts and instabilities in Africa and elsewhere; and

(9) Sustainable access to modern and cleaner energy resources as well as energy technologies as a major condition for a more sustainable worldwide economic development and global energy supply security.[64]

In January 2018, a new '*Global Commission on the Geopolitics of Energy Transformation*', chaired by the former president if Iceland, Ragnar Grimsson, has been established under the auspices of the *International Renewable Energy Agency (IRENA)* to study the geopolitics of renewable energy in effectively shaping global energy diplomacy. Renewable energy resources are considered as a '*game changer*' for interstate energy relations as geographic and technical characteristics are fundamentally different from those of fossil fuels. In contrast to the ultimate finite nature, unequal geographic distribution of fossil fuels and the separation between net-exporter and net-importers on oligopolistic markets with zero-sum, inherently conflict prone energy relations, renewables are worldwide abundant, albeit intermittent, which will lead in particular to a more decentralised electricity generation. The transition to renewables and the digitalisation "*will reshape strategic realities and policy considerations*".[65] The combination of those trends suggests

> "a world centred around '*grid communities'*, make up of 'prosumer countries'. In the grid community, countries share or even jointly operate (parts of) a tightly integrated electricity network and face a make-or-buy choice depending on their national capacity to service their energy needs, options for reliable cheap imports, reliability of energy partners, and political-economic-military capabilities to get what they want in case of emergency. The grid community would be of a continental size, a supergrid of you will, due to the losses of long-distance electricity transport... In this world of grid interdependencies, geopolitical tensions are reduced but power politics is far from gone."[66]

The EU, China and the U.S. have already supported an energy transition determined by disruptive technologies and the digitalisation, given their strong presence in R&D, patents and production of renewable energy and new smart grid technologies. Only the U.S. have been able to position itself as a traditional oil and gas producer (being highly competitive on the global oil and gas markets) as well as a technical-industrial leader of RES and the digitalisation. While renewables are available in different forms, globally a much larger number of countries will become energy producers and consumers simultaneously (so-

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64 See Megan O'Sullivan/Indra Overland/David Sandalow, 'The Geopolitics of Renewable Energy', Columbia/SIPA, Belfer Center/Harward and Norwegian Institute of International Affairs (NPI) 2017.

65 Daniel Scholten, 'The Geopolitics of Renewables – An Introduction and Expectations', in: idem (Ed.), ,The Geopolitics of Renewables', Lecture Notes in Energy, Vol. 61 (Cham: Springer, 2018), pp. 1-33 (1).

66 Idem, ibid., p. 23 f.

called ‘*prosumers*’).[67] As Daniel Scholten has concluded in his comprehensive publication of 2018:

> “Renewables provide new possibilities for energy production and less geographically determined dependencies, but may well make energy relations more complex due to the inclusion of new actors and business models and the managerial demands of electricity. We believe two core characteristics stand out: renewables’ abundance and electric nature.”[68]

2.3.1 Electrification and Cybersecurity Requirements

Increasing internet interconnectivity of the energy and other industrial sectors, a vast amount of sensitive data and asymmetric conflict patterns have dramatically increased the

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[67] Daniel Scholten and his authors in ‘The Geopolitics of Renewables‘ developed four expectations:
*„**First**, a move away from oligopolistic markets to more competitive ones, i.e. a shift from strategic leverage of producers to many countries having leverage: efficient producers, large consumers, and countries able to render cheap balancing services. The dominance of oil and gas producers is furthermore eroding by risks of stranded assets due to decline in oil and gas demand. This also results in a shift in concerns about getting access to limited overseas resources, diversification policies, and strategic reserves to a strategic make-or-buy decision between secure domestic production and cheap imports, availability at the right time and price volatility, and access to biomass and more geographically bound renewable sources.*
***Second**, a shift from a focus on centralized facilities run by major energy companies to decentralized modes of generation by a new and more varied set of actors (households, businesses, and communities), enabling new business models and local empowerment.*
***Third,** the use of rare earth materials in clean tech equipment increases competition for access to these materials between countries that aspire to be industrial leaders in renewable generation technology.*
***Fourth**, the electrification of energy systems implies (a) a regionalisation of energy relations, i.e. a shift from global networks to regional grids due to long-distance losses in electricity transport and less global entangle ments in the MENA and CACR; (b) a shift in focus from continuity of commodity supply to continuity of service supply, making control over infrastructure development, operations, and regulation (and in this way energy markets) even more urgent; (c) a decline in the possibility to target single countries to interrupt delivery due to a common interest in infrastructure operations (immediate cascading effects of any interruption); and (d) the de-diversification of transport infrastructure“* – see ibid., p. 308 f.

[68] Idem, ibid., p. 313. However, traditional supply dependencies remain important for ‘geographically bound renewables‘ such as hydropower or biomass and the access to them, albeit in a regional rather than global context. The original four expectations – see footnote 16 - have largely been confirmed in Scholten’s study by analysing both the similarities and differences compared with the geopolitics of fossil fuels:
*„**Similarities** can be found in new dependencies replacing the old: the need for access to biomass and raw materials instead of oil and gas sources, HVDC interconnection instead of pipeline politics, and new industrial leaders in clean tech instead of current major oil and gas companies and associated countries. All of these new dependencies seem weaker than the old, e.g. once sufficient generation capacity has been installed, little energy needs to be imported, more meshed interconnection allows for rerouting and more trade partners, and market power is not restricted to resource rich countries.*
***Differences** can be found in the nature of the game. The merging of producer, consumer, and transit countries into a collection of prosumer countries—that can to a greater or lesser extent source their energy needs domestically, export or import excesses or shortages via a continental grid, or can provide balancing services—broaden country options to secure an affordable energy supply. The electrification of the grid combined with the emergence of microgrids and supergrids, with their various new actors, limits critical junctures and classical transportation corridors, opens new market possibilities, but also raises managerial demands for cross-border coordination. More competitive markets and frequent interactions between regional neighbors suggest less opportunistic behavior and conflict potential“* – D.Scholten/R.Bosman ibid., p. 327.

risks and vulnerability of '*Critical Energy Infrastructures (CEIs)*' due to sophisticated cyberattacks by national hacker groups, transnational crime organisations and state supported secret services.

In recent years critical infrastructures have increasingly been the target of cyberattacks. In 2009, viruses were discovered in the U.S. electricity grid that supposedly originated from China and Russia. It could have made the USA a victim of blackmail if relations between the two countries were to sour.[69] While the knowledge of writing computer viruses are expanding exponentially, many industrial computer systems that control power plants (Supervisory Control and Data Acquisition/SCADA-systems) as well as other CEIs are often old and outdated even in Western countries, making them very vulnerable to cyberattacks. As all critical infrastructures (CIs) are dependent and directly or indirectly connected to the regular internet, and dependent on a stable supply of electricity, the energy and in particular electricity sectors of highly industrialised countries are considered as the Achilles heel of their political, social and economic stability.

Almost each and every private or public service is directly or indirectly dependent on a secure power supply. The size and complexity of the physical, virtual and logical networks have soared. A result of the growing mutual dependency between different critical infrastructures, the dependency and consequences of supply bottlenecks and disruptions are generally not obvious as long as a crisis does not hit causing a total collapse in supply. However, even smaller power fluctuations, outages and interruptions can have dramatic cascading and even transnational effects that cannot always be predicted as systems become ever more complex.[70]

CEIs include installations and networks for generating electricity, but also for the extraction of oil and gas, storage and refineries, liquid gas terminals, nuclear power stations, water dams as well as transport and distribution systems. All critical infrastructures in modern industrial societies are increasingly integrated and inter-linked by two things: electricity and the internet.[71] Any longer-term disruption to electricity and/or the internet would mean that

69 See also F. Umbach, 'United States Grows More Fearful of 'War' in Cyber Space', GIS, 11 April 2013; idem, 'Pressure Mounts on China over Alleged Cyber-Attacks', ibid., 19 April 2013, and idem, 'Cyber Security Firms Uncover Threats Stuxnet to Red October', ibid., 26 April 2013.

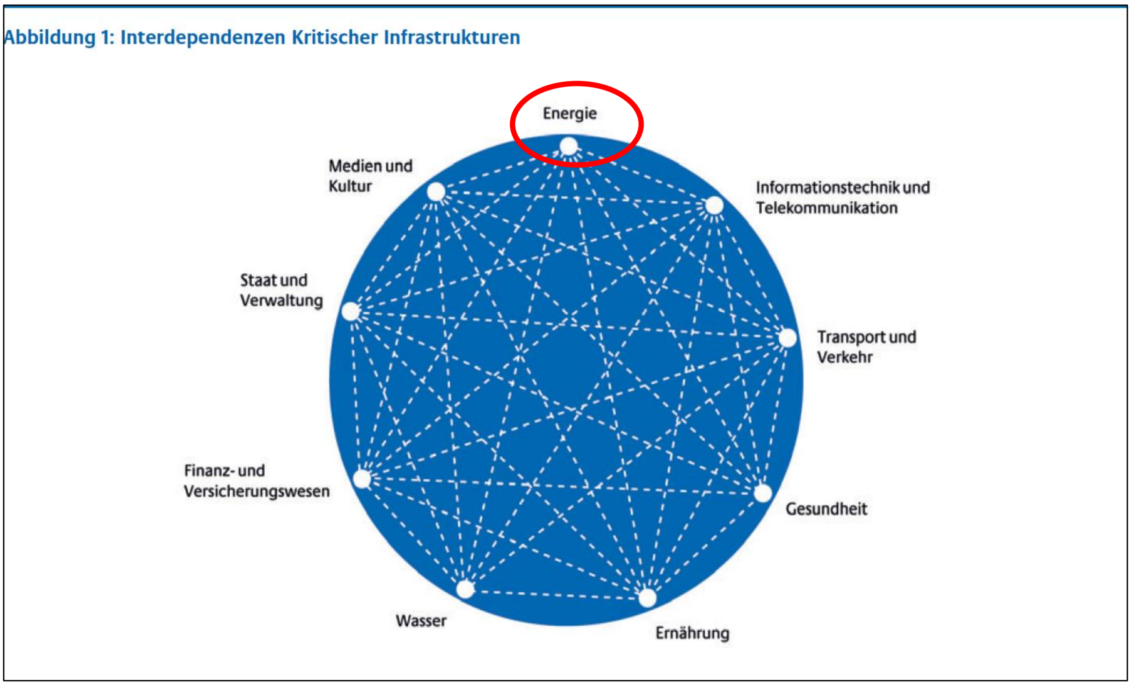
70 See also Commission of the European Communities, 'Protecting Europe from Large-Scale Cyber-Attacks and Disruptions: Enhancing Preparedness, Security and Resilience', SEC(2009)399/SEC(2009)400, Brussels, 30.3.2009, COM(2009) 149 final und F. Umbach, 'Waking Up to Cyber-Attack Threats in All Walks of Life', GIS, 13 October 2011.

71 See also F. Umbach/U. Nerlich, 'Asset Criticality in European Gas Pipeline Systems – Increasing Challenges for NATO, its Member States and Industrial Protection of Critical Energy Infrastructure', in: A.Gheorghe/L. Muresan (Eds.), 'Energy Security. International and Local Issues, Theoretical Perspectives and Critical Energy Infrastructures', NATO Science for Peace and Security Series – C: Environmental Security (Dordrecht: Springer 2011), pp. 273-303 und F. Umbach, 'Critical Energy Infrastructure Protection in the Electricity and

a country could lose essential services such as energy and water supply and thus could no longer guarantee the functioning of its critical infrastructures. The more an industrialised society and its critical infrastructures are linked to the internet, the greater its vulnerability and the potential risks it faces.[72]

Traditional whilst the industry has the experience to cope with those physical attacks. Increasing cyberattacks on CEIs present a rather new security threat, with little experiences up to now. It has fuelled a paradigm security change, in which traditional safety and security concepts are insufficient. Companies need to develop new holistic security concepts, in which safety and security will become a major management task. Only integrated comprehensive security concepts embedded in the business development decision-making and planning are able to cope with these new qualified threats.

Figure 6: Interdependencies of Critical Infrastructures



Source: Bundesministerium des Innern (BMI), Schutz kritischer Infrastrukturen. Risiko- und Krisenmanagement. Leitfaden für Unternehmen und Behörden, Berlin, Mai 2011, p. 10.

The cyberattacks against Saudi Aramco (the world's largest oil producer) and RasGas (a joint venture of ExxonMobile and the state company Qatar Petroleum), called 'Shamoon',

Gas Industries. Coping with Cyber Threats to Energy Control Centers', OSCE-CTN Newsletter, Special Bulletin: 'Protecting Critical Energy Infrastructure from Terrorist Attacks', Vienna, January 2010, pp. 25-28

72 See Thomas Petermann et al., 'Was bei einem Blackout geschieht. Folgen eines langandauernden und großräumigen Stromausfalls', Studien des Büros für Technikabfolgenschätzung beim Deutschen Bundestag, Berlin 2011.

crippled 30,000 computers of Aramco alone in the summer of 2012, whereas Rasgas was forced to shut down the company's website and some of its internal servers. In the aftermath, a national-wide investigation by a private computer security company concluded that 69% cent of all Saudi companies cannot cope with cyberattacks due to their lack of data backup operations on a daily basis.[73]

In 2010, the U.S. expert Richard Clarke warned that 20-30 countries beyond Russia, China, and the U.S., including economically and militarily much weaker powers such as Iran and North Korea, have developed offensive cyber capabilities.[74] The U.S. Defence Minister Leon Panetta called the '*Shamoon*'-cyber intrusions as "*the most destructive attack that the private sector has seen to date*". U.S. intelligence circles have blamed Iran for being responsible for the '*denial-of-service'*-cyberattacks on Saudi Aramco and RasGas by sending an endless flow of computer-generated requests aimed at overwhelming networks. US suspicion has focused on the newly created Iranian '*cybercorps*' of Iran's military – partly as a response to the U.S. and Israeli cyberattacks on the Iranian enrichment plant at Natanz, albeit its capabilities are considered far behind the U.S., Israel, China, Russia, Great Britain and others. As always in those cases, the U.S. could not made hard any evidence publicly and has offered any proof that the attacks were sanctioned by the Iranian government. But the attacks from Iran have increased both in sophistication and intensity during the last years.[75] While nuclear weapons have been considered as the '*ultimate currency of national power'*, cyber weapons are for countries like Russia, China, Iran, North Korea and others the opposite of nuclear weapons by having the following great advantages as effective tools for states of all sizes: "*hard to detect, easy to deny and increasingly finely targeted. And therefore, extraordinarily hard to deter*", and "*a way to disrupt and exercise power or influence without starting a shooting war*".[76]

The U.S. report of the cyber security company Mandiant of January 2013 has not only detailed the PLA's involvement in cyber espionage programs but also highlighted the fact that those attacks are increasingly focused on companies providing CEI, including electric power grids, gas lines and water systems. Reportedly, one target was a company with remote access to more than 60% of oil and gas pipelines in North America.[77]

At the same time, critical infrastructures must be made more robust, if it is impossible or undesirable to disconnect them from the regular internet and build a parallel intranet. In

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73 See F. Umbach, 'Cyber Attacks on Energy Infrastructures are Increasing Globally', GIS, 3 May 2013.

74 See Richard A. Clarke/Rob Knake, 'Cyber War. The Next Threat to National Security and What to Do about It' (New York: HarperCollinsPublishers, 2010).

75 See F. Umbach, 'United States Grows More Fearful of 'War' in Cyber Space', GIS, 11 April 2013, and idem, 'Cyber Attacks on Energy Infrastructures are Increasing Globally', GIS, 3 May 2013.

76 David E. Sanger, 'Why Hackers aren't Afraid of Us', New York Times (NYT), 16 June 2018.

77 See again F. Umbach, 'Pressure Mounts on China over Alleged Cyber-Attacks'.

future, redundancies and reserve capacities will more than ever be of strategic significance for energy supply security, particularly for electricity and network stability, in order to be able to cope with entirely new cyber threats and the risks of large-scale power cuts.

China, Russia, Iran, North Korea and some other countries have been suspected by western intelligence that their secret services have created a symbiotic and mutually exploitative relationship with professional hackers and crime organisations. In these countries, governmental and law enforcement agencies can't, often even less than Western states, keep up with the private sector's salaries for cyber experts. Instead, the intelligence services of these countries can offer other incentives, including legal immunity and access to information as well as a weaponisation for other cybercrime activities.[78]

The increase of state-sponsored cyberattacks has linked them more than ever with geopolitical rivalries and conflicts as well as undeclared '*hybrid*' and other asymmetrical warfare strategies.[79] Russia has used cyberattacks for years against its internal critics, It has stolen and manipulated their emails and falsified their documents in order to discredit their opponents. The scope and technique of those cyberattacks have also been a training exercise for more sophisticated and innovative attacks on the U.S. and European countries and their CIs and ICS as an instrument for its geopolitical conflict with the West.[80] Russia is accused to interfere (with hacker groups like '*APT28*', linked to its military intelligence agency GRU) in both the U.S. and French election campaigns, with massive and well-coordinated hacking operations. The Kremlin is suspected to conduct an undeclared asymmetric, hybrid warfare against Western democracies with fake news and other forms of '*desinformatsiya*'-campaigns for sowing doubt and misinformation as well as shaping new narratives in public opinion. Germany's domestic intelligence agency (BfV) and its Federal Office for Information Security (BSI) accused Russia of gathering a large amount of political data in cyberattacks on parliamentarians of the German Bundestag (lower house of parliament) during a cyberattack in May 2015. The BfV has called for legal changes to allow destroying potential dangerous servers being used by cyber hackers.[81]

North Korean linked hack groups such as '*BlueNoroff*' or '*Lazarus*' have been made responsible for other well-known cyberattacks such as the devastating attack against Sony Pictures in late 2014. Its large campaigns are often aimed at financial institutions

78 See also F. Umbach, 'The Fog of Cybersecurity', GIS, 10 July 2017.

79 See Adam Seagal, 'The Hacking Wars are Going to Get Much Worse', NYT, 31 July 2017; John Thornhill, 'The Battlefield is Everywhere in the Digital Age', FT, 24 July 2017; Kevin Townsend, 'The Increasing Effect of Geopolitics on Cybersecurity', www.securityweek.com, 3 October 2017; idem, 'Understanding Geopolitics Key to Analyzing Cyber Espionage: German Intelligence Service', ibid., 5 July 2017.

80 See also Bruce Averill/Eric A.M. Luiijf, 'Canvassing the Cyber Security Landscape: Why Energy Companies Need to Pay Attention', Journal of Energy Security, 18 May 2010.

81 See Kevin Townsend, 'Understanding Geopolitics Key to Analyzing Cyber Espionage: German Intelligence Service''.

worldwide. They are also considered as '*Advanced Persistent Threat (APT)*' actors, which are mostly financially motivated and have targeted commercial and government organisations in over 80 countries. Those sophisticated APTs are still attributed to foreign intelligence agencies and their support for non-state sophisticated hacker groups.

The worldwide increase of sophisticated cyberattacks on industrial control centres has alarmed industries, governments and cybersecurity experts alike. A national-wide electricity blackout has been considered as one of the most dangerous consequences of a cyberattack. Experts have warned for years that automated industrial systems that control critical infrastructures, such as power plants and electricity grids, are very vulnerable against cyberattacks.

Such a '*Cyber Pearl Harbour*'-scenario has been confirmed by a well-coordinated external cyberattack on Ukraine's power system and electricity grid in December 2015. It was the world's first known digital strike and cyber intrusion that caused physical disruption and widespread electricity outages for some 6 hours. The cyberattack was highly sophisticated by carefully tailoring it for causing sufficient Western attention and concern, but small enough not to escalate it with a major military response from the Ukrainian and Western side. Like in almost all of those cyberattacks, any hard evidence to support the attribution is difficult to find. It resulted in the disruption of the electricity supply of around 230,000 people, leaving 103 cities completely blacked out and another 186 cities partially without electricity.[82] In contrast to highly industrialised Western countries, Ukraine was able to restore services within 3-6 hours by switching to manual code. While the attack would have caused less damage in the West by disrupting its electricity supply, it would simultaneously be more difficult for operators to restore services since they are far more dependent on automated control systems.[83]

It also highlighted that the remote access functionality and modems are in particular unsafe as well as insecure and should be limited as much as possible. The Netherlands, for

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82 See F. Umbach, 'The Fog of Cybersecurity', p. 6 f., and idem, 'Schutz kritischer Infrastrukturen im Zeitalter von Cybersecurity', Mittler-Brief 2/2017.

83 See ibid., Olivia Brinich, 'Cyber Weapons Add Hybrid Edge to Russia-Ukraine War', 13 September 2017 (https://oliviabrinich.com/2017/09/13/cyber-is-the-new-nuclear-2/ accessed 20 September 2017); Hannah Kuchler/Neil Buckley, 'Hackers Shut Down Ukraine Power Grid', FT, 5January 2015; Jose Pagliery, 'Scary Questions in Ukraine Energy Grid Hack', www.money.cnn.com, 18 January 2016; David E. Sanger, 'Utilities Cautioned about Potential for a Cyberattack after Ukraine's', NYT, 29 February 2016, Eduard Kovacs, 'Ukraine Accuses Russia of Hacking Power Companies', www.securityweek.com, 30 December 2015; idem, 'Ukraine Power Outages not Directly Caused by Malware: Experts', ibid., 11 January 2016; idem, 'The December Attacks on Ukraine's Power Grid Were Part of a Long, Multi-Pronged Campaign that Targeted Several of the Country's Sectors, According to a New Report from Booz Allen Hamilton', ibid., 5 October 2016, and Industrial Control Systems-Cyber Emergency Response Team (ICS-CERT), 'Alert (IR-ALERT-H-16-056-01) Cyber-Attack against Ukrainian Critical Infrastructure', Department of Homeland Security, 25 February 2016.

instance, has opted for smart meters without the remote switch-off option. By introducing smart grids and smart meters at households and the industry, the future power supply will be much more exposed to cyber threats as their introduction will create hundreds of new million attacking points and vulnerabilities. The EU had originally planned to introduce 200 million of smart meters by 2020.[84] A scenario as described in the 2012 German best-selling novel '*Blackout*' by Marc Elsberg, portraying a nightmare scenario of the collapse of the European electricity grid triggering telecommunication problems, food and water shortages as well as an economic breakdown in various European countries, is no longer be seen as unrealistic.[85] The novel is based on a larger study of a German institute of the Bundestag in 2011. The study highlighted and confirmed again that neither states nor societies are really prepared for coping with the cascading impacts and the amount of replacement work for restoring the power supply fast enough.[86]

In 2017, the worldwide '*WannaCry*'-infection and later the '*Petya*'-cyberattack have highlighted again the need for stronger rules and regulations to force companies and public as well as private owners of CIs to disclose when they have become a victim of major cyber-attacks. Security risks to ICS are not determined just by vulnerabilities alone but rather by their systemic nature. As cyberattacks and risks, as well as vulnerabilities, will further increase with the rapid introduction of new technologies, the rapidly changing cyber security environment needs timely and more effective responses by governments and companies, including high fines, as their vulnerabilities and infected IT systems may impact other critical infrastructures and companies. Although the ultimate costs of the '*WannaCry*'-infection were not so worse, next time the world might not be so lucky again. In the next two years, an additional 2-3 bn people will come online, translating into the fastest adaptation in the Internet's history.[87]

According to new surveys, a synchronised and simultaneous massive cyberattack attack against multiple organisations and companies of the power and electricity sectors, healthcare, information technology, chemical plants, aviation systems, financial services, tele-

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84 See also Eduartd Kovacs, 'Critical Flaw Found in Siemens Smart Meters', www.securityweek.com, 6 October 2017; Peter Rost, 'Smart und sicher: Smart Grid effektiv schützen', Energiewirtschaftliche Tagesfragen, 1-2/2017, p. 100, and F. Umbach, ' The Vulnerability of Critical Energy Infrastructures', GIS, 9 May 2013.

85 See Marc Elsberg, 'Blackout. Morgen ist es zu spät', Munich 2012.

86 See Thomas Petermann et al., 'Was bei einem Blackout geschieht. Folgen eines langandauernden und großräumigen Stromausfalls'.

87 See BryanHarris/Katrina Manson, 'US Blames North Korea for WannaCry Cyber Attack', FT, 19 December 2017; 'The Internet Is Less and Less Spotify and More and More Wannacry'- From the MSC Cyber Security Summit Tel Aviv', Munich Security Conference, 30 June 2017 (https://www.securityconference.de/news/article/the-internet-is-less-and-less-spotify-and-more-and-more-wannacry-from-the-msc-cyber-security-sum/; accessed on 17 July 2017); Sam Jones/Aliya Ram, 'Petya Attack Raises Fears of Escalation of Global Cyber Arms Race', FT, 7 July 2017; Laurens Cerulus, 'Governments Scramble to Respond to Global Cyberattack, FT, 28 June 2017, and IISS, 'The Wannacry Ransome Attack', IISS-Strategic Comments, Vol. 23, Comment 16, May 2017.

coms and even nuclear facilities for bringing down some of a nations CIs for some hours, days or even weeks is no longer been considered as a '*Black Swan*' event, but rather seen as most likely (being "*3 meals away from anarchy*").[88] The disclosure of security holes in Intel, AMD and ARM processors and chips at the beginning of this year have added to already existing fears as the only safe, but the unrealistic solution to protect yourself is to completely replace the computer systems.[89]

In contrast to the period the Cold War and its history of arms control, containing the proliferation of cyber weapons through any negotiated arms control agreements appears rather unrealistic. An agreed cyber security pact (like between Australia and China last April or the one between the U.S. and China in 2015), in which both countries promise not to conduct or support cyber-enabled theft of intellectual property, trade secrets and confidential business information, should be viewed as a bilateral confidence building measure (CBM) rather than a real and verifiable arms control agreement.

Unlike arms control agreements between states during the Cold War-era, many of the hacker groups are non-state actors. Its '*weaponisation*' lies in their hands as well as private companies producing '*dual-use software'*, which is much more difficult to control it. Software and codes can easily be copied almost everywhere. A weapons' arsenal can fit on a USB stick. A verification of cyber arms control agreements, which is the foundation of any credibility and implementation, is practically impossible. As long as the identification and attribution of the sources of attack are facing major difficulties, and offensive cyber tools are becoming commonplace and available for rogue nations, jihadists and cyber-criminalists throughout the world, sophisticated cyberattacks on critical ICS-networks will further increase.

Those disruptive or destructive attacks against CIs have already been crossed our previous red lines and past security forecasts. Thus regional and global initiatives to build up trust and confidence as well as security standards are important and more realistic to implement than any arms control agreements for the cyberspace, which can't be verified as those in the past.

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88 See Eduard Kovacs, 'Utilities Fear Cyberattacks Could Cause Electric Grid Disruptions: Survey', www.securityweek.com, 5 October 2017; Adam Meyer, 'Analyst Perspective: 2018 Cybersecurity Forecast', ibid., 1 December 2017.John Thornhill, 'Competent Computers Still Cannot Comprehend', FT, 8 January 2018, and Rob Knake,'The Next Cyber Battleground. Defending the U.S. Power Grid from Russian Hackers', Foreign Affairs, 19 July 2018.

89 See Hannah Kuchler/Richard Waters, 'Security Experts Issue Dire Warning on Chip Flaw', FT, 4 January 2018; H.Kuckler, 'Companies Rush to Patch Security Flaws Meltdown and Spectre', FT, 7 January 2018; Eduard Kovacs, 'Industry Reactions to Meltdown, Spectre Attacks: Feedback Friday', www.securityweek.com, 5 January 2018, and idem, 'Intel, AMD Chip Vulnerabilities Put Billions of Devices at Risk', ibid., 3 January 2018.

2.3.2 Challenges of Raw Material Supply Security

The present worldwide energy discussions of a global '*Energiewende*' are focusing primarily on the decarbonisation process from a fossil fuel age to a future one based on RES. Those discussions on the context of global climate mitigation policies are directed towards effective demand management and the integration of RES in a more decentralised future energy supply system and related technology innovations, technocratic solutions and regulation approaches as well as new market designs.[90]

As already described above, the worldwide expansion of green technologies, including renewable energy resources, is heavily dependent on a stable supply of critical raw materials[91] such as *Rare Earths Elements (REEs)*.[92] These industrial minerals became known to the worldwide audience and politics in the autumn of 2010, when China as the world's largest producer and exporter of rare earth suspended its exports to Japan and apparently tried to use its de facto nearly monopoly of global production of REEs for political ends in the midst of an escalating diplomatic conflict over maritime territories and energy resources in the East China Sea.[93] Since that time, not only Japan but also the United

90 An example of those technocratic-technology and apolitical concepts can be seen in the Energy Transitions Commission, which collaborated with climate and environmental experts and industry leaders – see Energy Transitions Commission, 'Better Energy, Greater Prosperity. Achievable Pathways to Low-Carbon Energy Systems', April 2017. Another example can be seen in the 'Oil and Gas Climate Initiative (OGCI)' of the worldwide 10 largest oil majors, which will invest around 1 bn in the next decade for the development of innovative technologies with lower carbon emissions – see Ed Crooks, 'Business Leaders Back Transition to Low-Carbon Energy System', FT, 25 April 2017; Stuart Haszeldine, 'Oil Companies' Climate Initiative Lacks Initiative', energypost.eu, 9.11.2016 und Andrew Ward, 'Oil Groups 'Not Investing Enough' in Green Energy', FT, 18.11.2016.

91 See European Commission, 'Tackling the Challenges in Commodity Markets and Raw Materials'. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Region, Brussels, 2 February 2011 COM(2011) 25 final; European Commission, 'Critical Raw Materials for the EU. Report of the Ad-hoc Working Group on Defining Critical Raw Materials', Brussels, 30 July 2010; Bram Buijs/Henrike Sievers, 'Resource Security Risks in Perspective. Complexity and Nuance, CIEP-BGR Briefing Paper, November 2011; Gerhard Angerer, 'Rohstoffe für Zukunftsfragen. Einfluss des branchenspezifischen in rohstoffintensiven Zukunftstechnologien auf die zukünftige Rohstoffnachfrage, Fraunhofer-Institut für System- und Innovationsforschung ISI, 2009; PBL Netherlands Environmental Assessment Agency (PBL), 'Scarcity in a Sea of Plenty? Global Resource Scarcities and Policies in the European Union and the Netherlands, The Hague, 2011; BDI, 'Rohstoffsicherheit für Deutschland und Europa. 3. BDI-Rohstoffkongress, Berlin, 26 October 2012; Deutsche Rohstoffagentur (DERA)/BGR, 'Deutschland Rohstoffsituation', Hannover, December 2011 and Marc Humphries, 'Rare Earths Elements. The Global Supply Chain'. Congressional Research Service, Washington D.C., 8 June 2012.

92 See also World Bank Group, 'The Growing Role of Minerals and Metals for a Low Carbon Future', Washington D.C., June 2017; Maren Liedtke/Harald Elsner, 'Seltene Erden', Commodity Top News, BGR, Nr .31, 20 November 2009 and Harald Elsner, 'Kritische Versorgungslage mit schweren Seltenen Erden – Entwicklung „Grüner Technologien" gefährdet?', ibid., No. 36, 14 Sepember 2011; Hague Centre for Strategic Studies/TNO, Rare Earths Elements and Strategic Mineral Policy, The Hague 2010; Marc Humphries, 'Rare Earth Elements. The Global Supply Chain'. Congressional Research Service, Washington D.C. 2010.

93 To the Sino-Japanese Conflict of REE and its impacts on Japan, the U.S., and the EU see also the series of my analyses in 2012 and 2013 – F. Umbach, 'China Moves Closer to a Monopoly in Rare Earths', GIS, 14 December 2012; 'How China's Strict Rare Earths Policies Sparked a Backlash', ibid., 19 December 2012; 'Islands Dispute Puts Spotlight on China's Rare Earths Strategy", ibid., 28 December 212; 'The U.S. Fights

States, the EU and others are discussing their raw material supply security as well as the world's heavy dependence on China's rare earth production and seeking ways to diversify and reduce their import dependencies.

The name of '*rare earth*' dates back to the 18th and 19th centuries when these elements were isolated out of actually rare minerals. At that time, those rare elements actually turned out to be very common, mixed in small concentrations into the rocks all over the world. Lanthanum as the second-most abundant rare earth element, for instance, had been discovered in 1893 and is more available than silver as well as many other minerals. Thus it took a very long time between the discovery of the rare earth and the discovery of real practical uses for them. Even until the late 1970s and 1980s, Lanthanum, for instance, was mostly stocked for the day that it could be sold for much higher prices. But the big break-through in '*nickel-metal hydride*' car-batteries, providing to pack more power into a smaller space, has made those new batteries twice as efficient as the old standard lead-acid car-batteries.

Some experts have compared rare earth elements with vitamins as they have unique chemical and physical properties that allow them to interact with other elements and get results that neither element could get on their own. They are used in many applications for their magnetic and other unique properties and characteristics for a variety of commercial (i.e. energy and other green technologies) and military applications, including cell phones, computer hard drives, and precision-guided weapons and munitions. Some of these applications (i.e. windmills) rely on permanent rare earth magnets that have unique properties, such as the ability to withstand demagnetisation at very high temperatures.[94]

Figure 7: Civilian and Military Appliances of REEs

Military Applications	*Civilian Applications*
• Precision-guided munitions, lasers, communication systems, radar systems, avionics, night vision equipment, and • Satellites;	• Nickel-metal hybrid batteries; • Originally red colour of TV sets; • Today white-based LED lights as an energy efficient replacement of

Back against China's Rare Earths Domination', ibid.,, 8 January 2013; 'Japan's Plan to Reduce Dependence on China's Raw Materials', ibid.,15 *January* 2013; 'Germany Pays Price of Losing Direct Access to Critical Raw Materials, ibid., 22 January 2013; 'China Fights to Retain Dominance of Rare Earths Market', ibid., 29 January 2013; 'Europe's Plan to Safeguard Supplies of Raw Materials', ibid., 5 February 2013; 'Europe Demands More Transparency of Raw Materials Market', 13 February 2013, and 'China Is Losing the Trust of its Global Rare Earth Customers", ibid., 20 February 2013.

94 See also U.S. Geological Survey (USGS), ‚The Rare-Earths Elements- Vital to Modern Technologies and Life-styles', Fact Sheet 2014-3078, Reston, November 2014.

• Significance of the widespread use of commercial-off-the-shelf products in defence systems that include rare earth materials, such as computer hard drives; • Specific components within defence systems that rely on rare earth materials, such as traveling-wave tubes, which amplify radio-frequency signals using rare earth permanent magnets; • REEs materials are responsible for the functionality of the component and would be difficult to replace without losing performance. For example, fin actuators used in precision-guided munitions are specifically designed around the capabilities of neodymium iron boron rare earth magnets.	traditional incandescent and compact fluorescent bulbs; • Amplification (i.e. pulses in optical fibres) to assist the data movement and laser lights (to assist with surgery); • Very strong, but smaller and lighter magnets (i.e. in windmills); • Catalytic converters; • Superconductors

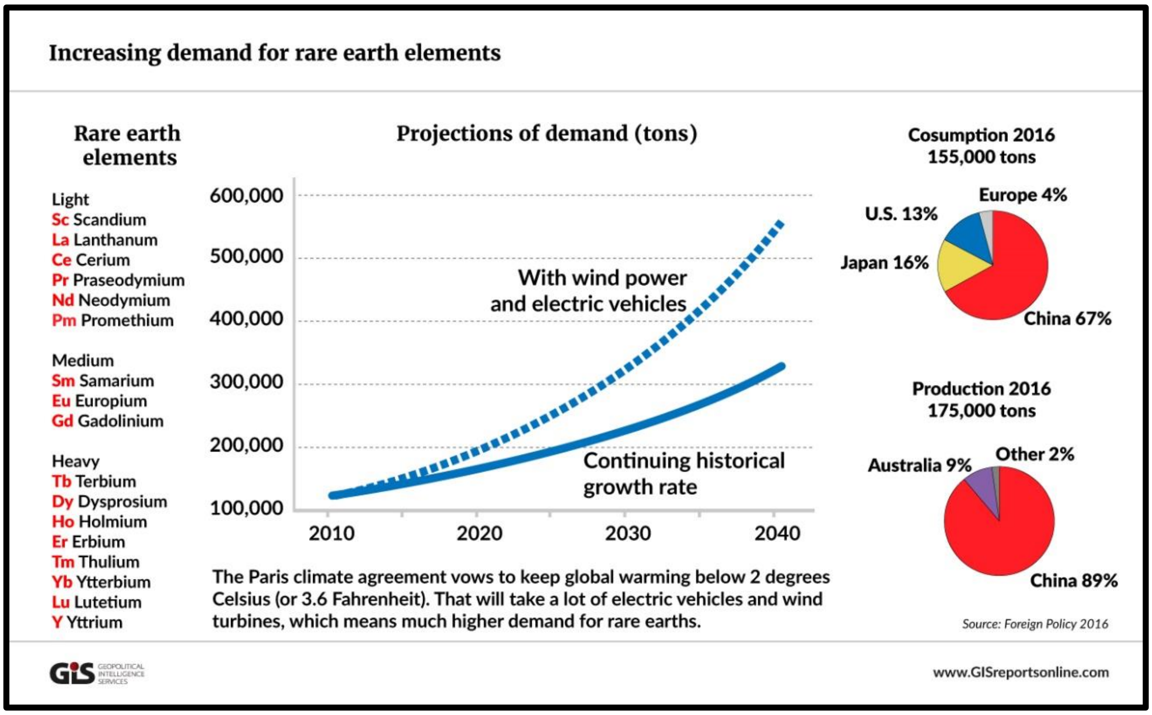
Source: Dr. F. Umbach based on various sources.

In 2010, the world's demand for REEs had been estimated to be about 136,000 metric t per year. In 2010, the demand was 134,000 tons (t) per year but met by just 124,000 t of the worldwide production. A U.S. Congressional report projected and warned in 2010 that the world demand for REEs could increase up to 180,000 t annually by 2012 and 200,000 t by 2014, dominated by China's production of 160,000 t per year.[95] With a worldwide shortage of 40,000 t by 2014, China would have benefitted not just economically by further rising prices of REEs, but also geopolitically. While the REEs demand has rather stagnated around 135,000 t during the last years, China's production and export monopoly of REEs has equally not really been weakened.

Alongside China's blackmail strategies of stopping all rare earth exports to Japan, the EU and Germany have also become more alarmed about China's long-term raw material policies as they are closely integrated within its larger industrial and technology policies to rival the U.S. as the future technology power.

95 See also Maren Liedtke/Harald Elsner, 'Seltene Erden', Commodity Top News, BGR, Nr .31, 20.11.2009 und Harald Elsner, 'Kritische Versorgungslage mit schweren Seltenen Erden – Entwicklung „Grüner Technologien" gefährdet?', ibid., No. 36, 14.9.2011; Hague Centre for Strategic Studies/TNO, Rare Earths Elements and Strategic Mineral Policy, The Hague 2010; Marc Humphries, 'Rare Earth Elements. The Global Supply Chain'. Congressional Research Service, Washington D.C. 2010.

Figure 8: Rare Earths Elements. Projections of Demand and Supply-Demand Balance (2016)



Source: GIS 2018/Foreign Policy 2016.

In 2010, the European Commission identified 14 out of 41 analysed raw materials as '*critical*' for EU high-tech and eco-industries. In 2014, it identified 20 CRMs for Europe's industry. In 2017, a new list added 9 more new materials up to 27 CRMs for the EU economy.[96]

In the summer of 2016, the EU launched a third legal WTO challenge to restrictions on Chinese exports of 11 key metals and minerals due to China's export duties and quota restrictions on 5 of them. In the view of the EU by joining the U.S. in suing Beijing, they have distorted the market and favoured China's industry at the expense of European and U.S. companies as well as consumers. China had already lost two WTO lawsuits against the EU and the U.S.[97] In order to preserve the EU's future international leverage, it needs to seek and promote new forms of international cooperation to avoid any new technology arms races with wide-ranging geopolitical impacts at the expense of global stability.

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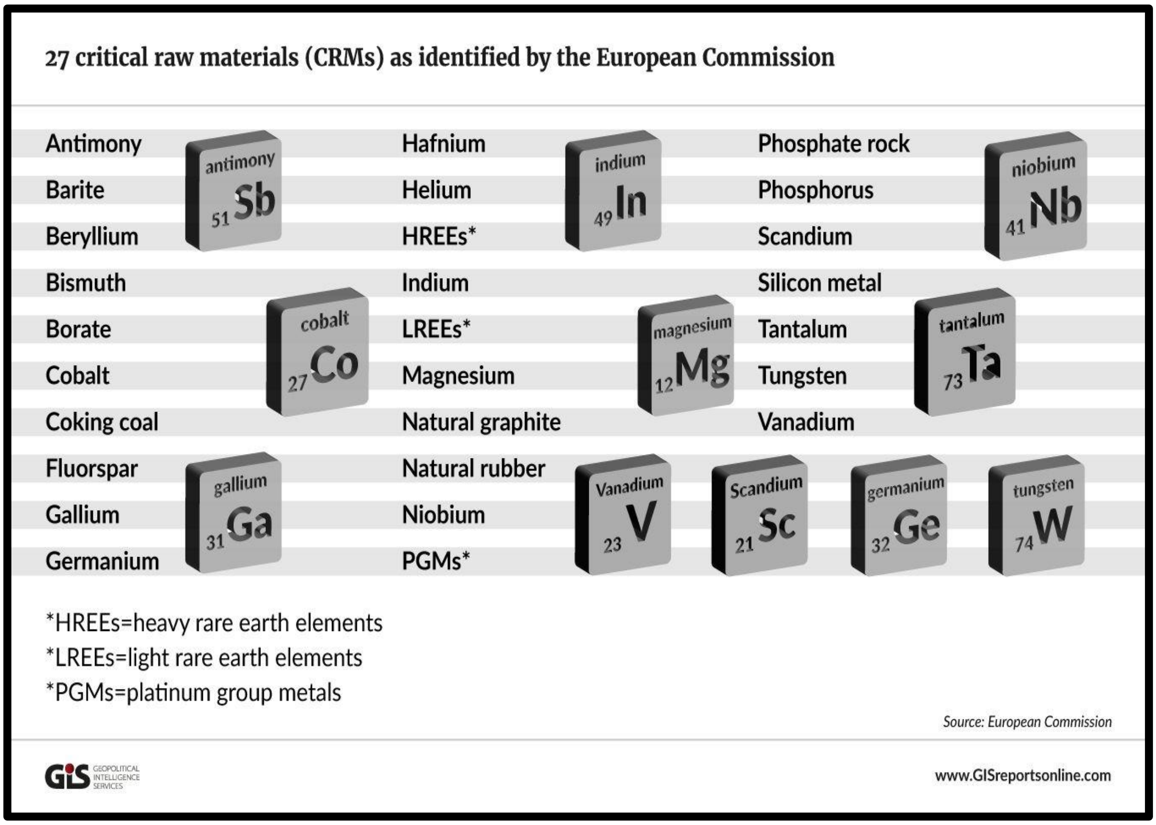
96 See European Commission, 'Report on Critical Raw Materials for the EU. Report of the Ad hoc Working Group on Defining Critical Raw Materials', Brussels, May 2014; idem, 'On the List of Critical Raw Materials for the EU. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions', Brussels, 13 September 2017 COM(2017) 490 final, and European Commission, 'Report on Critical Raw Materials and the Circular Economy', Commission Staff Working Document', Brussels, 16 January 2018SWD(2018) 36 final.

97 See Philip Blenkinsop/Michael Martina, 'EU Launches WTO-Challenge to Chinese Raw Material Supplies', Reuters, 19 July 2016 and Jocelyn Aspa, 'European Union Launches Third Dispute Against Chinese Raw Materials', Investing News, 20 July 2016.

Figure 9: 27 Critical Raw Materials identified by the European Commission



Source: GIS 2018/European Commission 2014.

The expansion of green technologies, the global demand for REEs and other strategic raw materials will increase. Furthermore, for some REEs (i.e. heavy rare earths elements/ HREEs), no material replacement has been found, such as for Neodymium that enhances the power of magnets at high heat and is crucial for hard-disk drives, wind turbines, and the electric motors of hybrid cars. While in principle, wind turbines can be built without rare earth, REEs could reduce the per megawatt cost of wind energy and improve its competitiveness through conservation of other materials such as steel and copper.

According to government and industry data, the future availability of materials from some REEs — such as neodymium, dysprosium, and terbium — is largely controlled by Chinese suppliers. When Beijing was accused in autumn 2010 to halt all REEs exports to Japan, after it had already announced restrictions of its worldwide exports of REEs, China's mercantilist raw material policies have sent shock-waves through markets and high-tech companies around the globe.

Figure 10: Selected CRMs and Associated Technologies

Selected Materials and Associated Technologies which have an important role in technologies aimed at reducing carbon emissions and/or improving energy efficiency:

1. **Dysprosium:** vehicles, wind	17. **Silver:** solar, lighting
2. **Lithium:** vehicles	18. **Lanthanum:** vehicles
3. **Graphite:** vehicles	19. **Samarium:** vehicles
4. **Tellurium:** solar	20. **Copper:** combined heat and power, solar, vehicles, grids
5. **Neodmyium-Praseodymium:** vehicles, wind	21. **Hafnium:** nuclear
6. **Indium:** solar, lighting, nuclear	22. **Cerium:** vehicles
7. **Platinum:** fuel cells	23. **Gold:** lighting
8. **Terbium:** lighting	24. **Rhenium:** fossil fuels
9. **Tin:** solar	25. **Tantalum:** geothermal, fossil fuels
10. **Europium:** lighting	26. **Chromium:** desalination
11. **Gallium:** lighting, solar	27. **Vanadium:** carbon capture and storage (CCS)
12. **Cobalt:** vehicles, fossil fuels	28. **Niobium:** CCS
13. **Nickel:** desalination, vehicles, geothermal	29. **Selenium:** solar
14. **Germanium:** lighting	30. **Lead:** grids, storage
15. **Yttrium:** lighting	31. **Cadmium:** solar
16. **Molybdenum:** desalination, wind	32. **Gadolinium:** lighting

Source: Dr. F.Umbach based on Stratfor.com 2015

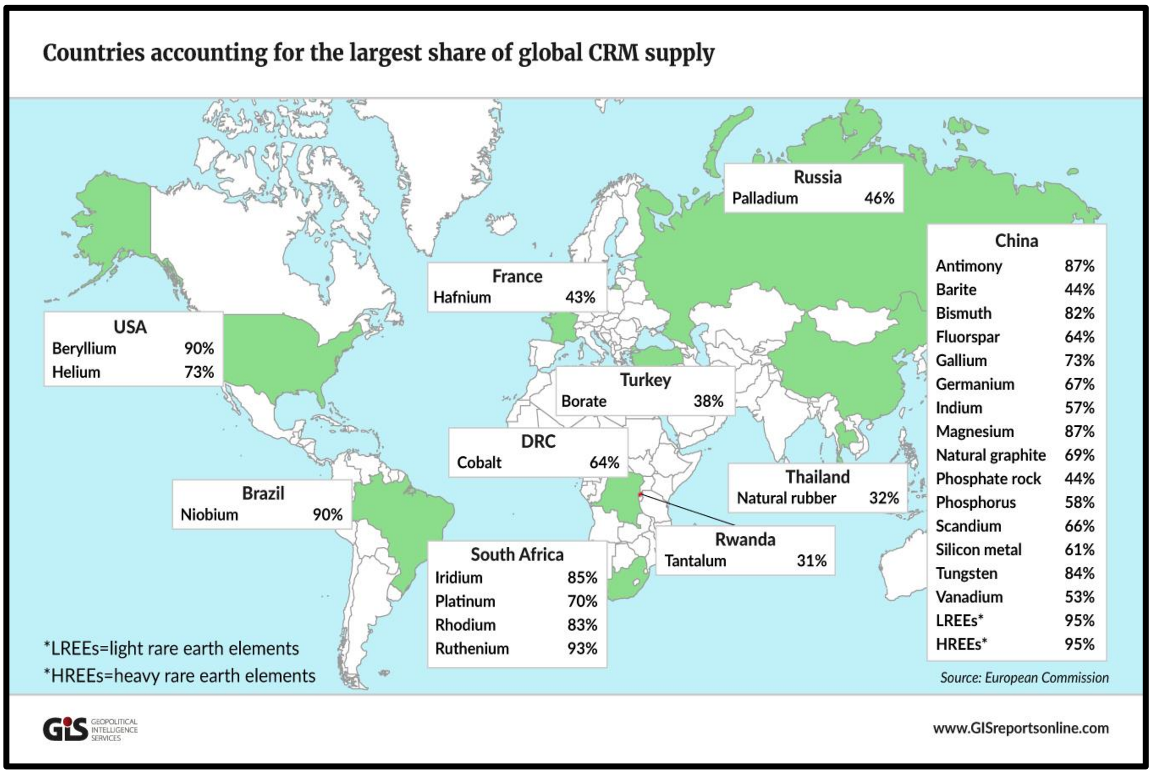
Some government and rare earth industry experts believe that China plans on the greater vertical integration of the rare earth materials market in the future, which would increase China's total market power and dominance. While China is currently exporting rare earth oxides and metals, some rare earth industry officials believe that in the future China will only export finished rare earth material products with higher value. China seeks to acquire the strategic control of worldwide available REEs and other CRMs by buying into international mines and receiving majority shares. Even Greenland with its large CRMs, including REEs, has been in the strategic investment focus of China.[98]

Against this background, not just Japan, also the U.S. and the EU have enhanced their attention on supply security challenges of CRM such as REEs. Those concerns have become even more important to address as emerging disruptive technologies such as electric cars and their batteries, robotics and artificial intelligence systems might dramatically raise the global demand of CRMs or so-called '*technology metals*', though they are often used in relatively small quantities to provide specific functionalities and performances. They are traded in comparatively small markets, which are often not very transparent, leading to overreaction and rapid changes in demand and supply as well as prices. Analyses of combined supply risks include concentration, and current as well as the future production of individual countries and regions, political stability of producing and

98 See also Jesper Zeuthen, 'Part of the Master Plan? Chinese Investment in Rare Earth Mining in Greenland', and Anna-Katarina Gravgaard, 'Greenland's Rare Earths Gold Rush'.

mining countries, current recycling volumes and an estimate of the substitutability of each raw material in each relevant field of use.[99]

Figure 11: Selected CRMs and Associated Technologies



Source: GIS 2018/European Commission 2014

While in most cases, geological factors do not constrain the future supply shortages and scarcity of those CRMs[100], (geo)political conditions and rapid market changes can lead to supply shortages, price spikes and volatility, and rising geopolitical dependencies. Thus the criticality of CRMs can rapidly change due to shifting geopolitical-economic environments. Environmental risks, social (public acceptance such as NIMBY-effects or '*social license for mining*' etc.) and other political factors can further constrain the global and regional supply security of CRMs. Primary supply concerns are focusing on the potential of supply disruptions and extreme price spikes, caused either by accident and by purpose such as:

- Accidental supply disruptions or price hikes;
- Intentionally supply disruptions by the use of exports or pricing as a political instrument;
- Unequal market conditions, causing an uneven economic playing field; and

99 See also Luis A. Tercero Espinoza, 'The Role of Emerging Technologies in Rapidly Changing Demand for Mineral Raw Materials', Polinares Project, European Commission/European Research Area, Polinares Working Paper No. 27, March 2012.

100 See David Humphreys/John Tilton, 'No Cause to Panic about Mineral Depletion', FT, 16 January 2018.

- Governance issues related to the resource sector.[101]

Compared with the concentration of conventional oil and gas resources, the one of CRM production is geopolitically more challenging and problematic – particularly when its future worldwide demand rise is taken into consideration. At present, 50% of CRMs are located in fragile states or politically unstable regions.

Furthermore, security of supply risks are not just constrained to primary natural resources and CRMs but also to the import of semi-manufactured and refined goods as well as finished products. Market imperfections in the form of manipulated prices, restricted supplies and attempts at cartelisation of CRM markets with wide-ranging negative economic consequences are not restricted just to producing and exporting countries. Powerful state and private companies have also been responsible for opaque pricing mechanisms for many precious CRMs. With ever more complex global supply chains, blurred boundaries between physical and financial markets, and weakly governed market platforms, the manipulation of prices, trading houses, major producers and financial institutions have increased and are threatening the stability of the future security of supply of CRMs.[102]

Those challenges and risks need no longer to be analysed just for concepts and strategies of raw material supply security, but need to be addressed and framed in a larger context as part of new holistic energy security concepts as Western countries and the world will become ever more dependent on a stable supply of those CRM for the digitalisation of the energy and other industrial sectors.

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[101] See Henrike Sievers/Bram Buijs/Luis Tercero, 'Critical Minerals for the EU', Polinares Project, European Commission/European Research Area, Polinares Working Paper No. 31, March 2012.

[102] See also Jaako Kooroshy/Felix Preston/Sian Bradley, 'Cartels and Competition in Minerals Markets: Challenges for Global Governance', Chatham House, London, December 2014.

3 Global Energy Megatrends: From Energy Scarcity to Energy Abundance

3.1 Expansion of RES and Decentralisation of Energy Supply

Since around 2010, the world has experienced a parallel energy revolution with wide-ranging impacts on global energy markets. In Europe, China, the U.S. and increasingly in many other countries of the world, renewable energy sources (RES) have expanded due to dramatic shrinking costs in particular of solar and wind power. Since 2010, costs of solar PV have decreased by 70%, wind by 25% and battery costs for electric vehicles by 40%.[103] In 2017, renewable-based electricity generation grew worldwide at 6.3%. It is the highest growth rate of any energy source. They now account for 25% of global electricity generation.[104] By 2040, they could account for at least 34% of the worldwide electricity generation[105] and even 50% by 2050. According to Bloomberg New Energy Finance (BNEF), solar and wind costs might further drop 71% and 58% respectively by 2050.[106]

But new global investments in clean energy have fallen during the last years, being in 2016 with US$287.5 bn around 18% lower than in 2015 (with a record investment of US$348.5 bn).[107] After worldwide clean energy investment slightly increased by 3% up to US$ 333 bn in 2017(see also figure 12), it declined again in the first quarter of 2018 by 10% compared with the same period a year ago. Contrary to widespread perception particularly in Europe, the new BNEF data highlights the ups and downs of the failing smooth transition away from fossil fuels. Conversely, it also confirmed again that (with some exception of coal) fossil fuels are not yet in a steady and irreversible decline.[108] Furthermore, declining costs for renewables do not include a number of hidden extra costs for the modernisation of grid, rising grid interventions and the subsidised back-up of conventional power plant capacities for grid stabilisation due to the rising intermittency problems of RES as the German '*Energiewende*' teaches.[109]

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[103] See IEA, 'WEO 2017', pp. 281 ff., and Editorial Board, 'Renewable Energy at a 'Tipping Point', Christian Science Monitor, 26 June 2017.

[104] See IEA, 'Global Energy & CO_2 Status Report 2017' (Paris: IEA/OECD, March 20 2018) and IRENA/IEA, 'Renewable Energy Policies in a Time of Transition' (Paris: IEA/OECD), April 2018.

[105] See Ed Crooks, 'Wind and Solar Expected to Supply Third of Global Power by 2040', FT, 15.6.2017. See also Tim Buckley, 'Cheap Renewables Are Transforming the Global Electricity Business', www.energypost.eu, 14 February 2018

[106] See Robert Walton, 'World on Track for 50% Renewables by 2050, Says Bloomberg Energy Outlook', Utilitydrive.com, 19 June 2018.

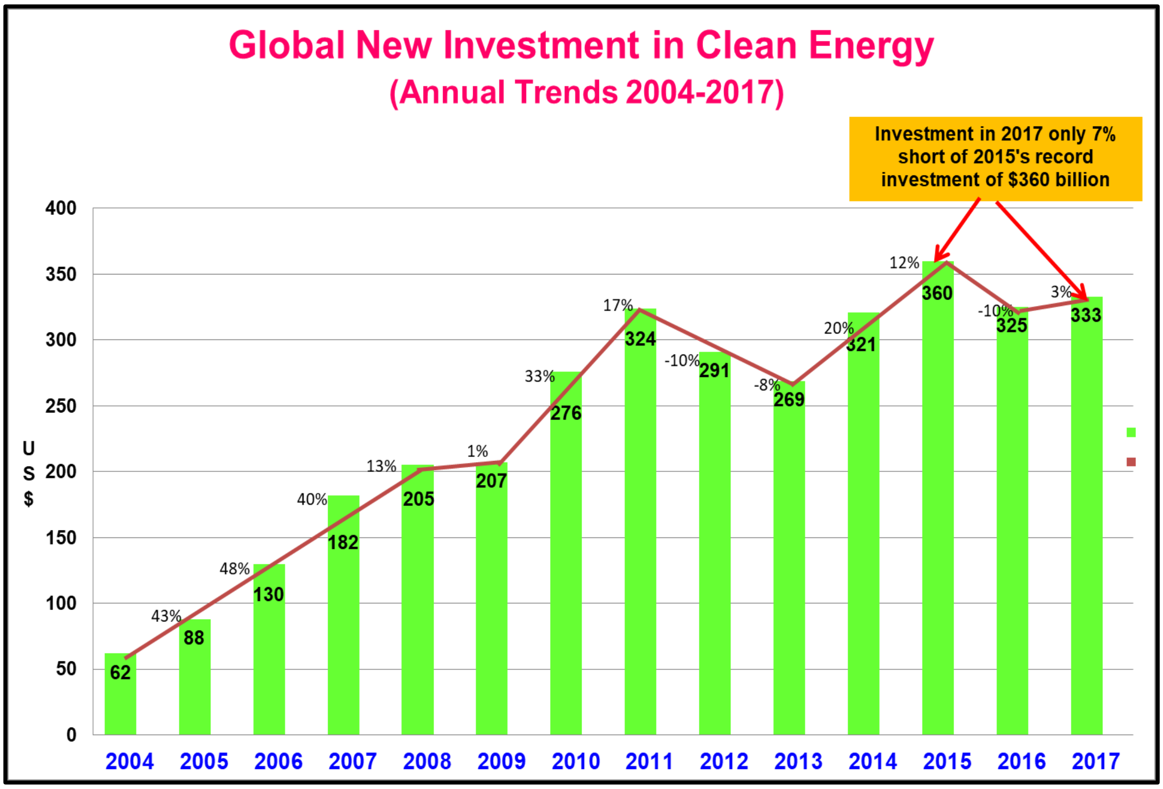
[107] See Michael Lynch, 'The 'Unstoppable' Renewable Energy Revolution Keeps Faltering', Forbes, 29 June 2017.

[108] See Abraham Louw, 'Clean Energy Investment Trends 1.Q 2018', BNEF, 11 April 2018.

[109] See also Jonathan Ford, 'The Hidden Costs of Renewable Power', FT, 21 August 2018.

Alongside of the insufficient global investment in clean energies for a faster transition to a non-carbon energy system, also total worldwide energy investment decreased by 2% to US$1.8 trillion in 2017 – primarily explained by the 6% decline in the global power generation sector to around US$750bn. China is becoming ever more important for the global energy megatrends as it is responsible for more than one-fifth of the global total energy investments.[110]

Figure 12: Global New Investments in Clean Energy (2004-2017)



Source: Dr. F.Umbach based on Bloomberg New Energy Finance (BNEF) 2018

At the same time, however, a new IEA report has warned that improvements in global energy efficiency "*slowed down dramatically in 2017, because of weaker improvement in efficiency policy coverage and stringency as well as lower energy prices*".[111] Global energy intensity improved by just 1.7% in 2017, compared with an average of 2.3% during the last 3 years. The newly published '*World Energy Outlook*'-report of the IEA of last November has identified four major mega-trends in international energy policies by the year 2040:

- Rapid development and falling costs of RES (with solar PV capacity growing worldwide larger than any other form of generation).

[110] See IEA, 'World Energy Investment 2018' (Paris: OECD/IEA, 2018).

[111] See IEA, 'Global Energy & CO_2 Status Report 2017' (Paris: IEA/OECD, 20 March 2018), p. 1.

- Growing electrification of energy as the worldwide consumers spent in 2016 for the first time as much as on electricity as on oil products. Electricity in expanding in sectors previously confined to other fuels such as cars, heating and cooling.
- In China, a shift to a more service-oriented economy and a cleaner energy mix has led to new initiatives to decrease the country's heavy coal reliance.
- The resilience and increased efficiency of the shale gas and tight oil evolution has made the U.S. since 2014 for becoming both the world's largest gas and oil producer at highly competitive prices, leading to an oversupply and dramatic price falls on the world's oil and gas markets. The U.S. will cement these positions by 2040. [112]

These unprecedented and mostly non-anticipated changes of technological innovations may even fasten in the forthcoming years with the digitalisation, automatisation, electric mobility, robotics and artificial intelligence entering and changing the entire energy sector.

The IEA has forecasted a 30% increase of the global energy consumption by 2040 from today, though rising more slowly than previously estimated in its '*New Policy Scenario (NPS)'*. But even the 30%-growth is an equivalent of adding the combined present energy consumption of China and India to the current global energy demand. Worldwide electricity generation will even increase by 60% and will make up 40% in final consumption to 2040 – equivalent to the share of oil during the last decades.[113]

But despite the impressive expansion of RES during the last years with solar power growing by 50% last year and might add another 660 GW just by 2022, the overall share of solar and wind power is just 2% of the world's primary energy demand (compared with 10% nuclear, 6% bioenergy, and 2% hydro).[114] Even by increasing annually 7% in the IEA's leading '*NPS*', by taking agreed but not (fully) implemented energy reforms and strategies for the mid-term perspective into account, the overall share of solar and wind power might only increase up to 8% by 2040.[115] In consequence, despite the Paris climate accord of December 2015, the continuing ambitious climate mitigation policies and a fastening expansion of RES, bolstered by further cost reductions of RES compared with fossil fuels, the present worldwide energy mix is still based on the fossil fuels oil, gas and coal at around 81%.[116]

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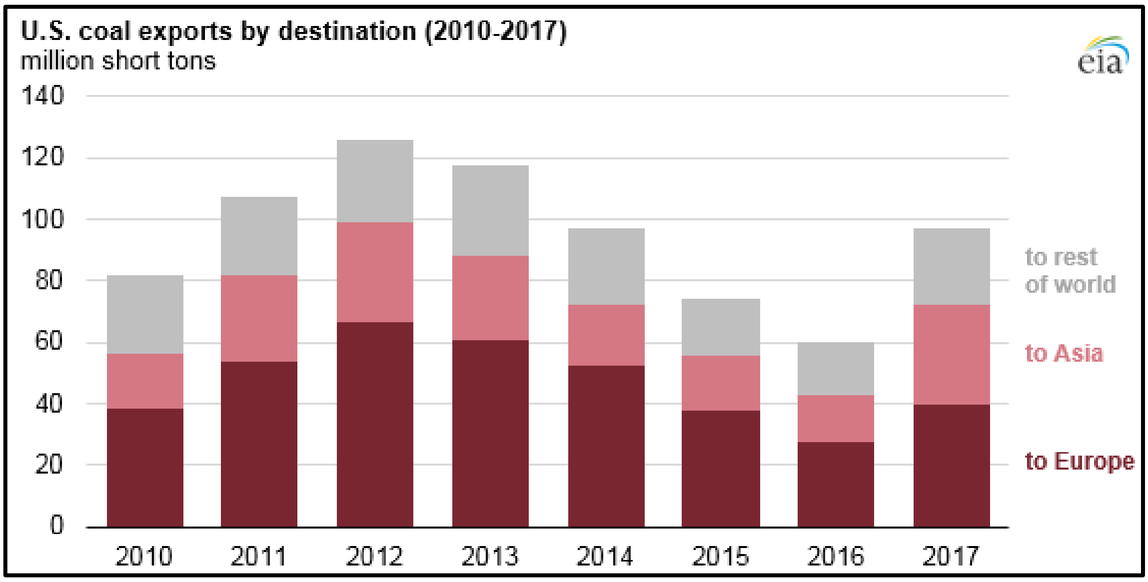
[112] See IEA, 'World Energy Outlook 2017', pp. 23 ff.
[113] See ibid., pp. 1 ff.
[114] See ibid., p. 716.
[115] See ibid., p. 717.
[116] See ibid., and idem, 'Global Energy & CO_2 Status Report 2017'.

Furthermore, fossil fuels still contribute around 72% to the rise in global energy demand.[117] Even the worldwide coal demand has increased again by 1% in 2017, reversing a declining trend during the last two years.[118] U.S. President Donald Trump did not only reject the Paris Agreement und the global climate change mitigation policies, he is also supporting the U.S. coal industry as he has promised to his electorate. While U.S. domestic coal consumption will hardly increase in the short- and medium-term due to cheaper shale gas, U.S. coal exports increased by 61% in 2017 and even more than doubled to Asia.[119]

Figure 13: U.S. Coal Exports by Destination (2010-2017)



Source: Energy Information Administration (EIA) 2018.

Hence the IEA expects that the worldwide primary energy mix of 2040 will be still based on fossil fuels at around 74% with its main '*NPS*'[120] - compared with its presently still less realistic '*Sustainable Development Scenario (SDS)*' of around 61% (and 39% of RES, hydro, bioenergy and nuclear compared with around 26% in the 'NPS').[121]

Overall decarbonisation trends are no longer questioned as such yet, the speed of the energy transition to a cleaner energy system cannot adequately be forecasted, which makes any investment decision highly risky. It is influenced by the uncountable uncertainties of global climate mitigation policies, the disinvestment movement of phasing out all fossil fuels (implicating '*stranded assets*' being '*literally unburnable*') and the impact

117 See IEA, 'Global Energy & CO_2 Status Report 2017', and Sylvia Pfeifer, 'Rising Energy Demand Fuels Increase in Global Carbon Emissions', FT, 22 March 2018.

118 See 'Global Coal Plant Pipeline is Half Empty (or Is It Half Full'), www.energypostweekly, 27 March 2018.

119 See Energy Information Administration (EIA), 'Today in Energy: U.S. Coal Exports Increased by 61%in 2017 as Exports to Asia more than Doubled', Washington D.S., 19 April 2018.

120 This is the main IEA-scenario which takes into account the present energy trends as well as announced future energy policy objectives and strategies though they are presently not (fully) implemented.

121 See IEA, 'World Energy Outlook 2017', pp. 648 f.

of disruptive technologies such as electric mobility, battery development, digitalisation and automatisation, robotics and artificial intelligence, and the resulting increase of electrification on the entire global energy system.

Given these uncertainties, the energy transition to decarbonise the worldwide energy system could also come faster than presently anticipated as the following recent developments highlight: meanwhile 20 countries and two U.S. states have joined the '*Powering Past Coal*'-alliance to phase out coal; France plans to end oil and gas production by 2040; the world's largest listed oil and gas group, *ExxonMobil*, has bowed to its shareholder pressure and demands for publishing reports on the possible impact and risks of climate policies on its business models, strategies and profits; and the *World Bank* will stop lending to any oil and gas projects after 2019. The bank will only make exceptions for gas projects in poor developing countries where fuel is needed to provide energy to local communities. The World Bank already stopped the financing of coal power projects in these countries in 2013.[122]

Newly developed technologies might prove to be disruptive such as the next battery generation for both EVs and becoming an integral component of future solar PV and wind power projects. The present expansion of RES has already transformed energy markets and broken traditional business models and strategies with great damages to European and in particular German utilities. A faster transition will also increase the uncertainties for investment decisions, political governance and geopolitics. The worldwide revolution EV, for instance, depends on the future capacity of battery production, more powerful batteries overcoming its present constraints of the driving range and time-consuming reloading but as well as on a sustainable and timely supply of many critical raw materials, concentrated in few (and often politically unstable) producer countries and mining companies.

3.2 Fossil Fuel Developments: The Impact of the U.S. Shale Oil and Gas Revolution

> „Normal diplomacy probably could not have achieved the geopolitical outcomes that have been produced in the past year by America's shale revolution. Oil prices have more than halved, which – coupled with the collapse of the ruble that stemmed from the turmoil in Ukraine – has gone a long way towards disabling the Russian economy. Cheap oil has weakened Iran's economy, too, lifting the chances of a realistic nuclear agreement. Finally, oil-rich Venezuela was on the edge of default even before the oil price decline. This amounts to a marked change in the economic and geopolitical landscape, of which the main beneficiaries are the US and its allies [...]. But the shale technology breakthrough is likely to be a far more effective stabiliser of oil prices than

122 See also F.Umbach, 'The Future Role of Coal: International Market Realities vs. Climate Protection?', EU-CERS-Strategy Paper Six, King's College, London, May 2015, and idem/ Ka-ho Yu, 'China's Expanding Overseas Coal Power Industry – New Strategic Opportunities, Commercial Risks and Geopolitical Implications', EUCERS-Strategy Paper No. 11, September 2016.

the cartel of oil producing countries, OPEC is now relinquishing its pricing power. It may never be regained."

Alan Greenspan, former chairman of the US Federal Reserve 1987–2006, 2015[123]

The impressive shale gas and shale oil revolution have only changed the U.S. energy market by fastening a coal-to gas change in its energy mix but also has had major impacts on the worldwide oil, gas and even coal markets.[124]

U.S. President Donald Trump has strongly supported higher oil and LNG exports for reducing trade deficits, including to China. Overall, the U.S. shale industry has proven much more flexible to changing market conditions and responsive to declining as well as short-term pricing than traditional multibillion-dollar megaprojects, particularly compared with conventional offshore oil and gas drilling. Since 2010, almost US$1 trillion have been invested in the upstream oil and gas production and another US$200 bn for new pipelines and other gas infrastructures.[125]

Breakeven prices for shale projects in the Permian basin as the '*new epicentre*' of the U.S. shale revolution had decreased from over US$50 to around US$35 per barrel, in some of the fields' even down to just US$20.[126] This basin has become the most important U.S. shale production source and could alone produce 8-9 mb/d in the forthcoming years.[127] The present challenge of the expansion is rather seen in shortages of operators and equipment as well as in accumulated debts.[128] Since 2007, U.S. energy companies have spent US$ 280 bn more than they acquired from their shale investments.[129] Some experts have even concluded that the shale oil and gas '*bubble*' may have already ended with

123 Alan Greenspan, 'OPEC Has Ceded to the U.S. its Power over the Oil Price', FT, 19 July 2015.

124 See also Christof Rühl, 'The Five Global Implications of Shale Oil and Gas', www.energypost.eu, 10 January 2014; Ed Crooks/Anjli Raval, 'Energy: The Indispensable Country', FT, 15 July 2014, and F. Umbach, 'Geo-political Dimensions of Global Unconventional Gas Perspectives', in: R. Quentin Grafton/Ian G. Cronshaw/ Michal C. Moore (Eds.), 'Risks, Rewards and Regulation of Unconventional Gas. A Global Perspective' (New York-Port Melbourne-Daryaganj/Delhi: Cambridge University Press, 2017), pp. 8-34 and idem, 'Global Out-look 2018: The Energy Revolution and its Growing Uncertainties', Geopolitical Intelligence Service (GIS), 30 January 2017.

125 See 'IEA Executive Director Holds Press Conference with US Secretary of Energy', IEA-News, 18 July 2017.

126 See David Blackmon, 'Gilmer: We Should View the Permian Basin as a Permanent Resource', Forbes, 17 August 2017; Sarah Ladislaw/Adam Sieminski/Frank Verrasto/Andrew Stanley, 'U.S. Oil in the Global Economy: Markets, Policy, and Politics', CSIS, Washington D.C., April 2017; Anjli Raval, 'IEA Says Scope of US Shale Oil Output Fall Will be Limited', FT, 10 February 2015; Alix Steel/David Westin/Grant Smith, 'Shale Will Beat OPEC as U.S. Oil Thrives at $40, Citigroup Says', Bloomberg, 15.8.2017

127 See Irina Slav, 'U.S. Shale Oil Production Rises at Record-Breaking Rate', Oilprice.com, 15 May 2018, and Ed Crooks/Andrew Ward, 'Big Oil Still Nervous after Profit Rebound', FT, 4 May 2017.

128 See Ed Crooks, 'US Oil Output Growth Hit by Lack of Operators and Equipment'; Housley Carr, 'With a Per-mian Well They Cried More, More, More-Looming Takeaway Constraints Out of the Hottest Shale Play', RBN Energy u.c., rbenergy.com, 1 May 2017.

129 See Justin Mikulka, 'The Secret of the Great American Fracking Bubble', www.energypost.eu, 24 April 2018.

production going rather flat instead of continuously increasing as investors and banks pay now much more attention to profits rather than growth.[130]

Cheap gas has hurt both coal and nuclear power by shutting down their electricity generation capacities. Between 2012 and 2016, the loss of 42,700 Megawatts (MW) of coal-fired generation in the U.S. has been offset by 55,700 MW of solar and wind power capacity. The mixed climate change legacy of the Obama administration and its coal-to-gas shift in the U.S. energy mix reduced its national CO_2-emissions to the lowest level since 1985.[131] The CO_2-emissions from power generation had been reduced by 30% from 2005 – more than half by switching from coal to natural gas.[132]

Beyond the highly symbolic step to withdraw from the Paris Agreement, its '*America First*' Energy Plan has also geo-economic and geopolitical implications for the global energy markets. The U.S. shale gas and shale oil revolution have already impacted the international oil and gas markets by increasing the global oil and gas glut and driving down oil and gas prices. As a non-OPEC-member and believing in the markets balance of supply and demand as well as by creating American jobs, the U.S. is not willing to restrict its oil production as the OPEC-members and other major non-OPEC oil producers such as Russia. By rolling back environmental regulations and decreasing taxes for the oil and gas industry, the U.S. shale oil and gas production as well as exports might even be fastened in the forthcoming years, though it is currently coping with rising financial challenges due to its accumulated debt of the last years and a lack of infrastructures (i.e. pipelines from the gas fields to LNG-export terminals).

Since 2012, the U.S. has surpassed Russia and Saudi Arabia as the largest combined petroleum and gas producer.[133] In 2014, it became both the worldwide largest petroleum producer (ahead of Saudi Arabia and Russia) and the largest gas producer (ahead of Russia and Iran). Since December 2015, when its oil export restrictions had been lifted, U.S. oil exports have continuously increased. Since then, the first 16 countries benefitting from the first U.S. oil exports included its traditional foreign policy allies such as Canada, the Netherlands, Italy and the Asian ally Japan.[134] By 2019, the U.S. might also overtake Russia

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130 See also John Dizard, 'Shale Oil and Gas Infrastructure Bubble Goes Flat', FT, 13 April 2018.

131 See Jude Clement, 'Thanks to Natural Gas, US CO2 Emissions Lowest since 1985', Realclearenergy.com, 6 July 2018 and also F. Umbach, 'The Limited Global Impact of Trump's 'America First' Energy Policies', GIS, 17 October 2017.

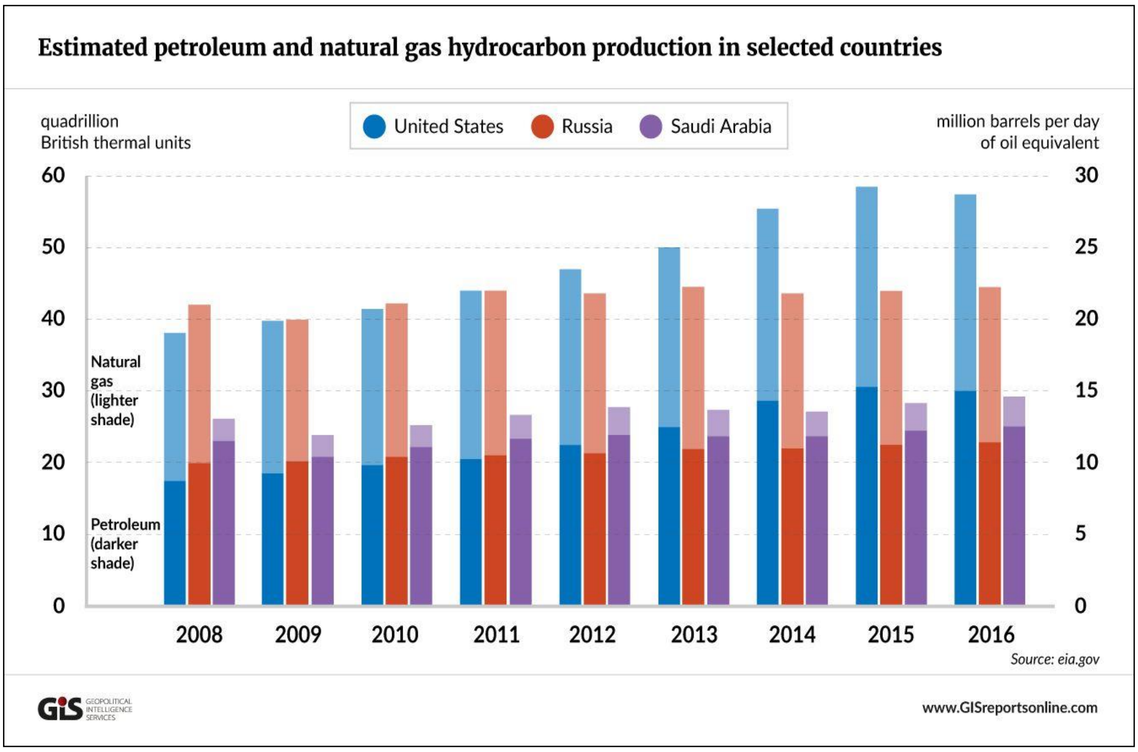
132 See Danel Yergin/Samuel Andrus, 'The Shale Gale Turns 10: A Powerful Wind at America's Back. What's ahead for the Next Decade?', IHS Market, Executive Commentary/Strategic Report, July 2018, p.7 f.

133 See EIA, 'United States Remain the World's Top Producer of Petroleum and Natural Gas Hydrocarbons', EIA-Today in Energy, 7 June 2017.

134 See Tsvetana Paraskova, 'Will U.S. Oil Exports Help Restore its Waning Geopolitical Influence', Oilprice.com, 27 October 2016.

as the world's largest crude oil producer with more than 11 mb/d per year.[135] The upward potential could even substantially higher, rising as high as 20 mb/d in the mid- and longer-term perspective.[136]

Figure 14: Estimated Petroleum and Natural Gas Production



Source: GIS 2018 based on Energy Information Administration (EIA), Washington D.C. 2017

In regard to Saudi Arabia's price war by targeting the U.S. shale production, the overall slowdown of it has been much less than expected due to increased efficiency, squeezing operational costs and technology innovation translating into higher well productivity and resiliency. Average production costs have been reduced by 30-40% for U.S. shale wells - compared with just 10-12% elsewhere. More than 60% of the oil production is now considered commercially viable at US$60 per barrel in U.S. shale, and only 20% in deep water.[137] The shale oil industry has been proved as much more price-elastic and the first to bounce back due to the short-cycle nature of drilling as it doesn't need large upfront

135 See Peter Stewart, 'US Hydrocarbons Continue their Relentless Rise', naturalgas.com, NGD, 25 July 2018, p. 6: Gregory Meyer, 'US Oil Output to Reach 11m Barrels a Day by the End of 2019- IEA', FT, 9 January 2018; Anjli Raval, 'Worries about US Shale Output as Oil Hits Three-Year High', FT, 14 January 2018; Liz Hampton, 'U.S. Oil Industry Set to Break Record, Upend Global Trade', Reuters, 16 January 2018; 'US Will Overtake Russia as Top Oil Producer by 2019, Says the International Energy Agency', CNBC, 27 February 2018; Anjli Raval, 'Rising US Shale Output May Lead to Early 2018 Oil Supply Surplus – IEA', FT, 14 December 2017.

136 See Amy Myers Jaffe, 'Could a U.S.-Russia Oil Showdown be Coming?', Council of Foreign Relations, 18 December 2017.

137 See Ed Crooks, 'U.S. Shale Is Lowest-Cost Oil Prospect', FT, 13 July 2016.

investment to recover quickly when prices rise again.[138] While worldwide conventional onshore drilling has risen by 17% since 2016, the drilling of U.S. shale oilfields has increased by 65% since the same time.[139]

As a result of the U.S. shale oil and gas revolution, the U.S. has become much less dependent on oil and LNG imports from the Gulf-region. It has strengthened the redefinition of the priorities in its foreign and security policies to East Asia, which was already underway during the era of former U.S. President Obama. It has reduced the U.S. engagement in the Middle East, added by the fact that the military interventions since 2001 did not produce a lasting, sustainable regional stability.

A complete oil import dependency of the U.S. appears not realistic in a national framework, but in a wider North American context by including Canada by 2030. Meanwhile, U.S. President Trump and some other U.S. politicians speak about the prospect of U.S. '*global energy dominance*' on the world's energy markets. It has four elements:

- The U.S. shall use the advantages of its huge oil, gas and coal reserves for domestic as well as foreign policy objectives.
- Expansion of its exports of all three fossil fuels – including for decreasing trade imbalances with its trading partners (such as China).
- Stronger reliance on energy imports from its allies such as Canada, Mexico and the Western hemisphere instead of imports from the politically unstable Middle East, Persian Gulf and North Africa
- The use of all three elements to strengthen the U.S. negotiation positions for foreign policy initiatives.[140]

The U.S. might remain a net oil importing country as more than 50% of the worldwide oil refinery capacities are located in the U.S. Thus the U.S. is not only directly export increasing volumes of its crude oil, but also still imports crude oil, and then export it as refined products. By 2020, the U.S. could even more export crude oil and refined products than the majority of OPEC-countries. In the future, the reduced oil import dependency from the Middle East decreases the political pressure for new military interventions in the crisis belt of world politics and increase its foreign policies' options and diplomatic room for manoeuvre. Two-thirds of the present U.S. oil imports are imported from Canada, whilst less than one-third is still being imported from OPEC-members. Hence a '*global energy dominance*' is for both economic and foreign policy reasons hardly plausible as exports of

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[138] See Sarah Ladislaw/Adam Sieminski/Frank Verrasto/Andrew Stanley, 'U.S. Oil in the Global Economy: Markets, Policy, and Politics', CSIS, Washington D.C., April 2017, pp. 1 und 7f.

[139] See David Sheppard/Anjli Raval, 'Oil Producers Face Their 'Life or Death' Question', FT, 19 June 2018.

[140] See F. Umbach, 'The Limited Global Impact of Trump's 'America First' Energy Policies'.

private U.S. oil and gas companies are guided by considerations of profitability. The Trump administration cannot dictate private U.S. energy companies – as i.e. Russia's state-own oil and gas companies – where to export.

3.2.1 Contradictory Trends in the Global Oil Sector and its Uncertainties

The present rise of oil prices back to more than US$75 per barrel is not just the result of OPEC's successful extension of oil production cuts. An higher economic growth worldwide, the collapse of Venezuelan oil production and new geopolitical crisis (i.e. U.S.-Iran, U.S.-Russian conflicts in Syria, the U.S.-China bilateral trade war) have all contributed to the recent oil price spike.

But "*the most dangerous confrontation for the oil market*" is currently seen in the increasing geopolitical confrontation between Saudi Arabia and Iran in the Middle East. The proxy wars in Yemen and Syria have the potential of a "*tripwire for a direct confrontation between Saudi Arabia and Iran*".[141]

While those geopolitical risks could even grow, they could equally decrease in the forthcoming months and years as they are currently difficult to predict. But higher oil prices between US$70-80 per barrel will inevitably lead to even higher shale oil production in the U.S. and other countries in the short-term perspective and, simultaneously, stimulating more investments and efforts in electric mobility in the mid-and longer-term perspective.[142]

Since 2010, the previous expectation of a '*peak-oil'*-era with an increasing worldwide shortage of oil and gas resources by around 2020 has been replaced with a perspective of a '*peak oil demand*'-scenario of a longer lasting oversupply of oil and gas reserves on the world's markets with lower oil and gas prices. It could even result in increasing concerns of a '*peak oil demand*'-scenario, in which even the oil price of the last years (US$40-60) could further decline. While, in the meantime, the IEA and many international oil experts concede that a much faster electric mobility revolution may curb an even more significant global oil demand by 2040, other oil demand drivers such as the petrochemical industry (+60%), freight shipping and aviation might still increase to outbalance any oil demand conservation impacts of the EV-revolution.[143] Given the worldwide transport sector being dependent on fossil fuels up to 96%, improving efficiency and decreasing emissions from *Internal*

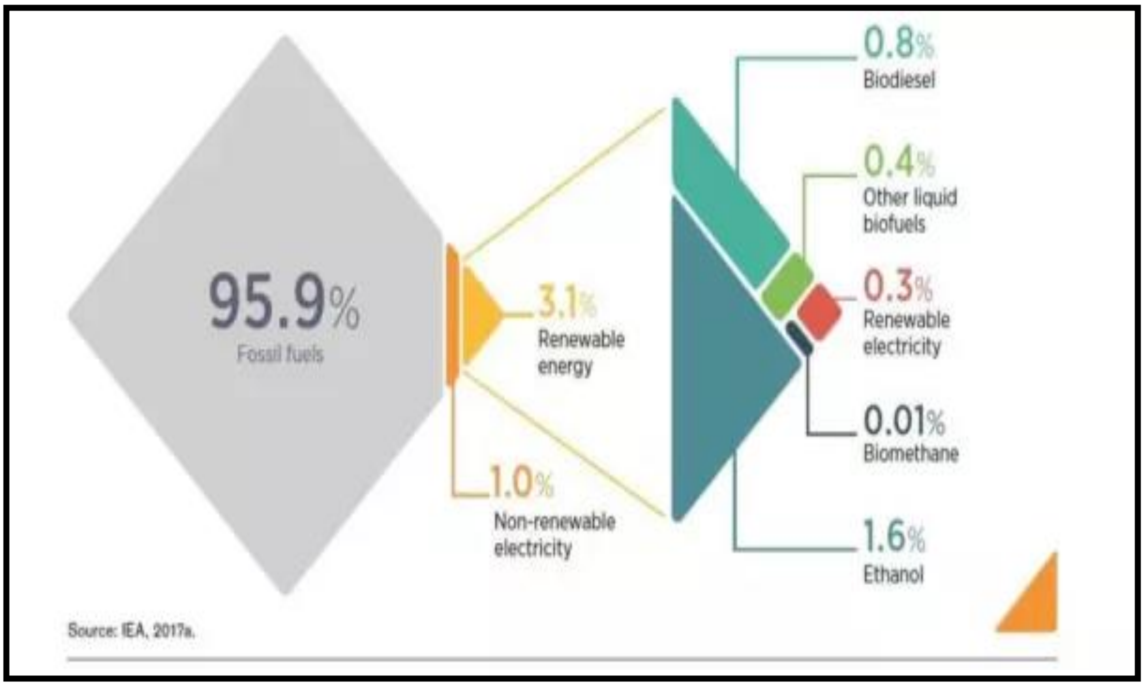
141 Quoted following David Sheppard, 'Oil Traders Will Find Middle East Power Struggle Harder to Ignore', FT, 5 April 2018.

142 See also Karel Beckmann, 'Oil Price up – What Happened to Peak Oil Demand, Why this Will Boost EVs', www.energypostweekly, 24 April 2018, and idem, 'Second-Shale Revolution in U.S., Shale Spreads to China and Gulf, Climate Suffers', ibid.

143 See also IEA, 'World Energy Outlook 2017', pp. 153 ff.

Combustion Engine (ICE) vehicles might be more effective at least in short- to medium-term perspective for mitigating climate change than expanding the share of electric cars.[144]

Figure 15: Global Transport Sector – Dependency on Fossil Fuels



Source: IEA, 'Renewable Energy Policies in a Time of Transition' (Paris: IEA/OECD, April 2018)

Any perceived peak in oil demand could result in increased competition among oil rich countries as it may force them to produce as much as of their remaining oil resources to avoid stranded resources. It would lead to a more dramatic fall of oil prices and lower extraction costs, which could slow down the decarbonisation processes.[145] But significant amounts of recoverable oil might indeed never been extracted. Low-cost producers such as Saudi Arabia and some other Gulf states might certainly use their comparative advantage to push out their higher-cost rival oil producers (incl. Russia) to gain higher market shares.[146]

During the last years, OPEC has surprisingly been willing and able to agree to curb its collective oil production, albeit it has become increasingly dependent on the support of non-OPEC oil producers (i.e. Russia), leading to a '*OPEC+*'. It has just successfully negotiated an extension of its production cut of 1.8 mb/d for the first half of 2018 as a result of a coordinated effort to help oil prices to rise above US$70 per barrel. But it is facing

144 See Ed Crooks, 'Looking for the Peak', FT, 19 January 2018.
145 See also Anjli Raval, 'Fixation on Timing of Peak Oil Is 'Misguided'', FT, 18 January 2018.
146 See also John Kremp, 'Peak Oil Demand and its Implications for Prices', Reuters, 19 January 2019.

increasing challenges at all fronts inside and outside OPEC[147], though the IEA has still maintained its forecast of global oil demand growth of up to 1.3 mb/d in 2018 despite pressures at all fronts:

- *U.S. Tight Oil Rise:* The recent return to a higher oil price of more than US$75 per barrel – not seen since the summer of 2014 - has already stimulated new and higher investments in US shale oil projects, including in those with a breakeven price above US$40-45. It has already grown faster than initially expected for next year due to rising drilling and well completion rates.[148] The number of rigs drilling the horizontal wells has more than doubled again from 248 in May 2016 to 652 at the beginning of December 2017.[149] The continuing technology innovation and efficiency gains for the exponential production growth have been repeatedly underestimated by international oil watchdogs and experts. The IEA had already revised again its oil supply and demand forecast last December by raising US crude oil growth to 870,000 b/d for 2018 in contrast to some oil experts' views that U.S. shale production has already peaked.[150] The U.S. Energy Information Administration (EIA) has recently raised the projected output from 9.77 mb/d in 2017 to 10.34 mb/ at the end of 2018.[151] Those U.S. shale oil exports will find new additional buyers in Asia because of new regulations of the International Maritime Organisation (IMO) as the U.S. tight oil has lower sulphur content than conventional, much heavier oil from the Gulf States.[152] Despite its accumulated debts, the U.S. shale companies are now able self-finance new wells and production with the rising oil prices and further declining shale production costs.[153] Nonetheless, the U.S. is still heavily importing crude oil with about 8 mb/d though it is largely re-exporting it as refined products.
- *Inside OPEC-Pressures:* Those OPEC-producers, facing production cuts and lost market shares due to political instabilities and civil wars (Iraq, Libya, Nigeria, Venezuela) as well as international sanctions (Iran), have a strategic interest to rise further their oil production to overcome their economic development constraints. So far, the agreed oil production cuts have offset the rising production in Libya and Nigeria in 2017. But

147 See also Jose A. Bolanos, 'The Future of Oil: Between Cooperation & Competition', EUCERS/ King's College, London, Strategy Papers, No. 13, December 2016.

148 See also David Sheppard, 'Shale is Back in Charge as OPEC Chooses to Watch and Wait', FT, 9 March 2018.

149 See Eric Platt/Ed Crooks, 'US Shale Groups Step up Bond Sales to Finance Drilling', FT, 14 December 2017.

150 See Anjli Raval, 'Rising US Shale Output May Lead to Early 2018 Oil Supply Surplus – IEA'.

151 See Anjli Raval, 'US Reliance on OPEC Endures despite Shale Boom', FT, 29 June 2018; Laura Blewitt, 'Trump's U.S. Looks Past Energy Independence to Global Dominance', Bloomberg, 2 May 2017, and 'Slippery Task of Balancing Supply and Demand in the oil Market', Stratfor.com, 12 January 2018.

152 See also David Sheppard, 'Will US Shale Give the Refining Industry Indigestion?', FT, 13 March 2018.

153 See Ed Crooks/Nicole Bullock, 'US Shale Groups Reach Self-Financing Milestone as Oil Prices Rises', FT, 23 April 2018.

during the internal negotiations in 2017, the last collective production cuts were only possible at the expense of Saudi Arabia's oil production. The financial reserves have decreased from US$750 bn to less than US$500 bn in just three years at a time, when the Saudi government is coping with an economic reform vision and seeks to diversify the country away from its oil and gas exports as well as revenue flows. As the '*Saudi Vision 2030*'–strategy needs huge investments to translate it into reality, any further extension of the cut may lead to a loss of market shares particularly in the oil-hungry Asia region because the U.S. made record oil exports to China since last November. The narrowing price spread between U.S. West Texas Intermediate Crude (WTI) and international benchmark Brent crude has also determined the U.S. inroads in China's oil import market two years after Congress lifted the 40-year ban on crude oil exports in December 2015 at the expense of Saudi Arabia and other rival oil exporters. Symptomatically for OPEC's continuing challenges, the cartel revised its crude oil demand growth by decreasing 200,000 b/d to 32.6 mb/d for the end of 2018, though it is still above the current output, and global oil consumption may rise up to 99.3 mb/d.[154] The problems can be aggravated by a development on the global market when the worldwide demand will fall again.[155]

- *Non-OPEC Producers:* Non-OPEC producers, led by the U.S., expanded by 630,000 b/d in 2017 and might further grow by another 1.2-1.7 mb/d this year. Total non-OPEC supply has been forecasted at 58.8-59.8 mb/d in 2018, while the global oil consumption expected to reach 98.5-99.1 mb/d this year.[156] Another 4 mb/d of U.S. shale oil exports are expected to arrive on the export markets by the mid-2020.[157] OPEC has revised again its forecast for the non-cartel oil producers (U.S. rising by 1.5 mb/d, but also Canada, Brazil and UK) for the fifth continuous month in April by increasing their output up to 59.6 mb/d.[158]

Russia in particular has become increasingly concerned and has already questioned the wisdom to agree to another collectively agreed cut as the unstopped and forthcoming fastening of oil exports will enrich U.S. companies by acquiring also larger market shares at the expense of Russia and OPEC. Despite extending a collective oil production curb and a return of the resent oil price to more than US$70 per barrel, a resurgent U.S. oil production

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154 See also Osamu Tsukimori, 'U.S. to Overtake Russia as Top Oil Producer by 2019 at latest – IEA', Reuters, 27 February 2018, and Anjli Raval, 'IEA Says OPEC Could soon Declare Victory in Oil Glut Battle', FT, 13 April 2018.

155 See also Jennifer Thompson, 'Oil Investors Face Dilemma as Demand Is Likely to Fall', FT, 14 December 2017.

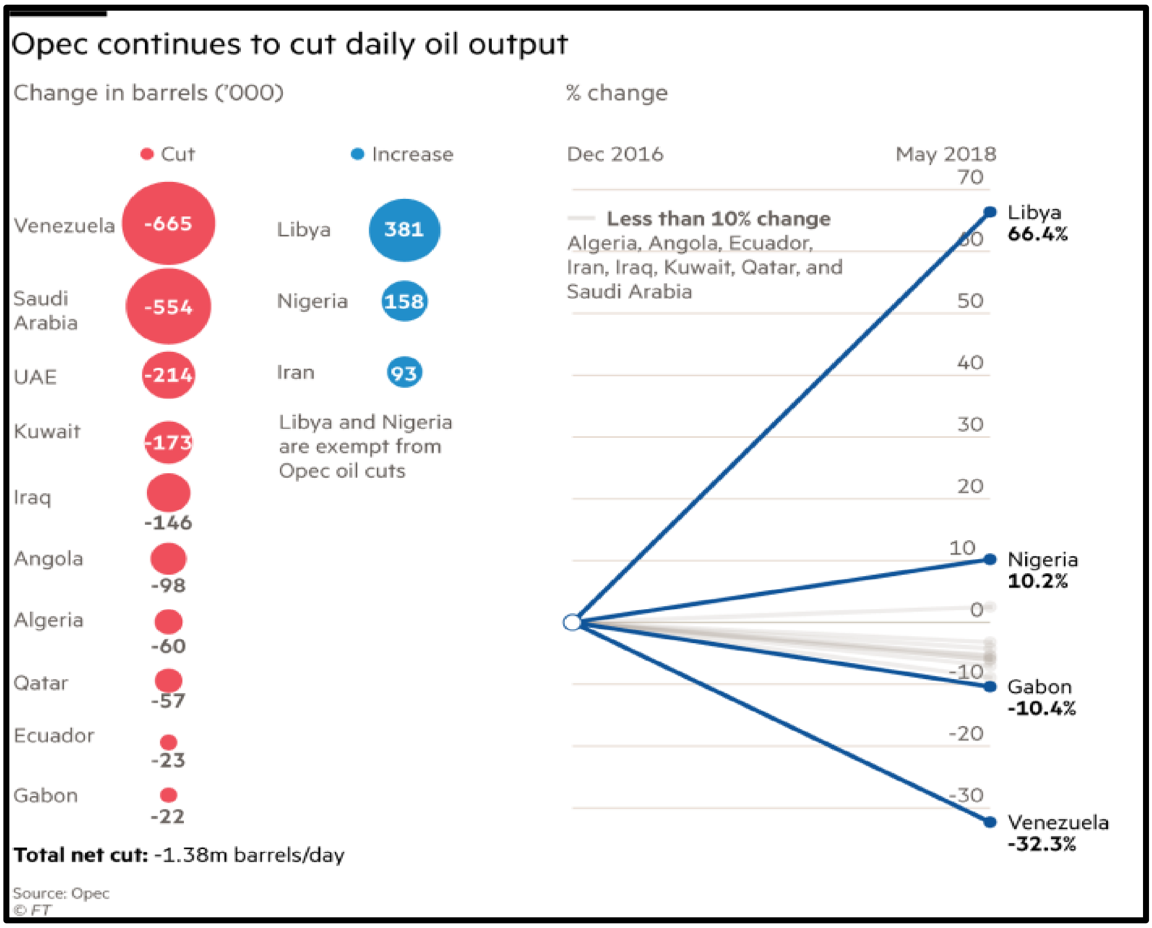
156 See Anjli Raval, 'Non-OPEC Oil Production Growth Predicted Higher than Expected – Cartel', FT, 18 January 2018 and idem ,'Returning to Heady Days': IEA Raises US Oil Growth Forecasts', FT, 19 January 2018.

157 See Anjli Raval, 'Saudi Arabia's Existential Crisis Returns as U.S. Shale Booms Anew', FT, 19 March 2018.

158 See idem, 'OPEC Revises Forecast for Non-Cartel Output for fifth Straight Months', FT, 12 April 2018.

could decrease the oil price in the second half of 2018 and 2019 down to US$40-45. Some experts would even not excluding lower prices down to US$30 when the OPEC and Russia would fail to agree on another extension of their oil production curb.[159]

Figure 16: OPEC: Extended Global Oil Output Cut (05/2018)



Source: FT 2018

While Russia has based its state budget calculations initially on a breakeven price of US$40 and meanwhile of US$53 per barrel to survive economically[160], most other oil producers are dependent on even higher oil prices and a less diversified economy. Russia and Saudi Arabia ("OPEC+") seem currently be interested in 10-20 year collaboration of their oil production.[161] Thus far, the unexpected fall of Venezuela's oil production from 2.5 mb/d at the beginning of 2016 to just 1.36 mb/d in May 2018 had initially helped the cartel's agreed oil production cut to implement and enforce it.[162] But in June 2018, the

[159] See Martin Tiller, 'Is Oil about to Collapse,', Oilprice.com, 10 December 2017.

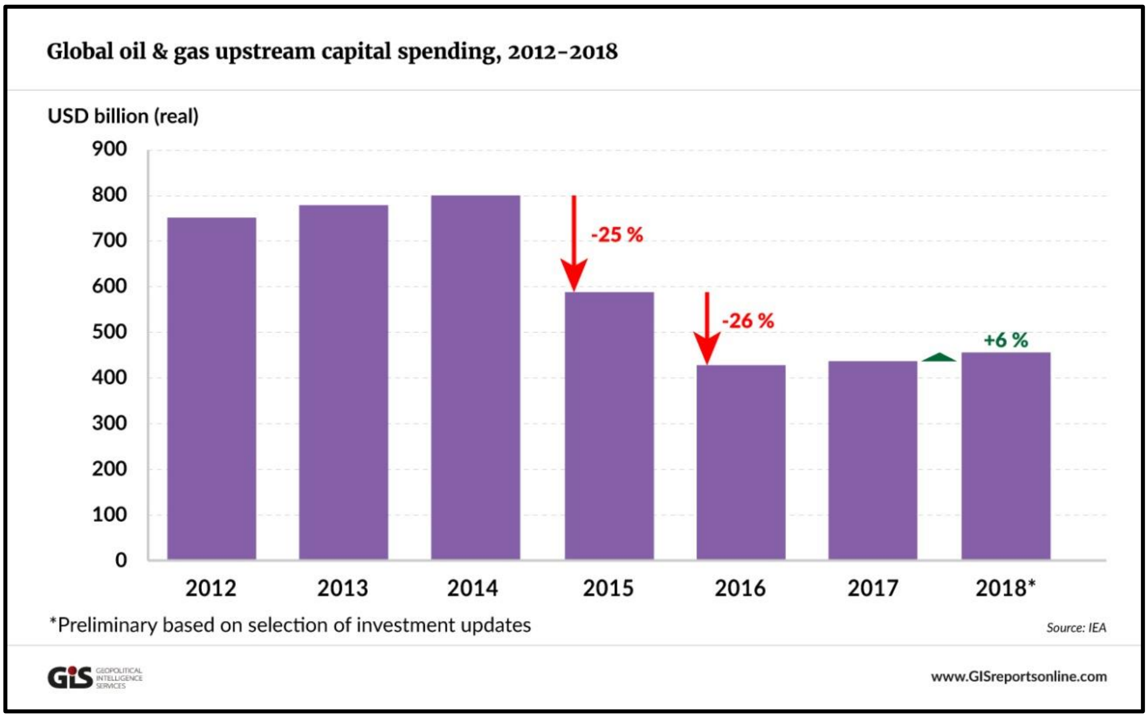
[160] See ibid.

[161] See also Anastasia Dmitrieva, 'Russia-Saudi-Led Oil Deal Makes Prices Rise Despite US Shale Output Boost', 27 December 2017; Amjli Raval, 'OPEC and Russia Considering 10-20 Year Oil Alliance', FT, 27 March 2018, and Summer Said/Benoit Faucon, 'An Oil Deal between Saudi Arabia and Russia Worked, Now What?', Wall Street Journal, 19 April 2018.

[162] See also David Sheppard, 'Five Main Drivers of Oil Prices in the Coming Year', FT, 13 December 2017.

worsening situation in Venezuela, together with new instabilities and declining oil production in Libya and Nigeria, it prompted OPEC to agree on a production increase of 1 mb/d.[163]

Figure 17: Decreasing Global Oil and Gas Upstream Investments (2012-2018)



Source: GIS 2018

The IEA and industry experts have also warned for 2019 that the past insufficient investments in new oil fields and exploration may already impact the market as the present oversupply on the oil markets might be replaced by a market tightness premium.[164] According to Saudi Aramco, the global oil and gas industry needs to invest more than US$20 trillion over the next 25 years to meet the global oil demand and to compensate the natural decline in the old developed fields.[165]

3.2.2 The Expansion of Natural Gas and LNG

These manifold uncertainties of the future global energy and oil demand are not only linked with the speed of a global energy transition, the expansion of renewables, the future climate change mitigation policies as well as the concrete potential of energy efficiency gains but also to the global gas consumption – in particular in Europe and Asia. In contrast

163 See also Nick Butler, 'Issues beyond OPEC will Drive Oil Prices in Coming Years', FT, 24 June 2018.
164 See Ed Crooks, 'Schlumberger Profit Tops View, Expects Oil Sector Spending to Grow', FT, 19 January 2018; Anjli Raval, 'IEA Warns of Potential 'Supply Gap' ahead of Key OPEC Meeting', FT, 13 June 2018, and Carole Nakhle, 'Global Competition for Upstream Oil and Gas Investment', GIS, 22 May 2018..
165 See 'Global Oil Sector Needs $20 Trillion Investments over 25 Years: Aramco CEO', Reuters, 6 March 2018.

to the IEA and the European gas industry, for instance, the European Commission hopes to decrease its rise of gas consumption by enhancing its energy efficiency efforts up to 20% by 2020 and 32.5% by 2030. An even faster transition to a cleaner energy mix might further decrease its overall gas consumption as well as its import needs – questioning the '*golden age of gas*' for Europe.[166]

Like the global oil market during the last decade, the global gas markets have undergone dramatic changes since 2010, leading to a present worldwide oversupply on the markets, a significant decline of gas prices and a shifting business environment with new rules, legislation and contract schemes. In general, the previous gas 'sellers' market' have been transformed to '*buyers markets*', changing the power balance from gas producers and exporters to gas importers and buyers in the light of a global gas glut. These changes on the global gas markets are primarily the result of two revolutions: (a) the shale gas revolution in the U.S., and (b) an often overlooked (rather creeping) revolution of the LNG-markets. Both revolutions are to a large extent the result of newly emerging technologies, which had wide-ranging strategic impacts on global markets.[167]

The U.S. shale gas revolution and its resiliency have been unprecedented during the last years. While in the period of 2000 to 2007, total US natural gas production increased by less than 1%, in the following decade from 2007 to 2017, the total gas output grew about 40%.[168] Once foreseen as becoming the worldwide largest LNG importer, the U.S. has become last November a net exporter of natural gas for the first time in almost 50 years. In 2011, it already became the world's largest gas producer surpassing Russia. The new Trump-administration seeks to fasten the national gas production and exports for achieving '*complete US energy independence*' by revising environmental legislation and taxes for U.S. energy companies. In this light, some observers have speculated that the U.S. may already become by 2019 the world's largest LNG-exporter.[169]

The first cargo of LNG from the U.S. Gulf Coast started in February 2016 to Brazil. Only four cargoes were sent to Europe in 2016: to Portugal, Spain, Italy, UK (Scotland) as well as two shipments to Turkey as the demand in South America, the Middle East and India had been stronger than expected. In 2018, the U.S. may already become the third largest LNG exporter as it can rapidly response to market price signals due to its unique contractual

166 See IEA, 'Are We Entering a Golden Age of Gas?', World Energy Outlook 2011. Special Report (Paris: IEA/OECD, June 2012).

167 See F. Umbach, 'Rising U.S. LNG Exports Could Lead to European Gas Price War', GIS, 21.2.2017; Rudolf Huber/Frank Radtke, 'Schlachtfeld Europa: LNG trifft auf Pipeline Gas – ein Preiskrieg?', in: Energy and Geopolitics. Monthly Report. Berlin,, No. 1/2016, March 2016, S. 35-39 und Sylvie Cornot-Gandolphe, 'The US Natural Gas Exports. New Rules on the European Gas Landscape', IFRI, June 2016.

168 See Daniel Yergin/Samuel Andrus, 'The Shale Gale Turns 10', p. 4.

169 See F.Umbach, 'The Limited Global Impact of Trump's 'America First' Energy Policies'.

structure of its exports. U.S. LNG exports are expected to increase from 41.1 mt/y (~56 bcm) in 2016 up to 50-62 mt/y (~85 bcm) with its five LNG export terminal projects by 2019 and may increase further to more than 120 bcm/y by mid-2020, exceeding those of Australia.[170] According to the latest forecasts, total U.S. production of natural gas will grow by another 60% during the next two decades.[171] In June 2018, the number of Drilled-but-Uncompleted (DUCs) shale wells has accounted a new record high of 7,943. They can quickly be deployed for additional production and are an indicator for forecasts of future production.[172]

The present oversupply of the global gas markets is the result not just of the rapidly increasing worldwide gas production, but also of the slower economic growth in China and India, increasing energy efficiency, the restarts of nuclear reactors in Japan as well as South Korea, and the strong position of cheap coal in the region.[173] Asia is the world's biggest consumer of LNG. Japan and South Korea consume a combined 125 mt/y of global LNG exports and account for 70% of all Asian LNG imports.[174]

While the IEA and others have forecasted a moderate increase, stagnant or even a declining global oil demand by 2040, the worldwide natural gas demand is considered as the only fossil fuel that will experience substantial growth by 45%. The U.S. might add some 300 bcm over the next 25 years, followed by China with 200 bcm and Russia as well as Iran with nationally another each 145 bcm. The present gas oversupply on the world's largest gas market will last for a few years as another 140 bcm of LNG capacity is currently under construction and will enter the markets soon.[175]

While the growth rate by 2020 is dominated by the U.S. and Australia, the production growth might be much more diversified afterwards, with East Africa and Argentina becoming new major gas producers and exporters alongside of rising production in the Middle East, China and Russia. The share of natural gas in the world primary energy mix will increase from 22% in 2016 to 25%, becoming the second-largest energy resource in the global energy mix after oil (27%) and ahead of coal (22%) in the IEA's major 'New Policies Scenario'.[176]

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170 See F. Umbach, 'Rising U.S. LNG Exports Could Lead to European Gas Price War'.

171 See Daniel Yergin/Samuel Andrus, 'The Shale Gale Turns 10', p. 4.

172 Peter Stewart, 'US Hydrocarbons Continue their Relentless Rise'.

173 To the global and in particular Asian (i.e. China) coal developments see F. Umbach/Ka-ho Yu, 'China's Expanding Overseas Coal Power Industry – New Strategic Opportunities, Commercial Risks and Geopolitical Implications', EUCERS-Strategy Paper No. 11, September 2016, 64 pp. and F. Umbach, 'The Future Role of Coal: International Market Realities vs. Climate Protection?', EUCERS-Strategy Paper Six, King's College, London, May 2015, 66 pp.

174 See F. Umbach, 'Rising U.S. LNG Exports Could Lead to European Gas Price War'.

175 See IEA, 'WEO 2017', pp. 333 ff.

176 See ibid., and p. 648.

The worldwide LNG trade has increased in volumes and shares versus global gas pipeline transports. It has become more standardised and shipped by an ever increasing pool of market players: rising from 9 importing and 8 exporting countries in 1990 to 34 importing and 19 exporting countries in 2015. New price indices are no longer been tied exclusively to the oil price, but have become more destination flexible and weakened linkages to oil prices by reflecting more market realities. The global pricing formulas have shifted away from oil-indexation from around 76% for contracts signed before 2010 towards more gas-to-gas linkages of around 50% of newer contracts. Fixed destination clauses in LNG contracts declined from 60% in 2014 to 40% in 2015. Technological innovation - such as the modularisation of liquefaction plant facilities and small-scale Floating Storage Regasification Units (FSRU) - has contributed to the LNG revolution.[177]

At present, Qatar is the world's largest LNG supplier, rivalling with Australia. Qatar seeks to maintain is world's status by having lifted its self-imposed development moratorium on its North Field. But by the mid-2020s, their leading position as the world's largest LNG exporters might be replaced by the U.S. becoming the leading global LNG supplier. The market share of LNG versus pipeline gas will increase of presently 39%% in 2016 to around 60% by 2040.[178]

The rising LNG supplies and trading opportunities will help the EU to diversify its gas imports though Russia will remain the EU's largest gas supplier. In contrast to the past, the future gas demand of the EU by 2040 might be around the same as of today (450 bcm annually). However, given its shrinking own gas production by around 50% to 65 bcm per year, the gas import demand might increase up to 390 bcm (+60 bcm) by 2040.[179] However, this increase is far below what the IEA, the European gas industry and many experts forecasted until 2010 (>500 bcm). According to other estimations, the EU's new energy security strategy and agreed efficiency and energy conservation efforts agreed in 2014 will further lower its gas import demand from Russia by another 12% by 2030.[180] But the EU's concerns on its gas import dependence on Russia have increased again during the last two years, as Europe's gas imports from Russia have climbed up again with 8% in 2017 towards the previous year, whereas its indigenous gas production have equally declined faster due to the shrinking production of the Groningen gas field in the Netherlands, which will completely end by 2030.[181]

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177 See F. Umbach, 'Rising U.S. LNG Exports Could Lead to European Gas Price War', GIS, 21 February 2017.

178 See IEA, 'WEO 2017', pp. 367 ff.

179 See ibid., pp. 352 ff.

180 See Christian Oliver/Pilita Clark/Henry Foy, 'EU Climate Change Deal Seen as Blow to Russia Exports', FT, 25-26 October 2014.

181 See also Andreas Walstad, 'Europe Imports More Gas to Meet Demand', www.interfaxenergy.com, NGD, 25 April 2018, p. 4.

Globally, the EU might remain the world's largest gas importer - ahead of China, which will become the second-largest gas consumer behind U.S. The Asia-Pacific region might account for around 85% of the global growth in net imports, highlighting a major shift in gas flows from the Atlantic basin to Asia. The shift will also be the result of new importers in South and Southeast Asia as well as their significant gas demand growth.[182]

China will remain the biggest wildcard for balancing LNG supply and demand in the region and globally. If China's expansion of its domestic gas production will prove to be insufficient and result in a much higher gas import demand, it might lead to higher gas prices in the region compared with those in Europe. It would make U.S. LNG exports to East Asia more profitable and decrease those LNG exports to Europe. In this case, a supposed price war between U.S. LNG exports and Russia's gas pipeline supplies will hardly take place in Europe.[183]

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182 See IEA, 'WEO 2017', pp. 355 ff.

183 See again F.Umbach, 'Rising U.S. LNG Exports Could Lead to European Gas Price War'.

4 Digitalisation of the Global Energy Sectors – An Overview and its Five Geopolitical Implications

4.1 The Cybersecurity Dimensions of the Digitalisation of the Energy and Electricity Sectors

At present, newly emerging cyber threats are worse than ever and the overall cybersecurity readiness during the 10 years has not sufficiently improved despite political and public awareness building and efforts of the industries to enhance their cyber defence and preparedness. In 2016, cyberattacks were estimated to cost global businesses around US$450 billion (bn) – with single events costly like major hurricanes.[184] Europol's 2017 '*Internet Organised Crime Threat Assessment*' warned that the global scale, impacts and rate are unprecedented.[185] Others have predicted that cybercrime damages will cost around US$6 trillion by 2021.[186]

While warnings of '*Digital Pearl Harbour'*-attacks on critical infrastructures (CIs) are not new, the future situation might be more vulnerable than ever - particularly of highly industrialised countries such as the U.S., the EU member states, Japan and others.[187] The global cyberattack trends come along with new technologies of digitalisation, electrification of the transport and heating sectors, robotics and artificial intelligence, which will revolutionise the worldwide energy sectors and other industries. They will also create numerous new risks and vulnerabilities, particularly for the stable functioning of Critical Infrastructures (CIs) and their Industrial Control Systems (ICS) as well as supply chains. For experts, security of ICS and CIs is viewed in particular as dangerously lax.[188] New industrial-scale operating systems with security embedded in the hard- and software as '*built-in system*'-architectures with multiple protection layers rather than using safety and security envelopes to protect the system have only slowly been introduced in the operating

184 See Gökhan Erton, 'Cyber Events' Potential to be Costly like Major Hurricanes', 19 July 2017 (https://www.linkedin.com/pulse/cyber-events-potential-costly-like-major-hurricanes-g%C3%B6khan/).

185 See 'Europol: The Response to Unprecedented Cyberattacks 'not Good Enough', 28 September 2017 (https://www.scmagazineuk.com/europol-the-response-to-unprecedented-cyber-attacks-not-good-enough/article/696298/; accessed on 29 September 2018); Hannah Kuchler, 'Cost of Cyber Crime Rises Rapidly as Attacks Increase', FT, 8 September 2017.

186 See Jocelyn Aspa, 'Cybersecurity Trends 2017: Cybercrime Rise', Cybersecurity Investing News, 5 December 2017.

187 See also Taylor Armerding, 'How Likely is a 'Digital Pearl Harbor' Attack on Critical Infrastructure?', 18 August 2017 (https://nakedsecurity.sophos.com/2017/08/18/how-likely-is-a-digital-pearl-harbor-attack-on-critical-infrastructure/; accessed on 23 August 2017); Michael Imeson, 'Electricity Industry on Alert for 'Cyber Sabotage', FT, 8 November 2017; 'Hackers Gain Direct Access to Power Grid Controls', www.wired.com, 6 September 2017; Gordon Corera, 'If 2017 Could be Described as 'Cyber-Geddon', What Will 2018 Bring?', www.bbc.com, 30 December 2017.

188 See also Jim Ivers,'The Time to Focus on Critical Infrastructure Security Is Now', www.securityweek.com, 8 February 2018.

industrial infrastructures.[189] The widespread presence and rise of security vulnerabilities is also the result of a rapid and often premature adoption of digital technologies and '*Internet of Things (IoT)*'-devices. According to Lloyd's of London, an extreme disruptive cyberattack could cause up to US$120 bn of economic damage – more than natural catastrophes such as Superstorm Sandy in 2012.[190]

More efficient, resilient cybersecurity strategies need to be based on layered '*defence-in-depth'*-concepts with much more attention on mitigating disrupting cyberattacks and restoring the operational functioning of CIs in order to prevent any wider cascading impacts. The spread of cyberattacks over the past year has been unprecedented. The international response to those attacks is insufficient and needs to improve resilience cybersecurity measures. While the digitalisation of the energy sector and other industries alongside the electrification of the world's transport and heating sectors and the worldwide spread of (IoTs)-devices are revolutionizing business models and transforming daily lives, it will make the global economy even more vulnerable to even more destructive cyberattacks and its potential cascading impacts.

In September 2017, the international cyber security company Symantec revealed that a group of hackers, known as '*Dragonfly*', '*Energetic Bear*' or '*Berserk Bear*', attacked major energy (including electricity) companies in the U.S., Europe and Turkey and entered their operational systems. The believed Russian-linked hacker group is known since 2014 due to previous cyberattacks on the energy industry, which have compromised systems of more than 1,000 organisations in 84 countries over 18 months. The new hacking campaign (called "*Dragonfly 2.0*") had been monitored since late 2015. While these cyberattacks did not cause any power outages as another Russian hack on Ukraine's electricity system in December 2015 and in December 2016 (primarily in Kiev), in more than 20 cases, the intruders successfully gained access to the companies' networks. Symantec evaluated the recent attacks as "*political motivated*" and warned that even a cyberattack on a small energy company could threaten the entire power grid.[191]

Symantec's assessment followed another warning of the Federal Bureau of Investigation (FBI) and the US Homeland Security department in July 2017 that the US energy industry,

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189 See also F. Umbach, 'Critical Energy Infrastructure and Risk of Cyber Attack', in: KAS-International Reports, September 2012, pp. 35-66.

190 See Oliver Ralph, 'Extreme Cyber Attack Could Cause $12bn in Economic Damage', FT, 17 July 2017; Alastair Paterson, 'Mitigating Risk of Supply Chain Attacks', www.securityweek.com, 9 November 2017.

191 See Eduard Kovacs, 'Russia-Linked Hackers Target Control Systems in U.S. Energy Firms', www.security-week, 6 September 2017; idem, Eduard Kovacs, 'Utilities Fear Cyberattacks Could Cause Electric Grid Dis-ruptions: Survey'; 'Hackers Gain Entry into US, European Energy Sector, Symantec Warns', www.cnbc.com, 6 September 2017; Hannah Kuchler, 'Hackers Infiltrate Systems of Energy Companies', FT, 6 September 2017; AFP, 'UK Cyber Security Chief Blames Russia for Hacker Attacks', www.securityweek.com, 15 No-vember 2017;

including nuclear energy plants, was targeted by Russian hackers being interested in gaining access to the control systems of energy companies. They infiltrated the control rooms of various electric utilities for gaining the ability to cause blackouts and grid disruptions. Officially, only administrative and business networks were impacted, not controlling systems. Nuclear plants are often much more secure as their operational computer systems are completely separated from the corporate network and their ICS isolated from the open Internet.[192] But those cyberattacks on U.S. and European power grids have already been identified as the '*next battlefield*'. The U.S. Department of Energy (DOE) has established a new office last February to protect the national power grid and other infrastructure against cyberattacks and natural disasters.[193] It is also concerned that no longer electricity supplies and the power grid are targeted for disruption, but has supplies and gas infrastructures as well with automated attacks by using automated bots or modular toolkits, which makes those attacks less expensive and more effective. Compromising, disrupting and falsifying information of the pipeline communications systems can disrupt supplies, cause fires, spills and other life-threatening disasters and affect delivery and prices as well as various other industry sectors dependent on a stable gas supply.[194]

In June 2017, energy companies, bus stations, gas stations, metro systems, the international airport and banks in Kiev were targeted again by a wiper called '*NotPetya*' destroying all of the data for routine functioning. Ukraine's Interior Ministry called the cyberattack the biggest one in Ukraine's history. Ukraine, NATO and other cyber security experts concluded that it was created by a state actor. Indeed, Ukraine has become worldwide the hottest cyber front and a testing field and '*blueprint for what's to come*'. The worm spread to 64 countries and affected companies worldwide with losses of more than US$600 million. But no other country has comparably been impacted as Ukraine.[195]

In July 2017, a supposed state-sponsored cyberattack on Ireland's EirGrid, providing electricity across Ireland and Northern Ireland, had been reported, which had comprised

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192 See also Ellen Nakashima, 'U.S. Officials Say Russian Government Hackers Have Penetrated Energy and Nuclear Company Business Networks', Washington Post, 8 July 2017; 'Russians Hacked US Nuclear Plant Systems: Report', The Hill, 9 July 2017 and Gavin Bode, 'Russian Hackers Infiltrated Utility Control Rooms, DHS Says', Utility Dive, 24 July 2018.

193 See 'U.S. Department Forming Cyber Protection Unit for Power Grids', Reuters, 14 February 2018.

194 See also James 'Spider' Marks, 'Cybersecurity: The Next Great Battlefield', RealClearPolitics, 19 July 2018; Silvia Favasuli, 'Energy Companies Face Increased Risk of Cyberattacks', Realclearenergy.com, 20 July 2018. To the background also see F.Umbach/Uwe Nerlich, 'Asset Criticality in European Gas Pipeline Systems – Increasing Challenges for NATO, its Member States and Industrial Protection of Critical Energy Infrastructure', in: A.Gheorghe/L. Muresan (Eds.), 'Energy Security. International and Local Issues, Theoretical Perspectives and Critical Energy Infrastructures', NATO Science for Peace and Security Series – C: Environmental Security (Dordrecht: Springer 2011), pp. 273-303.

195 See also Luke Tenery et.al., 'From Plausible to Probable: Cyberattack Targets Ukrainian Financial Sector Using Stolen NSA Tools', Ankura Consulting, August 2017, and Matthias Williams, 'Ukraine Finally Battens Down its Leaky Cyber Hatches after Attacks', Reuters, 1 August 2017.

the routers of the state-owned power provider.[196] Symantec and many other experts recommended keeping operational systems separate from administrative computer networks.

Those sophisticated state-sponsored attacks on critical energy infrastructures are viewed as another confirmation of an increasing trend of larger-scale (and often state-supported) cyberattacks against critical infrastructures with impacts of their destruction and incapacitation, to compromise and undermine national security.[197]

Most private cybersecurity companies and international experts agree that the global cyber threat landscape is undergoing an accelerating pace of change and sophistication with even more destructive and evasive cyberattacks in a rapidly changing and complex IT security environment, coping with resource-strapped security investments.[198] Instead of investing sufficiently in its own cyber defence and preparedness such as to use internal recovery procedures, for many companies protection against ransomware has often been downgraded just to a question of economics, in which it is cheaper to pay the ransom to get the encrypted or destroyed data back. Given such a prevailing security culture and the success of '*WannaCry*'-virus last year, the question of future copycat attacks with more destructive impacts is just a question of time.

Around 70% of energy companies have been breached in 2016.[199] Many energy companies still rely on outdated, insecure operating systems and hardware. Investing in cybersecurity has still not the adequate priority and is still considered as a liability rather than one strengthening its future competitiveness towards their markets' rivals.

New technology developments are mostly considered to create numerous new risks and vulnerabilities for cybersecurity of CEIs. But technologies such as blockchain and AI can also enhance cybersecurity and resilience of CEIs. Furthermore, newly introduced government and EU regulations such as '*security of design'* and enhanced cyber hygiene can also strengthening them.

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196 See Graham Cluley, 'Attack on Ireland's State-Owned Power Provider Blamed on State-Sponsored Hackers', 26 July 2017 (https://hotforsecurity.bitdefender.com/blog/attack-on-irelands-state-owned-power-provider-blamed-on-state-sponsored-hackers-18675.html).

197 See also Justin Fear, 'Cyber Trends Defenders Can Expect to See in 2018', www.securityweek.com, 6 December 2017; Baral Perelman, 'ICS Cyber Security Predictions for 2018 – The Bad, the Ugly, and the Good', ibid., 19 December 2017; Cisco, '2017 Midyear Cybersecurity Report', July 2017.

198 See also Matthew Rosenquist, 'Technology Convergence is Driving Change to Cybersecurity', 13 November 2017 https://www.linkedin.com/pulse/technology-convergence-driving-change-cybersecurity-rosenquist/; accessed on20 November 2017), and Nicholas Henke/Paul Willmott, 'Digital Trends and Observations from Davos 2018', McKinsey&Company, 2 February 2018.

199 See Jeff Lefkowitz, 'Assessing Cyber and Physical Risks to Oil & Gas Sector', www.securityweek.com, 21 August 2017.

4.2 Prospects of the Electrification of the Transport Sector

In July 2017, British and French governments announced to outlaw the sale of petrol- and diesel-powered internal combustion cars by 2040. The Swedish carmaker Volvo had already pledged only to sell electric or hybrid cars from 2019. Also mayors of Paris, Madrid, Athens and Mexico City want to ban diesel vehicles from city centres by 2025. The German diesel scandal has also fuelled the debate by fastening a transition to electric cars in the years and decades ahead. A phase-out of combustion engines by 2030 could cost Germany's car industry and suppliers around 600,000 jobs as EV production requires up to 40% less manufacturing labour than cars with Internal Combustion Engines (ICEs). As the biggest-value items in EVs are batteries, part of the production and jobs would move from European suppliers to China.[200] But even Germany's car industry is now moving towards EVs. Other automakers such as Toyota and Mazda are partnering for developing EVs.[201]

The unfolding electricity revolution in the worldwide transport sector highlights another major energy shift and game changer together with the digitalisation and autonomous car driving. They can displace the oil's major role especially in motor vehicles. More than 50% of the global oil market is based on road transportation. But today only 3.1 million (but a 54% compared with 2016) or 2.5% of the world vehicles fleet (of 1.3 bn cars) is based on electric vehicles (EVs). Neither the European car industries nor the governments or existing infrastructure for EVs (i.e. universal supercharging points, upgraded power grids on a national and local level) are currently really prepared for a faster transition.[202] Up to now, EVs have been much more expensive, a shorter driving distance and no real infrastructure in place for recharging the batteries – in cities and even less on the countryside and highways. Even by '*smart charging*' opportunities in place, the additional investment costs of the peak of worldwide electricity demand for EVs have been calculated at US$100-280 bn in electricity infrastructure.[203]

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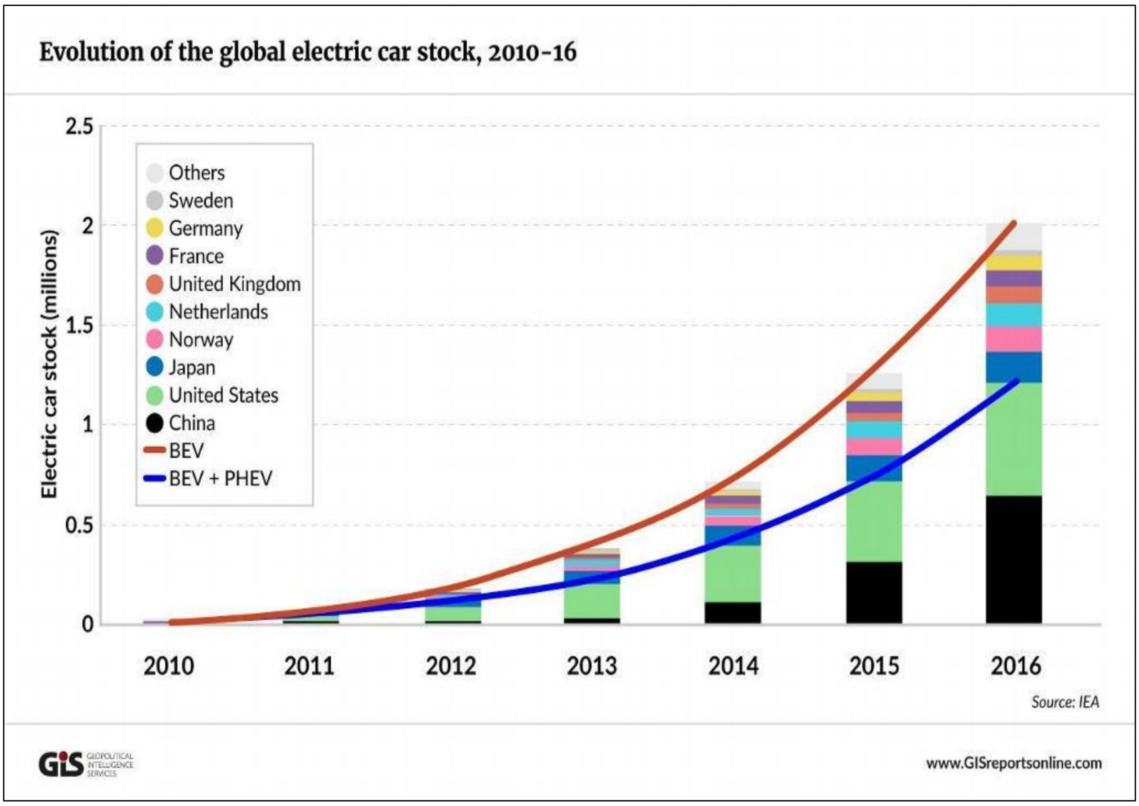
200 See Peter Campbell/Patrick McGee, 'Electric Car Dream Collides with Reality on Profits', FT, 15 September 2017; 'Electric Cars Need to Take Steam out of Kettles', FT, 1 September 2017; Amy Myers Jaffe/Lewis Fulton, 'How Electric Vehicles Could Take a Bite out of the Oil Market', www.energypost.eu, 2 August 2017.

201 See Zac Estrada, 'Toyota and Mazda are Making a New Company to Develop Electric Cars', The Verge, 28 September 2017.

202 Finance ministries, for instance, have to replace the lost revenue from fuel tax for petrol and diesel cars and to adopt new incentives as well as regulations for the much needed investors of the power infrastructure for EVs. Supercharging points, for instance, are relatively expensive and also imply peak-time charging with higher electricity prices. They may require expensive electricity transmission to remote locations - at least in countries with large territories and a lower population density. In UK, EVs might create an additional electricity demand as much as 18 GW (the equivalent of almost six Hinkley Point nuclear power stations) at peak times by 2050 –Nathalie Thomas, 'Electric Cars Forecast to Create Extra 18GW Demand for Power in UK', FT, 13 July 2017.

203 See IEA, 'Digitalisation & Energy', p. 95.

Figure 18: Evolution of EVs 2010–2016



Source: GIS 2017

In contrast to the US$100,000 Tesla S car, the much cheaper Tesla-3 EV went on sale for US$35,000 in July 2017. Passenger vehicles currently account for 28% of global final energy demand, 26% of global oil demand (total transport sector: 54%) and 23% of the worldwide CO_2 emissions – more than aviation, freight shipping and petrochemicals combined.[204]

Given the manifold problems described above, OPEC, many oil companies as well as energy and industry experts are still sceptical and believe that it will take a longer time to displace motor vehicles.[205] Projections significantly differ in regard to the future global share of EVs due to uncertain forecasts in particular for China, which might be boosted to more than 6 m cars by 2030 (or 60% of the worldwide sale).[206] Last year, nearly 580,000 EVs (an increase of 72% towards 2016) had been sold in China – accounting for half of all sold EVs globally.

204 See ibid., p. 35.

205 See also Peter Stewart, 'IEA at Odds with Industry Consensus on EV Growth', www.interfaxenergy.com, NGD, 22 March 2017, p. 7; Schalk Cloete, 'Why the Electric Car Hype is Overblown', www.energypost.com, 15 September 2017; Carole Nakle, 'The Long Road ahead for Electric Vehicles', GIS, 26 September 2017; Neill Collins, 'Politics not Economics Propels Electric Car Growth', FT, 7 July 2017; Oliver Arnhold et. Al., 'Turning Around the Transport Sector: What Effects do Battery and Fuel Cell Vehicles Have on our Energy System', Reiner Lemoine Institut gGmbH, Berlin, gwf Gas + Energie 10/2016.

206 See also F. Umbach, 'Four Implications of Electric Mobility'; Andrew War/Leslie Hook, 'Oil Majors Plug into Electric Vehicle Technology', FT, 31 May 2018; Tom DiChristopher, 'Electric Vehicles will Grow from 3 Million to 125 Million by 2030, International Energy Agency Forecasts', CNBC, 30 May 2018.

China is also leading in bringing electric buses on the street with globally 100,000 in 2017.[207] Electric buses may already reach cost parity with conventional buses next year. They might account for up 84% of China's bus market by the late 2020s, whereas the rest of the world may reach an 80% target of the global municipal bus fleet being electric only by 2040.[208] But several forecasts have predicted that the upfront costs of EVs will become competitive on an unsubsidised basis within the period of 2022-2024.[209]

Against the background of highly different forecasts of EVs, it is hardly surprising that estimates for saving a global oil demand differ significantly, too. BNEF expects that EVs will cut 2 mb/d in the short-term perspective by 2023 with a continued annual 60% global growth of EVs and 2028 with a moderate global EV growth.[210] In its long-term analysis, it will cut 8-13 mb/d from the worldwide oil demand by 2040.[211] One major reason of the more sceptical view of the IEA and others is not related just to the EV-revolution but to the growing demand in worldwide aviation, freight and the petrochemical industry as well as in emerging countries (+60% by 2040).[212] OPEC has forecasted the global oil demand is rising from 95.4 mb/d in 2016 to 102.3 mb/d by 2022 despite the expansion of EVs.[213]

Other experts caution the prospects for EVs as even in best-case scenarios of worldwide 200 m EVs by 2030; it will contrast with 1.8 bn conventional vehicles on the road. While the global oil demand might peak around 2025/2030, afterwards the oil demand might still stay on a longer plateau keeping oil demand around 90-100 mb/d and 80 mb/d by 2040. The 3 m EVs today displaced just about 0.38 mB/d. By 2030, even a best-case the expansion of the worldwide fleet of EVs and e-buses might decrease not more than 2.57-4.74 mb/d.[214]

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207 See IEA, 'Global EV Outlook 2018.Towards Cross-Modal Electrification'(Paris: OECD/IEA, 2018).

208 See Nicholas Cunningham, 'EVs to Make up Third of Market in 2040, E-Buses to Dominate End 2020s', energypost.eu, 28 May 2018.

209 See ibid., Tom Randall, 'Here's How Electric Cars will Cause the Next Oil Crisis', Bloomberg, 25 February 2018, and Karel Beckmann, 'EVs are Entering Crucial Phase – and beginning to Transform Electricity Markets' Energypostweekly.eu, 5 June 2018.

210 See Tom Randall, 'Here's How Electric Cars will Cause the Next Oil Crisis'.

211 See Chris Midgley, 'Reports of Oil Demand's Death Have been Greatly Exaggerated', FT, 2 March 2018; 'The Future is Supercharged', World Energy Focus, No. 36, August 2017, p. 5 f.; Geoffrey Styles, 'Can China's EVs Lead to Peak Oil Demand', www.energypost.eu, 28 September 2017; Andrew Ward, ''Rise of Electric Cars Challenges the World's Thirst for Oil', FT, 8 August 2017; idem, ''Big Oil' Dismisses Predictions of Collapse in Demand', FT, 10 July 2017; idem, 'BP Says Oil Demand to Peak by late 2030s', FT, 20 February 2018; Min Zhu, 'The Oil Price is Living on Borrowed Time', FT, 19 July 2017; Salman Ghouri/Andreas de Vries, 'Wake up Call for Oil Companies: Electric Vehicles Will Deflate Oil Demand', www.energypost.eu, 28 March 2016; Pilita Clark/Andrew Ward/Neil Hume, 'Oil Groups 'Threatened' By Electric Cars', FT, 18 October 2016; David Yager, 'Electric Vehicles no Threat to Oil Prices Anytime Soon', Oilprice.com, 27 July 2017.

212 See also IEA, 'WEO 2017', pp. 153 ff.

213 See Amjli Raval,'OPEC Sees More Global Oil Demand Despite Electric Cars', FT, 7 November 2017.

214 See Nick Cunningham, 'EV Sales to Triple by 2020', Oilprice.com, 30 May 2018.

Another reason is that OPEC is much more concerned about the '*shale revolution 2.0*' with '*digital oilfields*' (see Chapter 4.3.1).[215] The efficiency gains of this '*digitally driven hydrocarbon tsunami'* may add five times more oil to world markets than 100 million EVs would take off the markets. In this light, the presently much discussed 'peak oil demand' scenario might rather be replaced by a '*peak oil price*'-development, which could even slow down the EV-revolution due to the market oversupply and very low oil prices. But the return to higher oil prices (to more than US$75 per barrel) will encourage global investors to spend more risk capital in the development of EVs and related infrastructures.

Figure 19: Projections of the Global Rise of EVs in the Transport Sector by 2040

Projections of EVs' Global Rise in the Transport Sector:

- IEA:
  - total number in the world will rise from 3 million (m) today to 9-20 m by 2020, and up to 125- 220 m (130 m battery EVs and 90 m plug-in-hybrids) by 2030;
  - total cars by 2035/2040: roughly 2 bn.
- BP: number of EV will reach 300m by 2040 (~15% of global car fleet);
- OPEC: increased its projections of the global share of EVs from 6 to 22% by 2040.
- Bloomberg New Energy Finance (BNEF):
  - EV sales topping 11 m by 2025 and 30 m by 2030.
  - 2040: EV sales hitting 60 m (55% of global market for light-duty vehicles) and around 559 m EVs will be on the road (a third of worldwide cars);
  - China as the world's largest EV market will account for almost 50% of global EV sales between today and 2025, and 39% in 2030
- Total: could make up to 15-30% of new vehicles by 2030.
- Carbon Tracker/Grantham Institute at Imperial College London): more than 50% of the global number of cars by 2040.
- IMF: share could even reach 90% by 2040 (fast-adoption scenario).
- Stanley Morgan: EV rising up to 500 m by 2040 and would surpass the number of ICE cars by 2050.

Source: F. Umbach 2018 based on various sources.

A faster deployment would certainly decrease the worldwide oil demand and could support the climate change mitigation efforts of the Paris accord. But if the scientific results of lifecycle analyses are taking into account by including emissions of the battery production for EVs, the overall climate balance is very questionable. Firstly, the total emissions of EVs depend very much on the electricity mix that fuels the EVs. This is still a huge problem in China, Germany and other countries as their electricity generation is still largely on coal-based power plants. But with the expansion of RES, the CO_2 balance will certainly improve

[215] See Mark P. Mills, 'Do Electric Vehicles Spell OPEC's Doom', RealClear Policy, 9 August 2017.

over time.[216] Secondly, as a lifecycle emissions study of the IVL Swedish Environment Research Institute concluded the battery production creates tons of CO_2 before the battery leaves the factory. As a result, larger diesel cars can drive 8 years of absorbing the CO_2 of the battery production for Tesla S and 2.7 years of those of the battery production for the Nissan Leaf.[217] But another study concluded that EVs emit significantly less greenhouse gases over lifetimes than diesel engines even when they are powered by the most carbon intensive energy mix (such as in Poland). However, is based on the condition that no battery manufacture and electricity supply is taking into account as no battery manufacture currently exists. As the study admits by taking battery manufacture outside the EU into account, GHG emissions (GHGE) are not so impressive. But technological improvements of battery chemistry, the reuse of batteries for stationary storage purposes[218], and the development of a recycling industry for EV batteries will improve the future sustainability and environmental GHGE of the battery production and the overall EV emissions towards ICEs.[219]

Supply chains from mining to end products are often not fully transparent despite many efforts to improve industry practice for responsible and ethical sourcing. In developed countries, the environment might get cleaner with EVs and an expanded battery use for EVs and RES. The opposite might be true in the developing countries producing the raw materials for the rich world as environmental and social costs are increasing with expanded mining of these CRMs. These countries may face even more water shortages, rising emissions and toxic pollution and other environmental problems, and have to cope with human rights abuses, international labour standards and rights any child labour.

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216 See Lukas Bay, 'Die umstrittene Klimabilanz des Elekroautos', Handelsblatt, 6 July 2017; Charles Glover, 'Pollution Studies Cast Doubt on China's Electric-Car Policies', FT, 20 May 2018; Henry Sanderson, 'Electric Car Growth Sparks Environmental Concerns, FT, 7 July 2017; Johannes Winterhagen, 'Schützen Elektroautos das Klima?', Frankfurter Allgemeine Sonntagszeitung, 3 September 2017.

217 See Johan Kristensson, 'New Study: Large CO2 Emissions from Batteries of Electric 3Cars',The Global Warming Policy Forum, 12 June 2017; 'Umweltsau Tesla? 17 Tonnen CO2 bei der Produktion der Akkus? Es ist komlizierter', 4 August 2017 (https://www.mobilegeeks.de/artikel/umweltsau-elektromobilaet-akkus-co2/; accessed on 31 August 2017); Philipp Vetter, 'Zweifel am sauberen E-Auto', Die Welt, 22 June 2017,p. 9; 'E-Auto-Batterie', Die Welt, 14.6.2017; Patrick McGee,'Electric Cars' Green Image Blackens beneath the Bonnet', FT,8 November 2017, and Anthon Watts, 'Tesla Car Battery Production Releases as Much as CO2 as 8 Years of Gasoline Driving', 20 June 2017 (https://wattsupwiththat.com/2017/06/20/tesla-car-battery-production-releases-as-much-co2-as-8-years-of-gasoline-driving/; accessed on 23 August 2017).

218 Nissan batteries, for instance, are already used for stationary storage options, which can extend the lifetime of batteries before they are being recycled. It will also reduce the emissions of the battery production as their amortisation over a longer period is higher and decreased the demand for critical metals.

219 See European Commission, 'Electric Vehicle Life Cycle Analysis and Raw Material Availability', Briefing, Transport & Environment, Brussels, October 2017 and Arthus Neslen, 'Electric Cars Emit 50% Less Greenhouse Gas than Diesel, Study Finds', The Guardian, 25 October 2017.

Given China's heavy reliance on coal to more than 60% of its energy mix, the lifecycle GHG emissions of cars produced in China, taking its battery manufacturing into account, is even more problematic.[220]

Geopolitically, the world might be able to reduce its oil import dependence from the unstable Gulf region and the Middle East. But the world will become increasingly dependent on China's exports of rare earth, other CRMs, and batteries. No other country has offered so many subsidies for its more than 200 companies selling and making either partially or fully EVs.[221] The number of cars has soared from 76 m cars in 2009 to 172 m on the road in 2015. The annual production of cars in Chinas rose up to 24.5 m (U.S.: 12.1 m) in 2015. While its environmental policies have fuelled the EV-revolution in China, its support is much more driven by its industrial policy such as 'Made in China in 2025' to create national champions in 10 high-tech industries. It is already the world's largest car market and has set ambitious goals by 2025. China's automobile company Chongqing Changan announced last October to stop selling combustion-engine cars by 2025.[222] The plan should help to make China's economy less dependent on foreign technology (viewed as a national security risk) and instead boost the country to become the world's leading technology superpower.

At present, China is subsidizing the research and development of electric cars with more than US$1 bn and has set a target of 5 m new EVs or other new energy vehicles to be on the road by 2020. In September 2017, Beijing declared that it might follow UK and France in phasing-out ICEs by 2030. It is already consolidating its market by slashing subsidies on car sales by 20% and seeks to phase out them completely by 2020.[223] At the end of 2017, China announced to phase out all local subsidies.[224] China also plans to build 4.8 m charging stations, which will cost around US$19 bn.[225] At the same time, Western automakers feel to be forced to strengthen their market engagement in China and to build their EVs increasingly in China, which has both the most CRMs and the battery manufacture

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220 See Mark Buchanan, 'China's Electric Cars are Actually Pretty Dirty', Bloomberg, 5 July 2017.

221 See Ken Davies, 'The Greening of China's Auto Industry', GIS, 7 March 2017; Charles Clover, 'Subsidies Help China Sell the Most Electric Cars', FT, 24 October 2017, and Keith Bradsher, 'China Hastens the World Toward an Electric-Car Future', NYT, 9 October 2017.

222 See 'China: Automobile Company to Stop Selling Combustion Engine Cars in 2025', Stratfor.com, 19 October 2017.

223 See Emily Feng/Charles Clover, 'China Puts a Stop to Electric Car Gold Rush', FT, 27 June 2017; Daniel Ren, 'China's Green Car Sales Hit Speed Bump as Beijing Cuts Subsidies', South China Morning Post, 27 July 2017; Joe McDonald, 'China Sets Target for Electric Car Quota, but Delays Rollout', The Associated Press, 29 September 2017; 'Steve Hanley, 'China Pushes Electric Car Plan Back to 2019', Cleantechnica, 30 September 2017.

224 See Ying Tian/Heng Xie/Yinan Zhao, 'China Plans to Kill Local Subsidies for Electric Cars', Bloomberg, 18 December 2018; 'China: Beijing to Halt Electric Vehicle Subsidies', Stratfor.com, 22 November 2017; Charles Clover, 'China's Electric Car Push Set to Trigger 'War of Attrition', FT, 15 November 2017;

225 See Charles Clover/Sherry Fei Ju, 'Range Anxiety Powers China to Invest in Electric Car Charging Points', FT, 3 December 2017.

under its strategic control. Already before, foreign car makers had to hand over their technological know-how in exchange for access to its giant market.[226]

4.3 Digitalisation and Its Impacts on Energy Supply Security

4.3.1 Digital Oil and Gas Fields – The Transformation of the Oil and Gas Industry

In many ways, the energy sector has always been at the forefront of adapting technological innovations. Power utilities have proved to be '*digital pioneers*' since the 1970s by using technologies to improve grid management and operations, whilst oil and gas companies used digital technologies for modelling exploration and production assets.[227]

During the last decade, the worldwide energy markets have already undergone tremendous changes. They are the result of the U.S. shale gas revolution, the slowing of the global energy demand and the expansion of renewables. They themselves are the consequence of technological innovations with wide-ranging disruptive impacts on global energy markets. They are also shaping new relationships inside the energy sector itself, but also with companies from other industry sectors. The fastening processes of digitalisation and electrification have also led to rising competition among energy companies and energy companies facing new competitors from outside (i.e. IT companies), which were not part of the industry earlier. This is even true for the oil and gas companies, which have created strategic alliances and partnerships with IT companies (such as between the oil service company Halliburton and Microsoft). It signals that a new digital era in energy has arrived and may fasten even more radical changes in the forthcoming years, which encompasses all energy demand sectors.[228]

Confronted with the global decarbonisation efforts to mitigate climate change and the rise of green technologies, oil and gas companies have begun to invest in green technologies themselves through external acquisitions or through in-house investment shifts as renewables (i.e. solar and wind power), as well as energy storage options, have become much cheaper and competitive. It also offers the companies to diversify their energy sources and businesses. It has led to a new class of hybrid energy enterprises, comprising and reconciling fossil fuels as well as renewables.[229] The oil and petroleum industry places

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226 See Charles Clover et.al., 'Renault Nissan Agrees Deal to Make Electric Cars in China', FT, 29 August 2017, and Keith Bradsher, 'China's Electric Car Push Lures Global Auto Giants, Despite Risks', NYT, 10 September 2017.

227 See also IEA, 'Digitalisation & Energy', pp. 65 ff.

228 See also 'Blockchain Enters the Upstream', Upstream Intelligence (upstreamintel.com), 14 May 2018; 'Machine Learning Gains Renewed Momentum as Oil Companies Tap into AI', ibid., 14 May 2018, and 'Russian Oil Producer Goes Digital; GE and Noble Digitize Their Marine Operations', ibid., 14 May 2018.

229 See also 'In the Energy Sector, a New Kind of Hybrid Emerges', Stratfor.com, 16 February 2018.

its hopes primarily on the expanding gas sector as a transition bridge to a low carbon future. In the mid-and longer-term perspective, however, it might be a risky game phasing out of all fossil fuels to limit the worldwide warming to 1.5-2°C. The global energy transition might take place much faster than the oil and gas industry expects.[230] In Europe, Royal Dutch Shell and Total have also begun to invest in the further expansion into the electricity supply chain (including in advanced battery technology for storing electricity) and building a retail energy business in Europe for an integrated power supply chain from generation to retail supply, and, therewith, challenging traditional power companies.[231] In Germany, being at the forefront of an '*Energiewende*', the two biggest utilities, RWE and Eon, have split their growing renewables portfolios into separate companies to insulate from the competition of their conventional power businesses.[232] In March 2018, both companies agreed to the acquisition of the renewable company Innogy by Eon and a series of asset swaps that will give Eon control of regulated energy networks and retail customers, become the leading energy producer with ownership of the renewables businesses of both Eon and Innogy.[233] These strategic changes are also leading to geopolitical shifts, and changes as the prospects of a '*peak oil demand'* and '*stranded assets*' of fossil fuel projects have led to new, unusual partnerships such as between Middle East and Asian National Oil Companies (NOCs).[234]

In the U.S., oil and gas companies have been more reluctant to invest in green technologies as part of a '*wait-and-see*'- and the '*least value-destructive*'-approach, which bet their hopes in the 'shale gas revolution 2.0'. In 2017, the U.S. shale oil production levels have grown by more than 600,000 b/d as investors have already become interested at new opportunities for shale oil projects due to rising oil prices and decreasing production costs. The recent increase of oil prices have allowed the U.S. shale oil production further to grow up to 9.9 mb/d until the end of last year – and surpassed the previous record of 9.6 mb/d of 1970. According to the projection of the U.S. Energy Information Administration (EIA), the U.S. production will further soar by another 20% up to 11 mb/d in 2019 and surpass Russia's level of 2017 being presently the world's top oil producer. In March 2018, the '*Drilled-but-Uncompleted shale wells (DUCs)*' in the U.S. reached a new record high at

[230] See also Anjli Raval/David Sheppard, 'Oil Industry's Swagger Takes Knock from Gas Boom', FT, 19 February 2018.

[231] See also Andrew Ward, 'Oil Majors See their Chance in Staid World of Utilities', FT, 18 February 2018.

[232] See also idem, 'Oil Majors Seek Survival in Transition to Low-Carbon World', FT, 23 May 2017.

[233] See Tobias Buck, 'Germany's €43bn Energy Shake-up Wins Market Favour', FT, 12 March 2018.

[234] See Verity Ratcliffe, 'The Rise of NOC-NOC Partnerships', www.interfaxenergy.com, NGD, 6 March 2018, p. 3.

7,692 DUCs (+29% compared with the previous year).[235] It allows the U.S. to rapidly increase further its shale oil and gas production in the forthcoming months and years, only constrained by the international oil prices and the constraints of pipeline and other gas infrastructures.

The future U.S. position on the world oil markets is also been strengthened by a study of Rystad Energy in 2016, which concluded for the first time in history that the U.S. might hold more recoverable conventional and unconventional oil reserves from existing fields, discoveries, and yet-to-be-discovered oilfields (totalling 264 bn barrels) than both Saudi Arabia (212 bn barrels) and Russia (256 bn barrels). More than half of the remaining U.S. oil reserves are unconventional shale oil – compared with 30% of the global recoverable oil reserves.[236]

The IEA and U.S. analysts have already warned that a '*major second wave*' of U.S. shale production is coming and will create even more competition on the world's oil and gas markets (i.e. Asia) along with higher oil prices and increased demand from China and India. Over the next 3 years, U.S. shale oil is expected to cover 80% of the world's demand growth. With additional rising oil supplies from Canada, Brazil and Norway, it will be difficult for OPEC and Russia to increase their own exports.[237]

During the last five years, the U.S. shale industry has achieved impressive efficiency gains by increasing its production at 30-40% due to further technology innovations and the digitalisation of the hydro-fracking technology, which includes multi-well pads, longer laterals and more targeted stimulation strategies. Within just two years, for instance, production in Pennsylvania's Marcellus shale increased by 46% or 29 bcm to about 93 bcm in 2014. The progress and innovation in the hydro-fracking drilling technology sliced costs and boosted output in multiple ways in a declining price environment.[238] In 2014, Accenture expected another cut of the average cost of a U.S. shale well up to 40% in the forthcoming years not just by further technical innovation, but also by better management

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235 See Peter Stewart, 'US DUC Well Numbers Hit Record High', www.interfaxenergy.com, Natural Gas Daily (NGD), 19 April 2018, and Gabriel Collins, J.D./Kenneth B. Medlock, III, 'Assessing Shale Producers' Ability to Scale-up Activity', Rice University/ Baker Institute for Public Policy, Issue Brief, 17 January 2017.

236 See Rystad Energy, 'United States Now Holds More Recoverable Oil than Saudi Arabia', Press Release, 4 July 2016; 'For the First Time, U.S. Recoverable Oil Reserves Top Those of Saudi, Russia', Oilpro.com, 5 July 2016, and Anjli Raval, 'US Oil Reserves Surpass Those of Saudi Arabia and Russia', FT, 4 July 2016.

237 See Justin Worland, 'A 'Major Second Wave' of U.S. Fracking Is About to be Unleashed upon the World', Time, 6 March 2018, and Sharon Cho, 'OPEC Beware: Asia Seen Favoring U.S. Shale Oil as Volumes Soar', Bloomberg, 6 March 2018; Nick Cunnigham, 'A Nightmare Scenario Is Unfolding for OPEC', Business Insider, 7 March 2018.

238 See Margaret Ryan, 'US Companies Make More Gas with Less Money', www.interfaxenergy.com, NGD, 10 March 2017, p. 7, and idem, 'US Producers Cut Costs to tackle Falling Prices', ibid., 11 November 2014, p. 8.

of planning, logistics, and relationships with suppliers.[239] These developments of the U.S. shale revolution demonstrated that major technological gains as the result of the digitalisation and automation made in a high-price environment can decrease production costs. Its shale oil and gas will remain economical even in a much lower price environment and will have wider geopolitical impacts.

Oil and gas companies already operate some of the world's most powerful supercomputers. A new U.S. '*shale revolution 2.0*' includes clout computing services, which store and analyse data of seismic information, drilling and production much more precisely to be maximised through the lifetime at even lower costs and offer new appliances for a much wider range. According to Chevron, the volume of its data handling has been doubling every 12-18 months, though only a small portion of the data volume (down to 5%) is presently been used. 70% of oil executives expected in 2017 to invest even more in digital technologies with data storage and services being the top priorities. Digitalisation and automation as well as new alliances between oil and IT companies will make future operations of oil and gas drilling even safer, environmentally cleaner, cheaper and efficient by maximizing output.[240] But the IEA expects that the digitalisation will allow the oil and gas industry only to reduce production costs to just 10-20% through advanced processing of seismic data, automated drilling rigs, the use of sensors and enhanced reservoir modelling. It will increase safety, security, and reliability of equipment and operations as well as decrease labour costs. Finally, the IEA has estimated that technically recoverable oil and gas resources could increase by some 5%, with the best prospects in shale gas.[241]

That analysis does not include the impacts of the use of '*Artificial Intelligence (AI)*', which is still at its infancy, though it promises even more disruptive impacts and benefits. The industry is already coupling AI with new advanced sensors, sophisticated seismic data processes and management as well as automated drilling rigs to maximise production of tight oil and shale gas with only a few engineers and technicians. But the barriers and challenges to implement the full spectrum of new digital technologies and AI - ranging from adequate timing of capital intensive large projects, the age of existing infrastructures, the traditional internal focus by insulating them from other industries, the rather risk-averse management perspectives to introduce new disruptive technologies, its high fragmentation along the supply chains, long-term demand trends, dependence on a up-to-date Information

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[239] See Ed Crooks, 'Falling Oil Price to Cut Shale Costs', FT, 22 October 2014, and idem, 'Boom Times for US Shale Oil Producers', FT, 4 March 2018.

[240] See Ed Crooks, 'Drillers Turn to Big Data in the Hunt for More, Cheaper Oil', FT, 12 February 2018, and Peter Kaznacheev, 'Application of Artificial Neural Networks in the Oil and Gas Industry', EUCERS-Newsletter No. 66, June-July 2017, pp. 6-8.

[241] See also IEA, 'Digitalisation & Energy', pp. 17 ff. See also David G. Victor/Kassia Yanosek, 'The Next Energy Revolution', pp. 126 ff.

Technology (IT) support infrastructure and an overall conservative management culture - shouldn't be underestimated and suggest the industry's preference for more evolutionary digital developments.[242]

A new shale drilling method, called '*cube development'* has been developed by the oil and gas drilling company Encana. It is designed to tap multiple layers of petroleum-soaked rock in a shale basin "*all at once rather than the one-or-two-well, one-layer-at-a-time approach of the past*." If it will be implemented successfully, the '*cube development*' could accelerate the already impressive drilling boom with "*rewriting the rules of global energy markets*". But some oil companies see the new method as too aggressive, expensive and would create logistical nightmares.[243]

Regardless of this technology option, the Trump administration might give permission to drill new wells in the Arctic region of Alaska, where huge new oil resources have been discovered during the last years. A new wave of Arctic oil development could further increase the U.S. oil production and influence the global oil market for the next decades.[244] The U.S. shale revolution 2.0 might also spread to the Gulf region (Saudi Arabia, Bahrain), Canada, Australia and Argentina.[245] Bahrain (until now the smallest oil producer in the Gulf) has recently discovered the world's biggest shale oil reserves of 80 bn barrels (and additional 14 trillion cubic feet of gas) equivalent of Russia's entire reserves. Bahrain might become a big global oil producer and exporter in 5 years.[246] Furthermore, Australia, China[247], Argentina, Canada and some other countries are beginning to replicate the U.S. shale revolution, though on a much lower level.[248]

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242 See IEA ibid., p. 72 f.

243 See Karel Beckmann, ''Very Very Scary' – the Shale Oil Technique to End all Oil Scarcity?', www.enegypostweekly.eu, 27 February 2018, and Alex Nussbaum, 'Very, Very Scary': This Mammoth Is about to Supersize the Future of Fracking', Financial Post, 23 February 2018.

244 See Scott L. Montgomery, 'Large-Scale Fracking Comes to the Arctic in a New Alaska Oil Boom', www.energypost.eu, 27 April 2018.

245 See also Karel Beckmann, 'Second Shale Revolution in U.S., Shale Spreads to China and Gulf, Climate Suffers', www.energypostweekly.eu, 24 April 2018, and Jamie Smyth, 'Australia Aims to Replicate US Shale Revolution in Northern Territory', FT, 17 April 2018.

246 See 'Shale Revolution 3.0: Bahrain Hits (Black) Gold with Biggest Shale Discovery in World', The Times, 5 April 2018, and 'Tiny Bahrain's Big Oil Discovery Will Boost the Country's Fortunes –Eventually', Stratfor.com, 5 April 2018.

247 Despite China might have the world's largest shale gas and substantial shale oil reserves, its ambitious shale programme, has been disappointing up to now as it may increase from just 9 bcm per year today to just 17 bcm by 2020, falling short of the government's target of 30 bcm in 2020. The reasons for not duplicating a Chinese shale revolution is not just that its resources are based in more complex rock formations in often mountainous regions, but also in the unrivalled U.S. history of 150 years of oil and gas exploration, competitive and open markets, well-developed pipelines and other gas and oil infrastructures and an attractive business environment with all kind of service companies and independent producers – all non-existing conditions in China and other potential shale gas producer countries – see also Ed Crooks, 'The Week in Energy: China's Challenging Shale Gas', FT, 24 April 2018. Nonetheless, China owns the world's second largest shale gas field ('Fuling') with an annual capacity of up to 10 bcm – see 'China Owns World's Second Largest Shale Gas Field', China Daily, 29 March 2018.

But the '*shale 2.0*'-revolution also means disruption and shifts of the management of the oil and gas industry, with operational changes, job losses and newly developed business strategies, working patterns and companies' culture. But the increased mobile connectivity, cloud computing, the greater use of operational data and automation also create new security vulnerabilities and demand the deployment of the most advanced technology, including against cyberattacks, to protect the newly introduced technologies.

4.3.2 Digitalisation of the Electricity Sector (Smart Meters, Smart Grid, Smart Home Technologies)

The electricity sector is expected to undergo the greatest digital transformation as it will break down the traditional boundaries between the various energy sectors, increase flexibility, blur the distinction between generation and consumption, and fasten the integration across entire systems. The rapid digitalisation and widespread use of '*information and communication technology (ICT)*' will fundamentally change basic assumptions about energy markets, business models and consumption patterns. New providers and platforms, coming from outside of the energy sector, are already attacking and changing established industries.[249] These drivers will demand changes not just by adapting those new technologies. They are also changing the companies' internal business cultures and strategies as well as the management of the energy companies.

Those changes will be even more dramatic in an increasingly transformed electricity sector, as the entire energy sector is undergoing growing electrification, which includes the transport, heating and cooling.[250] Digitalisation is just another factor fuelling and fastening the changes of the electricity industry by introducing a range of new technologies. Since 2014, global investments in digital electricity infrastructure and software have increased by 20% per year, accounting for US$47 bn in 2016.[251] Even more astonishing is the fact that around 90% of the world data were created just over the past two years![252] While the digitalisation is a technology revolution, its impacts on companies and governments will be

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248 See Jamie Smyth, 'Australia Aims to Replicate US Shale Revolution in Northern Territory', FT, 17 April 2018; Edward White, 'China to Miss Shale Production Target by 'Considerable Margin': Report', ibid., and Colin Shek, 'China's Shale Gas Optimism Belies Geological Challenges', www.interfaxenergy.com, NGD, 18 April 2018.

249 See also Liam Denning, 'Big Energy Confronts an Unfamiliar Power: Competition', Bloomberg, 22 February 2018.

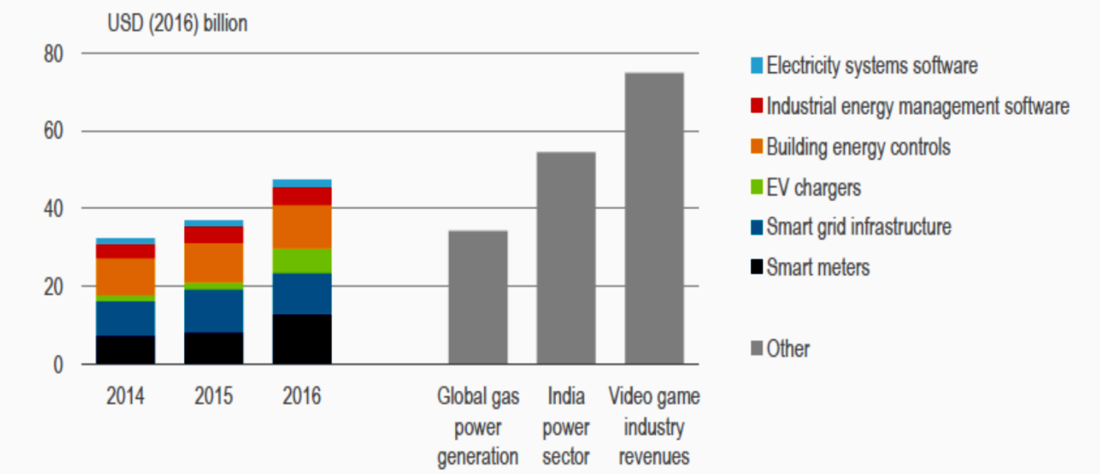
250 See also IEA, 'WEO 2017', and Kelvin Ross, 'IEA Spotlights 'Deep Rippling Effect' of Electrification', Power Engineering International, 14 November 2017.

251 See IEA, 'Digitalisation & Energy', p. 25.

252 See ibid., p. 22.

far outreaching and change markets, business models, organisational structures and companies' cultures.

Figure 20: Investments in Digital Electricity Infrastructure and Software (2014–2016)



Key message: Investment in digital electricity infrastructure and software grew over 20% annually between 2014 and 2016, overtaking global investment in gas-fired power generation.

Notes: Global gas power generation and India power sector are 2016 investments; EV = electric vehicle.

Sources: Calculations for investment in digital infrastructure and software based on MarketsandMarkets (2016), *Internet of Things in Utility Market*; BNEF (2016), *Digital Energy Market Outlook*.

Source: IEA 2017

The potential of saving costs and investments in the worldwide power sector alone as the result digitalisation has been estimated at around US$80 bn between 2016 and 2040 by reducing operation and maintenance costs, improving the efficiency of the power plants and networks, decreasing unplanned outages and downtime, and extending operational lifetimes of assets.[253]

The IEA has identified four interrelated opportunities:

(1) "Smart demand response" by preserving energy consumption and massive investment in new installed electricity supply capacity;

(2) help to "integrate variable renewables" in electricity generation and in smart grids;

(3) promoting "smart charging technologies for electric vehicles", and

(4) promoting the development of "distributed energy resources" (such as household solar PV panels and storage').[254]

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253 In the U.S. alone, the costs of power supply disruptions have been estimated around US$100 bn per year - see ibid., pp. 65, 78, 80.

254 See also IEA, 'Digitalisation & Energy', pp. 17 ff.

In the future, much more decentralised electricity sector will be connected directly to local distribution networks of '*mini grids*'.[255] Together with the expansion of RES and new electricity storage options (incl. various battery options), the current electricity model is increasingly disrupted and under major change. Even fundamentals are increasingly questioned such as:

- electricity prices are no longer always based on usage based prices (i.e. negative electricity prices),
- only energy companies will generate and sell electricity,
- all private and industrial customers need electricity and wider grid connection as well as regional system operator, and
- local distribution companies are functioning as a stable and profitable source of funds to local governments owning them.

In consequence, the whole electricity industry needs to adopt radical changes in its business models as many won't probably survive and/or being able to compete in fundamentally different future markets.

The power sector may face the most wide-ranging impacts of digitalisation, using a hitherto unknown amount of digital data about the state and performance of its own assets, processing information and data (with real-time actions by owners and operators) through new software platforms, which will change business models and strategies as well as service activities.[256]

The greatest potential for the digitalisation in the energy sector is the effect of breaking down the traditional segmentation and boundaries between various energy sectors themselves but also with other sectors and industries, which will enforce the integration of entire systems and create new ones. The digitalisation of the electricity sector is closely linked and dependent on the construction of smart grids (incl. micro-grids) and the introduction of smart metering in all private houses and industrial facilities. Smart grids will transform the old, '*dumb*' and centralised power grid into flexible, intelligent and decentralised energy networks. It will have the ability to manage fluctuations in supply, maintain the security of the supply, and incorporate the micro-generation of electricity by individuals, businesses, smart appliances and electric vehicles. Thereby it will improve the efficiency and availability of the power system by constantly monitoring, controlling and managing the demands of customers. Smart Grid gives them and utilities real-time data

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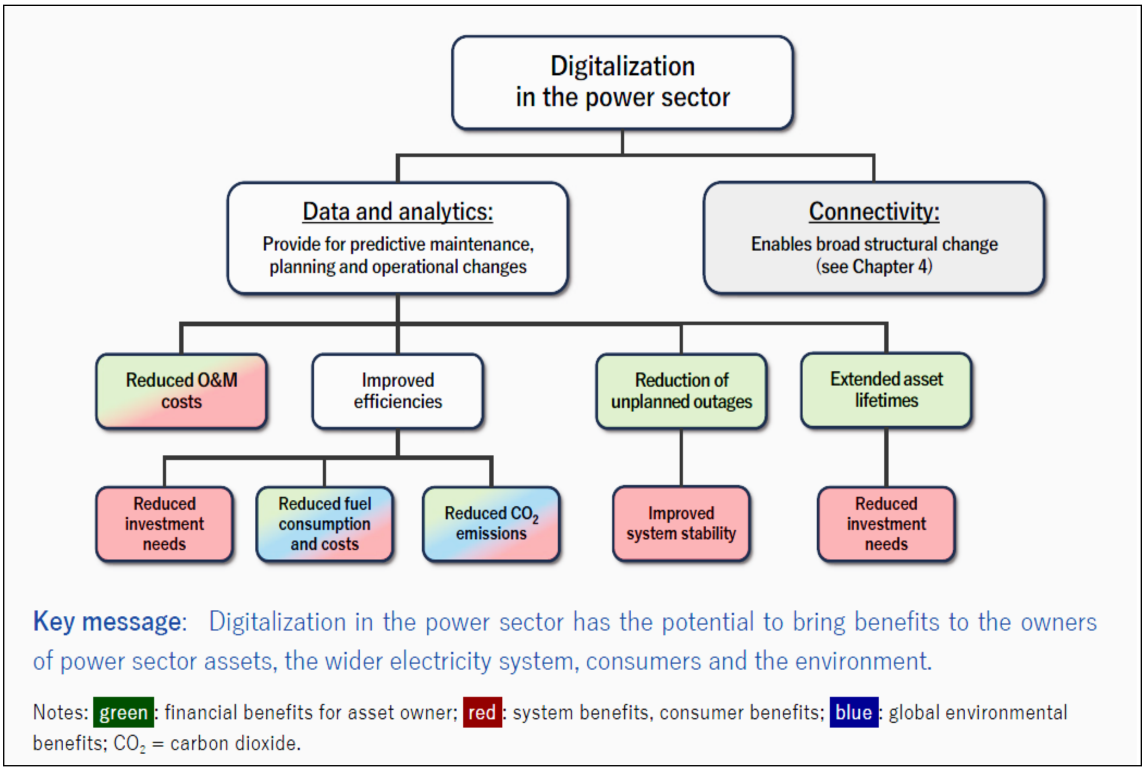
255 See also Patrick McGee, 'Mini-Grid' Household Energy Sharing Begins to Take off', FT, 22 December 2017, and Fereidoon Siaoshansi, 'Microgrids: From Niche to US$100 billion Market', www.energypost.eu, 9 February 2018.

256 See IEA, 'Digitalisation & Energy', here pp. 76 ff.

about when, where and how much energy households consume, enabling energy providers to monitor and adjust energy flows.[257] In the beginning, the industry promoted smart meters by saving annually 7-8% of the electricity consumption for private consumers. But experiences indicate that the real energy conservation might only be 1-2%, making the introduction for private consumers currently rather expensive.[258]

Figure 21: Impact of Digitalisation on Electricity Sector Assets



Source: IEA 2017

Digitalisation of the electricity sector is also linked with the digitalisation of the building sector and '*smart home*'-technologies such as smart thermostats, smart lighting and various IoT-devices. By 2020, more than 20 bn connected IoT-devices, and nearly 6 bn smartphones are expected to be online. By 2040, 1 bn households and 11 bn smart appliances could be an active part of a highly interconnected electricity system. Their 'smart demand response' has been estimated to provide 185 GW of inherent flexibility of the system (the presently installed electricity supply capacity of Italy and Australia combined). It could save up to US$270 bn of investment in new electricity supply infrastructure needed to ensure energy supply security). The roll-out of '*smart charging*' of

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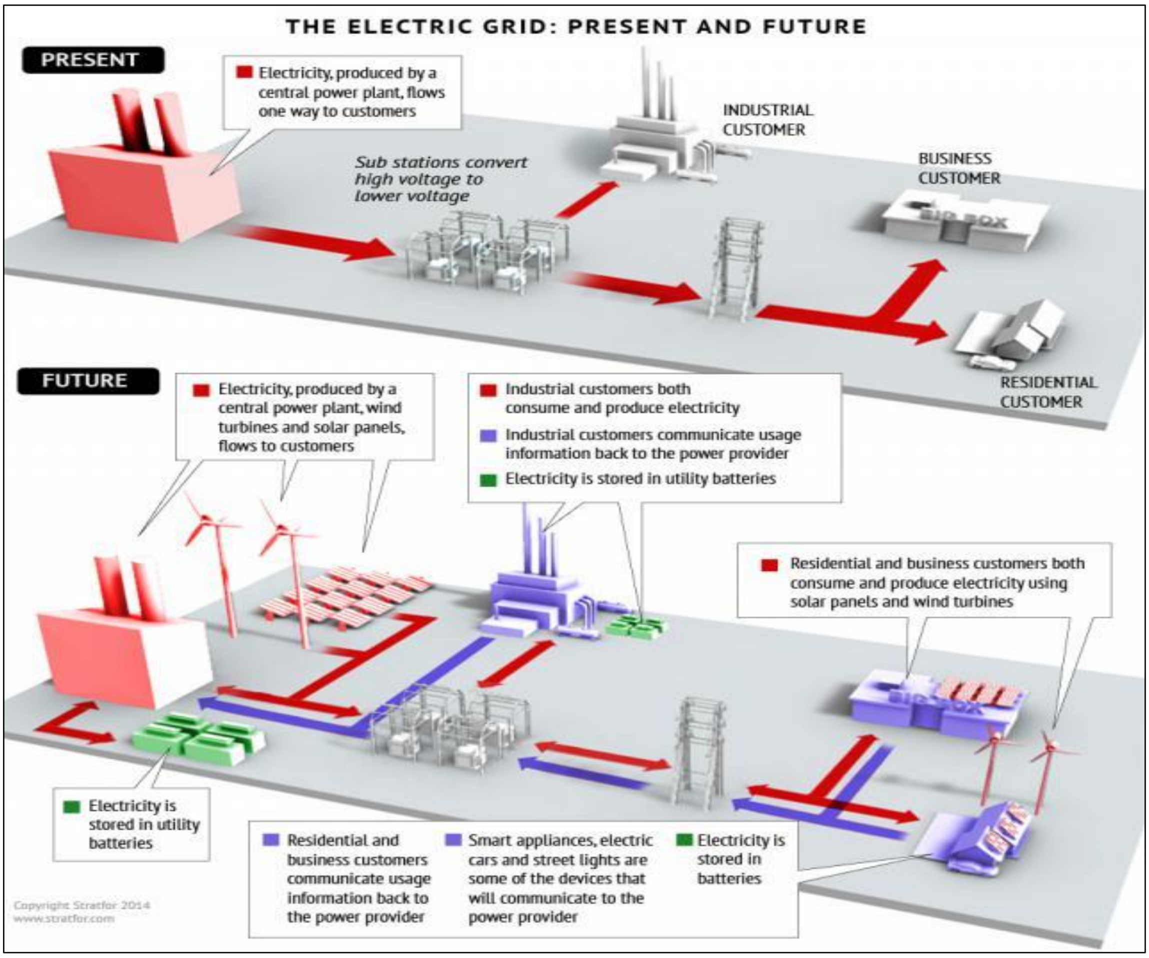
257 See also 'Smart Grids Will Revolutionize Power Distribution', Stratfor.com, 7 July 2014; Marius Buchmann, 'Smart Meter Data Hubs: Europe vs. Germany', www.energypost.eu, 23 May 2017, and '5 Problems the Internet of Energy Can Solve', www.greenbiz.com, 27 February 2018..

258 See F. Umbach, 'Cyber Security Issues for Advanced Metering Infrastructure: Implications for Future Electrical Grids and Critical Infrastructures'. PPT-Presentation at the European Cooperation Network on Critical Infrastructure Protection (EUCONCIP)-Training Workshop, Bucharest, 5-6 November 2015.

electric vehicles (EVs), shifting the charging to off-peak times, could save another US$100-280 bn by avoiding to build new electricity infrastructure by 2040.[259]

Figure 22: Electric Grid System – Present and Future One



Source: Stratfor.com 2014

Connectivity becomes the most important driver factor for the industry's and the electricity sector's digitalisation. For realizing the full potential of the connectivity and digitalisation of the electricity sector with all its benefits, the low-voltage electricity distribution grid network as part of the overall transmission grid needs to be modernised to take over the role of balancing demand and supply as well as to integrate more distributed renewable energy resources. In addition, new regulatory, financial and institutional structures defined by governments in collaboration with the industries need to be implemented in time to ensure the overall system's stability and security as the system's hard- and software is more than ever dependent on each other.

But the widespread introduction and use of the digital technologies and devices, as well as their benefits, are dependent on overcoming the manifold challenges in regard to technical

259 See IEA, 'Digitalisation & Energy', pp. 41 ff., 83 ff. and 103 ff.

and economic considerations (cost-benefit calculations of private consumers and industry), safety and security risks (against cyberattacks) and concerns of private data security and timely as well as adequate political guidelines (introducing new regulations and defining new standards). Critical questions of how much information people are willing to share with electricity and internet service providers, how confidentiality can be best protected, and who owns, collects and uses consumer-specific data (incl. for prosumers), including for third parties, need to be answered. A new close and trustful collaboration and the public, private partnerships (PPP), involving the energy and internet industry as well as governments in institutionalised PPP-discussions, has yet to be created.[260]

[260] See also Anna Steiner, 'Von Kilowatt zu Kilobyte', FAS, 15 October 2017,p. 32.

5 Five Geostrategic Implications of the Digitalisation

5.1 A Higher Increase of the Regional and Worldwide Electricity Demand?[261]

The international discussions of a '*global Energiewende*' have focused on the expansion of renewables and decarbonisation of the worldwide energy system as well as new prospects for enhancing energy efficiency and conservation. But a closer look suggests that these prospects need to be balanced with rather increasing energy and in particular electricity demand growth. The increasing electrification and fastened digitalisation of the entire energy systems, including the transport and heating sectors, alongside the expanded introduction of robotics and AI systems as well as billions of IoT-devices in smart homes have raised the question, whether the forecasted worldwide electricity demand might not be underestimated despite the fact that the introduction of various new technologies will also increase energy efficiency and conservation.

The IEA has forecasted in its latest '*WEO-2017*' report that the global electricity demand might rise 60% in its major '*New Policy Scenario (NPS)*' twice the estimated total worldwide energy demand growth. 85% of it will come from developing countries and take into account the growing world population from presently 7 bn to 9 bn people by 2040 and further rising living standards worldwide.[262] In 2016, capital expenditure in the global power sector (incl. generation and transmission) was rising up to US$720 bn and surpassed for the first time the US$650 bn investment in the global oil and gas industry despite investment reductions in the power sector due to cost fall of renewables. The share of electricity in the global final energy consumption might grow from presently 20% up to 23% in the NPS and 27% in the SDS by 2040.[263]

The EU already decided in 2007 to adopt three 20% targets by the year 2020, namely (1) to reduce 20% of its overall energy demand, (2) to expand renewables to 20% of its Primary Energy Consumption (PEC), and (3) to decrease its GHG-emissions by 20% towards 1990. The new wave of digitalisation and technologies as well as concepts for the future energy sector (such as smart metering, smart grids and smart home etc.) promise even more prospects for decreasing Europe's future energy demand. In this light, the EU has adopted more ambitious targets by 2030 for expanding RES, enhancing its energy efficiency and conservation as well as decreasing its GHGE. Despite some struggling with its previous three 20% targets, the EU – seeing itself as a technological and climate change mitigation

261 This chapter is a revised and updated version of my previous article – F. Umbach, 'Increased Electricity Usage Could Derail EU Energy Targets', GIS, 8 January 2017.

262 See IEA, 'WEO 2017', pp. 229 ff.

263 See ibid., p. 98 f.

leader – has been underway of largely achieving its agreed targets by 2020.[264] The IEA has projected the EU's electricity demand by decreasing 0.7–1.0% and the overall energy demand by 0.8–1.2% by 2040 compared with 2016, depending on the NPS or the Sustainable Development Scenario (SDS).[265]

Figure 23: Targets and Objectives of the EU's Integrated Energy and Climate Policies

Share	Targets/Year	Present Situation 2015/2016
Share of RES at PEC:	• 2020: **20%** • 2030: **32%** (nationally non-binding)	**17%** (estimated in 2016)
Share of RES at Electricity Generation:	• 2020: **~30%** (not officially agreed) • 2030: **45-50%**	**29%** (2016: of that 12% hydro; +45% since 2011)
Emissions Reductions (since 1990s):	• 2020: **20%** • 2030: **+40%**	**23%**
Energy Efficiency Increase for Reduction of Primary Energy Consumption (PEC):	• **2020: 20%** • **2030: 32.5%**	**18.4% (2015)**

Source: Dr. Frank Umbach based on EU declarations and statistics.

The full development of the EU's declared '*Digital Single Market*' as one of the top ten priorities during President Juncker's mandate will have to facilitate the clean energy transition in the EU and making the EU energy sector more stable, competitive and sustainable for the 21st century. The digitalisation and many of the new technologies suggest a greater potential for enhancing energy efficiency and conservation to achieve the agreed targets by 2030 as described above. But the following technology introduction may result in an even faster and higher growing EU electricity and overall energy demand than previously forecasted and projected:

- *Smart Metering:* the EU was originally hoping to introduce around 200 million (m) smart meters for electricity and 45 m for gas in private homes and the industries (almost 72% of European consumers for electricity and 40% for gas). Meanwhile, the introduction has been slowed down due to various circumstances. In contrast to the original hopes to save annually 7-8% of a private household's electricity consumption, recent experiences suggest just 2-3%, making the investment for private consumers currently rather expensive. Furthermore, the rollout of smart meters in Europe (i.e. UK

[264] See also F. Umbach, 'Europäische Energiesicherheit im Wandel. Globale Energiemegatrends und ihre Auswirkungen', Aktuelle Analysen, Hanns-Seidel-Stiftung, Munich, November 2017, pp. 27 ff.

[265] See again IEA, 'WEO 2017', p. 238.

and Germany) has been repeatedly delayed due to newly defined security standards and conditions (including using the Blockchain technology) and rising costs.[266]

- *Smart Home and Internet of Things ('IoTs'):* The next technology wave of the 'IoT' with its network of smart-sensor-enabled devices that can communicate and coordinate with each other via the Internet, will create new businesses, providing healthcare, and manage 'smart cities'. As IoT devices for smart homes and buildings are viewed as a usual commodity, it demands low prices. This contrasts with the need for adequate security excluding any breaches of private and commercial data. The sheer numbers of size - often combined with short replacement cycles – do not undermine the development of tailored security technologies, but also higher investments in better energy efficiency solutions for IoTs. The expected widespread introduction of those IoTs for smart home appliances and smart home concepts will definitely increase the electricity demand of households and industries.[267]
- *Battery Storage for Electric Vehicles and RES (i.e. Wind Power and Solar Panel Systems):* Alongside of RES and other '*green technologies'* (including for the further digitalisation), batteries storage is an energy intensive business. As already explained in chapter 4.2 of this study, the production of batteries is already highly energy intensive and produce much CO_2 before they leave their manufacturing sites that their overall carbon footprint is very questionable – particularly when the energy intensive mining production of its raw material basis (like lithium, rare earth, cobalt and others) is included in lifecycle analyses.
- Even more challenging is the present energy efficiency or better intensity of *self-driving cars* as they will be equipped with at least 20 sensors using cameras, radar and lidar to identify its surroundings for safe driving. A self-driving car collects a data volume of up to 15 gigabytes per second. The energy required to power those self-driving systems and to handle those data volumes, partly transmitted to energy-intensive clouds, is presently often overlooked but considered so great that prototypes of electric cars with a theoretic 400 km range can de facto drive only 200 km autonomously. Present calculations have shown that those prototypes require as much as energy by the computers, sensors and radars to drive autonomously as it does to move the vehicle.[268]

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[266] See also Sylvia Pfeifer, 'UK Smart Meter Rollout Hit by Rising Costs and Delays', FT, 13 May 2018.

[267] See also Daniel Alsen/Mark Patel/Jason Shangkuan, 'The Future of Connectivity: Enabling the Internet of Things', Mc Kinsey&Company, December 2017; Vineet Gupta/Rainer Ulrich, 'How the Internet of Things Will Reshape Future Production Systems', ibid., September 2017, James Manyika,' Unlocking the Potential of the Internet of Things', McKinsey Global Institute, June 2015, and Ed Crooks, 'The Internet of Things: Industry's Digital Revolution', FT, 27 June 2017.

[268] See Peter Campbell/Patrick McGee, 'Electric Car Dreams Collides with Reality on Profits', FT, 15 September 2017.

Thus the development of self-driving cars needs to be guided by much more energy-efficient technologies.

- *A Rapid Decarbonisation:* The transformation of the energy sectors for clean energy mixes may even produce higher emissions at least in the first phase. Coping with the waste of solar panels and wind turbines are still challenging as their recycling process proves highly energy intensive.
- *Blockchain-Technology:* The example of the introduction of the *Blockchain* technology is symptomatic for the perceived contradicting implications for the energy and other sectors, i.e. financial one. At present, the new technology is adopted and implemented particularly in the financial sector. The advantages in the energy sector would also be much faster and less costly as well as more secure.[269] But at the same time, this widely perceived disruptive technology has not been designed is accordance with any requirements.
- *Bitcoin and other Cryptocurrencies:* Digital financial transactions and the tremendous growth of cryptocurrencies need rapidly increasing computer networks behind to solve math problems to "*mine*" more bitcoin with extreme electricity consumption. If these estimates of and its related growing climate footprint would be confirmed, then it would cause increasing electricity blackouts in many countries. The global climate mitigation efforts wouldn't have any positive impacts at all as the global energy and electricity demand would completely offset those efforts. Even when the estimates of Digiconomist are based on questionable models as well as projections and overstate the consumed electricity demand as criticised, it might be another example of underestimating the future global electricity demand.[270]

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269 See also David Groake, 'Energy and Blockchain: Here are the Most Promising Applications', www.energy-post.eu, 24 May 2017; Andrew Ward,'BP Experiments with Blockchain for Oil and Gas Trading', 3 October 2017; Marius Buchmann, 'Blockchain in the Energy Sector: Three Takeaways from the European Utility Week 2017', www.theenergycollective.com, 18 October 2017; Luis Colasante/Taniga Krish, 'How Block-chain is Transforming the Energy Industry', ibid., 31 October 2017; Meredith Taylor, 'Why the Next Oil Boom will be Fueled by Blockchain', ibid., 1 March 2018; Aaaron Wood,'Chile Adopts Blockchain Technology for National Grid', 3 March 2018 (https://cointelegraph.com/news/chile-adopts-blockchain-technology-for-national-energy-grid; accessed on 5 March 2018; Silvia Favasuli, 'Blockchain Tech Holds Potential for Ener-gy Sector', www.interfaxenergy.com, NGD, 7 April 2017; Michael Rühle/Lukas Trakimavicius, 'How Block-chain Can Counter Cyberthreats to Energy Security', Los Angeles Times, 14 June 2017; Sam Muratovic, 'Energy (R)evolution?', www.theenergycollective.com, 27 December 2017; Silke Finken/Andreas von Eich-born/Götz Walter, 'Blockchain: Anwendungen und mögliche Folgen in der Energiewirtschaft', ET, 5/2017, pp. 40.

270 See Eric Holthaus, 'Bitcoin Could Cost us our Clean-Energy Future', 5 December 2017 (https://grist.org/article/bitcoin-could-cost-us-our-clean-energy-future/; accessed on6 December 2017); Scott Campbell, 'Bitcoin Mining 'is Using so Much Energy that is Causing Electricity Blackouts' amid Fears it will Consume More Power than the World by 2020', Daily Mail, 9 December 2017; Niklas Maak, 'Auch das Internet hat einen Auspuff', FAZ, 13 January 2018, p. 9; Daniel Eckert/Holger Zschäpitz, 'Die größte Bed-rohung für den Bitcoin: Sein Energieverbrauch', Welt am Sonntag, No. 3, 21 January 2018, p. 46; Sam

Figure 24: Estimated Electricity Demand of "Bitcoin Mining"

Estimated Electricity Demand of "Bitcoin Mining" (by Digiconomist and others):

- At present, each bitcoin transaction requires around 147 kWh per transaction - the same amount of energy used to power nine homes in the U.S. for one day;
- Bitcoin runs an average or more than 300,000 transactions today, requiring an annual electricity demand of more than 16 TWh – 0.1% of the world's electricity consumption
- the present total energy use of the worldwide computer power could amount to 31 terawatt-hours per year - more than Ireland (23 TWh) and 159 countries in the world consume annually;
- the power-hungry network is increasing every day by about 450 GW-hours-the same amount of electricity consumed annually by Haiti;
- by 2020, Bitcoin could replace Denmark's equivalent electricity consumption of around 33 TWh; others have even estimated that in 2019, the rapidly growing bitcoin network could require more electricity than the entire U.S. is currently using;
- around 70% of the world's Bitcoin mining is based in China, where electricity prices are very low. One of its facilities has 25,000 computers running a daily bill of US$40,000. Instead of physically transporting coal volumes, it's easier and more cost-effective to establish a Bitcoin mining operation near a source of coal and convert carbon directly to crypto.
- if a new world super-cryptocurrency were to replace the annual VISA and Mastercard process of more than 100 bn transactions and assuming 100kWh per transaction, it would consume around 10,000 TWh – almost a third of the current world's electricity production;
- The rapidly raising electricity demand might lead to new stress on the grid systems and power production using coal and dirty technologies to cope with the rapidly rising demand.

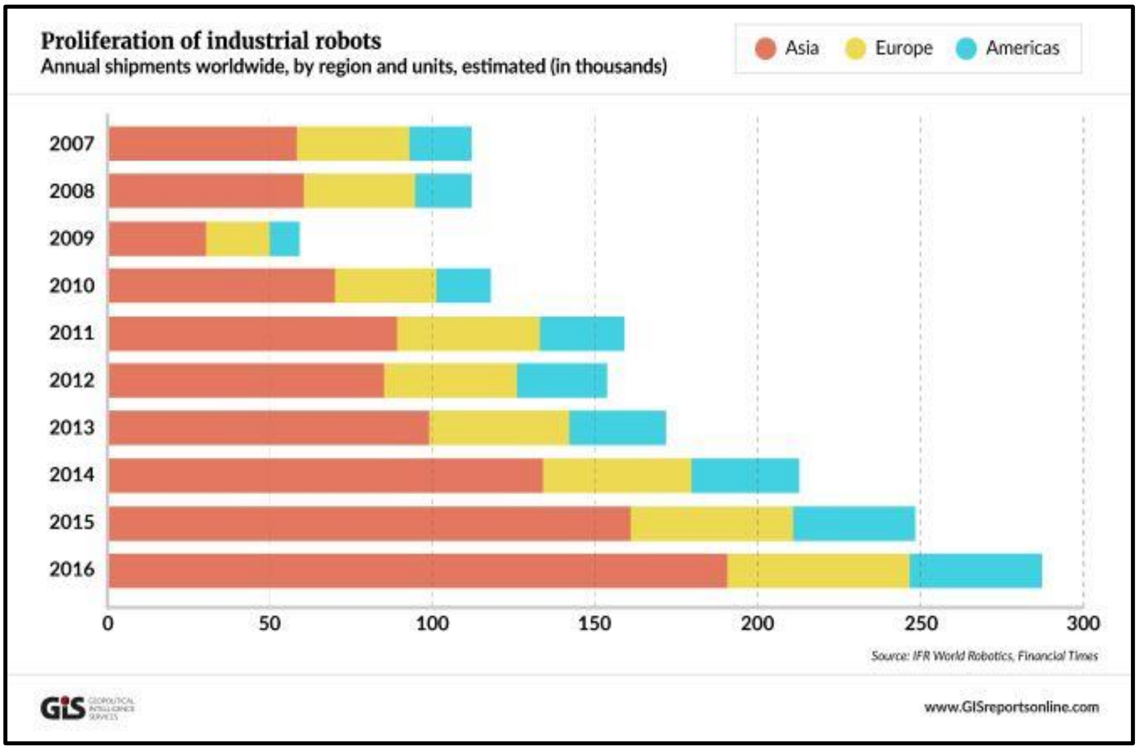
Source: Dr. Frank Umbach based on various sources.

- *Digitalisation of the Industry ('Industry 4.*0'): The accelerating pace of automation in the industries is based on the digitalisation, robotics and artificial intelligence systems. In 2016, global sales of industrial robots increased by 18% to a record of US$13.1bn. As a result, about 30% of tasks in 60% of employment could be

Hartnett, 'Beyond Bitcoin: How to Build an Energy-Efficient Blockchain that Can Help the Energy Transition', www.energypost.eu, 24 January 2018;Daniel Shane, 'Bitcoin Boom May be a Disaster for the Environment', 7 December 2017 (http://money.cnn.com/2017/12/07/technology/bitcoin-energy-environment/index.html); and Tom DiChristopher, 'No, Bitcoin isn't likely to Consume all the World's Electricity in 2020', www.cnbc.com, 21 December 2017.

automated, according to McKinsey. The technology breakthroughs in robotics is another example for combining them with ICT adopted for electronic communication between equipment and computers in factories ('*industrial internet of things*'). While the present international discussions are focusing on the implementation challenges and implications for companies as well as a drastically reduced working force in the manufacturing industry, the overall increasing energy and electricity demand of this '*industry 4.0*' revolution and the spread of robots are still overlooked or marginalised.

Figure 25: Proliferation of Industrial Robots (2007-2016)

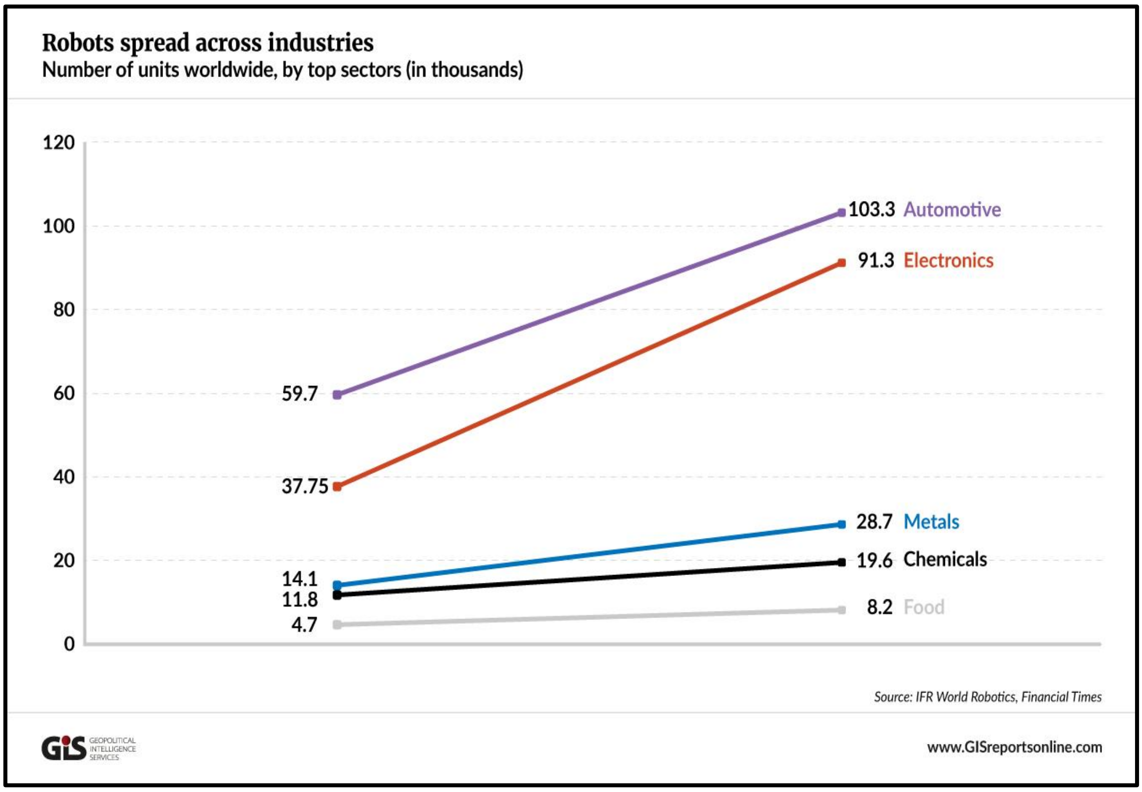


Source: GIS 2018

But as the IEA and many energy experts admit due to the manifold uncertainties of the range of new technologies to be introduced, and the circumstances as well as conditions (i.e. speed, scalability, regulations, consumer behaviour and patterns, business models and strategies etc.), it is almost impossible to conclude at the present stage to which extent the additional electricity and energy demand can be balanced with the technologies' inherent energy efficiency potential to conserve energy.[271] But the EU's and IEA projected energy developments and forecasts that the EU's and the world's future energy demand growth will be limited or even being reduced by 2040 compared with today, is by no means an assured assumption and needs to be critically monitored and reviewed.

271 See ibid., p. 115 f.

Figure 26: Robots Spreading across Industries



Source: GIS 2018

5.2 Rising New Cyber Security Threats and the Need for Critical (Energy) Infrastructure Protection

The worldwide '*WannaCry'* cyber infection in May 2017 has encrypted victim's data on hard drives and demanded payment for unlocking again. It was the latest wake-up call that the world and in particular the highly industrialised countries of the US and in Europe are insufficiently prepared to defend themselves and to cope with major cyberattacks. By exposing security vulnerabilities in even the largest organisations and companies, it highlighted how interconnected the global digital economy and critical infrastructures with the regular internet across the world has become – alongside with rising interconnected risks and vulnerabilities.[272]

The malicious software has been considered as one of the most virulent and indiscriminate attacks to date, affecting worldwide more than 200,000 computers in more than 150 countries. Its high-visibility impact on UK's National Health Service, knocking out a third of it, highlighted the potential impacts even on critical infrastructures as hospitals, but also others such as infecting some of the biggest companies in Europe like Telefonica (the Spanish mobile phone giant), the Deutsche Bahn (the German national railway operator),

272 See also F. Umbach, The Fog of Cybersecurity'.

Renault (the French carmaker) and FedEx in the U.S. It also spread to Russia, forcing more than 1,000 computers of its Interior Ministry to be taken offline. In China, almost 30,000 institutions had been affected. The malicious software held infected users' hard drives hostage to ransom, demanding US$300 payment in bitcoin for receiving decryption keys. British hospitals had been forced to cancel and delay surgeries and treatment of patients. The cyberattack was indiscriminate and not targeting any specific institution. Cyber security experts have called the British health service IT preparedness a systemic nightmare, which needs an enormous security investment to make its IT systems up to current standards.[273]

The infection highlighted again the fact that governments and companies are targets of constant and increasingly sophisticated cyberattacks launched by rival nation-states and their intelligence services, terrorist groups, hackers and cybercriminals. Despite the progress on these fronts, the overall preparedness and defence capabilities have not lived up with the worldwide offensive cyberattack capabilities of transnational crime and governmental-supported hacking groups.

Most cyberattacks are still not reported by companies (i.e. in the financial sector) as they fear to lose their customers to competitors. Some companies and CIs like hospitals have seen no other chance or even time for any considerations other than to pay their ransom as the loss of up-to-the-minute data prevents their immediate functioning (such as patients' surgeries and their constant monitoring) and may cause immediate deaths.[274]

International consciousness, awareness and preparedness and the exchange of information, as well as expertise between Western countries, have increased, National law enforcement and intelligence agencies have also enhanced their cooperation both nationally and internationally. In 2016, investigators in the U.S. and 39 other countries (incl. in Europe) collaborated to destroy the global '*Avalanche'*-network existing since 2010. It comprised of a distributed, cloud-hosting network of up to 600 servers worldwide that was rented by cyber-criminals to launch worldwide phishing attacks and malware.[275]

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273 See also See BryanHarris/Katrina Manson, 'US Blames North Korea for WannaCry Cyber Attack'; 'The Internet Is Less and Less Spotify and More and More Wannacry'- From the MSC Cyber Security Summit Tel Aviv'; Sam Jones/Aliya Ram, 'Petya Attack Raises Fears of Escalation of Global Cyber Arms Race'; Laurens Cerulus, 'Governments Scramble to Respond to Global Cyberattack', and IISS, 'The Wannacry Ransome Attack'.

274 See also F. Umbach, 'Commercial Confidentiality: An Obstacle to Effective Mitigation to Cyber Attacks on Critical Energy Infrastructures?', Energy Security Forum (ed. by the NATO Energy Security Centre of Excellence, Vilnius/Lithuania), Vol. 2 (8), December 2013-January 2014, pp. 4-8.

275 See Europol, 'Avalanche Network Dismantled in International Cyber Cooperation', Press Release, 1 December 2016 (https://www.europol.europa.eu/newsroom/news/%E2%80%98avalanche%E2%80%99-network-dismantled-in-international-cyber-operation); accessed on 30 July 2017), and Michael Kan, 'Major Cybercrime Network Avalanche Dismantled in Global Takedown', PCWorld, 2 December 2016 (https://www.pcworld.idg.com.au/article/610998/major-cybercrime-network-avalanche-dismantled-global-takedown/; accessed on 15 January 2017).

The '*WannaCry*' malicious code in 2017 has also highlighted the competing security interests between private actors and law enforcement agencies (i.e. of secret services), relying themselves on offensive cyber weaponry capabilities. They have used flaws and loopholes in commonly available software to be exploited for fighting terrorism, transnational crime and foreign secret service activities. The '*WannaCry*' cyber infection was only able after a sophisticated cyber spying tool (known as '*EternalBlue*') from the U.S. National Security Agency (NSA), which may have worldwide the most powerful cyber arsenal, was stolen by a cybercrime group known as '*Shadow Brokers'* (probably a proxy of Russian intelligence services) last year. It then was sold on for weaponsation by other cyber-actors in the '*darknet*', the global underworld marketplace.[276]

The NSA tool exploits those loopholes in common file-sharing protocols to run Windows computer software. It allows hackers to move through various networks and between organisations by setting up legitimate enterprise file-sharing protocols. Critical cyber experts have warned and criticised for years that U.S. intelligence agencies have either created those exploits themselves or have at least the knowledge about those loopholes. By employing those state-developed '*stockpiled cyber weapons'*, they have facilitated their own offensive cyberattacks, but not sharing known loopholes with other governments, international businesses and the public. The leaked NSA tool has not created the ransomware itself but has helped the hackers to fasten its distribution all over the world.

As Europe is developing its own offensive cyber capabilities, its intelligence services and law enforcement agencies also need to balance carefully the '*vulnerability equities process (VEP)*' similar to the U.S. and an adequate cost-benefit calculus, whether it should disclose previously unknown computer vulnerabilities (also known as '*zero-day'*) or use them for fighting cybercrime and attacks. While all Western governments officially promote a policy of software and network flaws disclosure, also European countries have favoured backdoors and mechanisms to access encrypted communications for fighting terrorism and transnational cybercrime.

The next technology wave of the '*Internet of Things (IoTs)*' with its network of smart-sensor-enabled devices that can communicate and coordinate with each other via the Internet will create new businesses, providing healthcare, and manage '*smart cities*'. McKinsey has estimated an annual economic impact of US$3.9 trillion to US$11.1 trillion worldwide by 2025.[277]

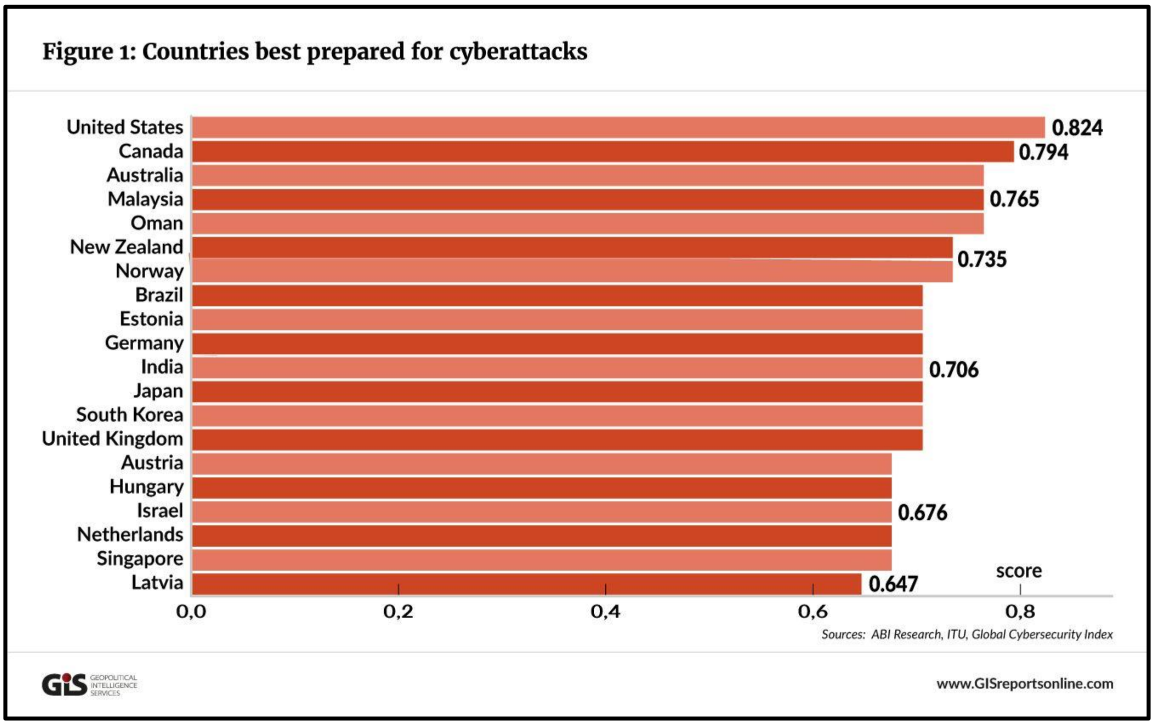
As these internet-connected devices will increase dramatically, international crime might exploit those devices by entering their unprotected doors using them for theft, data

276 See F. Umbach, 'The Fog of Cybersecurity'.

277 See James Manyika, 'Unlocking the Potential of the Internet of Things'.

falsifying, creating zombie computer networks (‘*botnets*’) and attacking networks as well as websites by bombarding them with information requests for crippling those chosen targets.

Figure 27: Countries Best Prepared against Cyberattacks

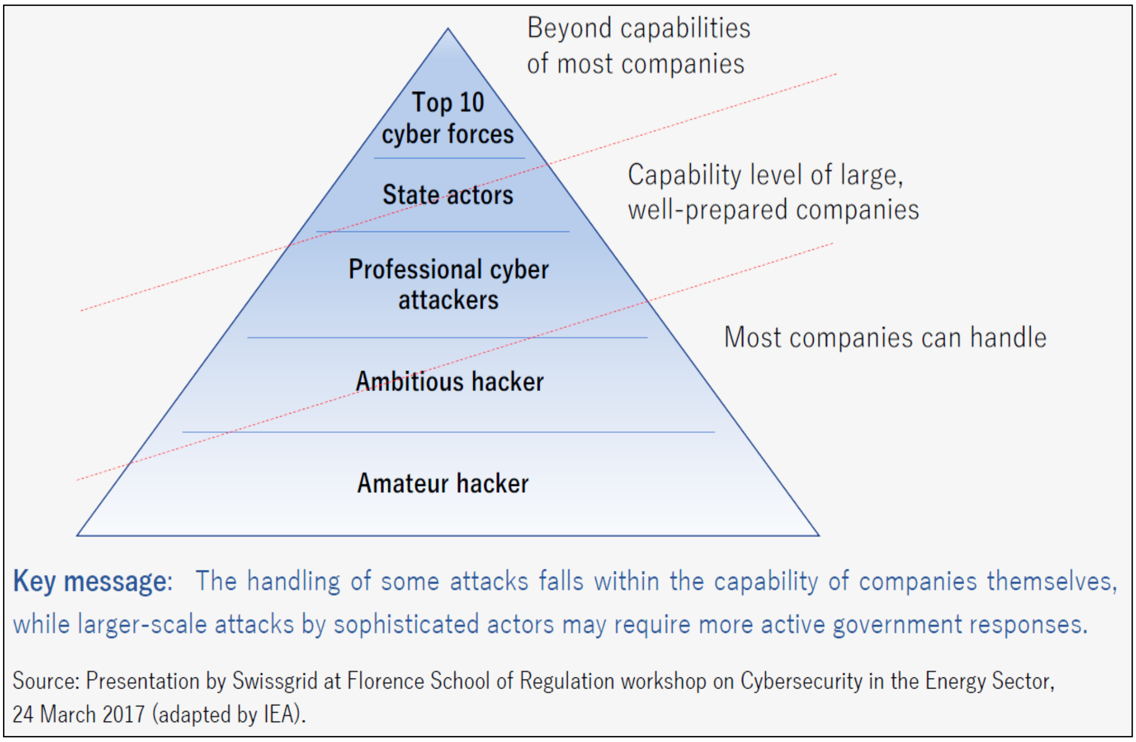


Source: GIS/World Economic Forum 11/2017

The IoT security is challenged on various fronts: (1) by the lack of overarching standards, as the large worldwide actors and industry organisations have preferred their own solutions. It results in incompatible technology standards by the major players and hinders the development of new technical end-to-end security solutions; (2) the sheer numbers of size introduce an unknown multitude of new attack vectors. They are often combined with short replacement cycles, which undermine the development of tailored security technologies; (3) while both customers and producers view safety and security as very important, IoT devices for smart homes and buildings are viewed as a usual commodity, which demands low prices. This contrasts with the need for adequate security excluding any breaches of private and commercial data. But customers are mostly unwilling to pay any premium or even expect that those security costs will decline. IoT producers need to convince its end customers that security demands additional costly investments. Under these pressures, semiconductors companies are already struggling to make profits with their security investments; (4) the industry is facing special challenges of innovative industrial IoT applications (‘*industry 4.0*’) as many businesses and industrial operations are running on outdated computer systems and software. Connecting older legacy systems with the internet often undermines end-to-end security as well as stable industrial processes.[278]

But for governments, coping with sophisticated state-supported cyberattacks (i.e. Advanced Persistent Threats/APTs) on its own CIs and/or for industrial as well as other espionage purposes, those state-supported APTs are considered as the most threatening security challenges.

Figure 28: Capabilities of Companies to Handle Cyber-Attacks



Source: IEA 2017

Most worrying is the continual adoption of increasingly-interconnected ICS, including in the oil, gas and electricity industries.[279] Fixing flaws in sensors and devices by updating software or other ways is not simple, quick or sufficient as engineers need years to design or redesign. Replacing the architecture of ICS equipment, by really taking network segmentation seriously, may even take 25-35 years. It is further complicated by the different approaches, viewpoints and background and missions between IT and engineering professionals. Defining and conceptualizing government regulatory frameworks and

278 See F. Umbach,'Energy Cybersecurity: The Need for Effective Resilience'; Ed Crooks, 'The Internet of Things: Industry's Digital Revolution'; Molly Wood, 'CES: Security Risks from the Smart Home', NYT, 7 January 2015Barbara Bachmann, 'Dein Haus kennt dich', Die Zeit 4 December 2014; Holger Kroker, 'Angriff der Bot-Armee', Die Welt, 7 November 2016; Brian Girardi, 'Endpoint and the Internet of Things', www.securityweek.com, 13 June 2017; Beau Woods, 'Confronting Transatlantic Cybersecurity Challenges in the Internet of Things', Atlantic Council-Issue Brief, February 2017; Harald Bauer, 'Security in the Internet of Things', McKinsey&Company, May 2017.

279 See also IEA, 'Digitalisation & Energy', pp. 123 ff.

standards takes often years.[280] When they are implemented, they are often no longer adequate and sufficient due to the speed of technology innovation.

In many cases, regulations are also impractical and contradict with efficiency and the needs of the business as well as markets. Moreover, policy makers need to balance privacy concerns with state security requirements and the industry's interests for their sold products and (international) market competition.

The billions of IoTs being introduced in the coming years, for instance, have neither been designed by any safety and security standards at all, nor with rudimentary standards for specific countries as no international standards exist, though they are sold and exported around the world, having short replacement cycles, and compete on price on world markets as most customers are unwilling to pay higher costs for higher security standards.

Figure 29: Definition of Resilience Concepts

Resilience Concepts are defined by:

- maintaining the entity's ability to deliver the intended outcome continuously at all times, when regular delivery mechanisms have failed, such as during a crisis and after a security breach.

They include:

- the ability to restore regular delivery mechanisms after operational disruptions and the ability to continuously change or modify delivery mechanisms if needed in the face of new risks.
- Backups and disaster recovery operations as part of the process for restoring delivery mechanisms.

Source: Dr. Frank Umbach

In the future, the energy companies won't have to cope with ever-expanding cybercriminals responsible for the majority of cyber threats emanating from the Deep & Dark Web targeting indiscriminately the various industries. They also have to fight and survive much more sophisticated attacks targeting their specific ICS and SCADA-systems aimed at disrupting the operational continuity of their major production and supply functions.

280 See Galina Antova,'We Need a New Framework for Thinking about ICS and Critical Infrastructure Network Security', www.securityweek.com, 13 February 2018;idem, 'The Year to Come in ICS/Critical Infrastructure Security', ibid., 5 December 2017; Eduard Kovacs, 'New 'Triton' ICS Malware Used in Critical Infrastructure Attack', ibid., 14 December 2017; idem, 'Increasing Number of Industrial Systems Accessible from Web: Study', David Bond, 'Critical Infrastructure Threat as New Malware Is Identified', FT, 14 December 2017.

But also the expansion of renewables, alongside smart grids and smart metering, is creating new cyber security challenges.[281] In August 2017, a Dutch researcher discovered 17 vulnerabilities in internet-connected inverters, which convert electricity produced by solar panels for being used on the grid.[282] It could allow attackers to remotely control the devices, alter the flow of power and overload the grid which could result in a power outage, dependent on a sufficient number of successfully attacked inverters. Fresh flaws have also revealed at wind farms, whose operations can be paralysed by attackers causing damage to the turbines.[283]

Like other industries, energy companies in general and electricity companies in particular, as all other CIs are dependent on a stable supply of electricity for 24 hours. They need to safeguard their critical assets (i.e. their ICS and SCADA-systems), proactively address physical and cyber threats, and assess as well as mitigate risks effectively. It requires a comprehensive understanding of all vulnerabilities and risks, including preparing for the worst case such as the disruption of production and supply functions. But companies must also realistically assess the international and their specific cyber threat risks and environment and set priorities for their own cyber defence and cyber resilience strategies as they cannot defend themselves against all sophisticated (i.e. state-supported) cyberattacks.

Given the fact that cyber threats might further increase with much more potential disruptive and cascading impacts, companies and organisations also need to focus on restoring their attacked and compromised production and supply functions as soon as possible. It includes a constant internal awareness building by training its own employees not just limited to the IT and security staff and simulate worst-case scenarios in training (learning-by-doing) exercises.[284]

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281 See F. Umbach, 'Cyber Security Issues for Advanced Metering Infrastructure: Implications for Future Electrical Grids and Critical Infrastructures'.

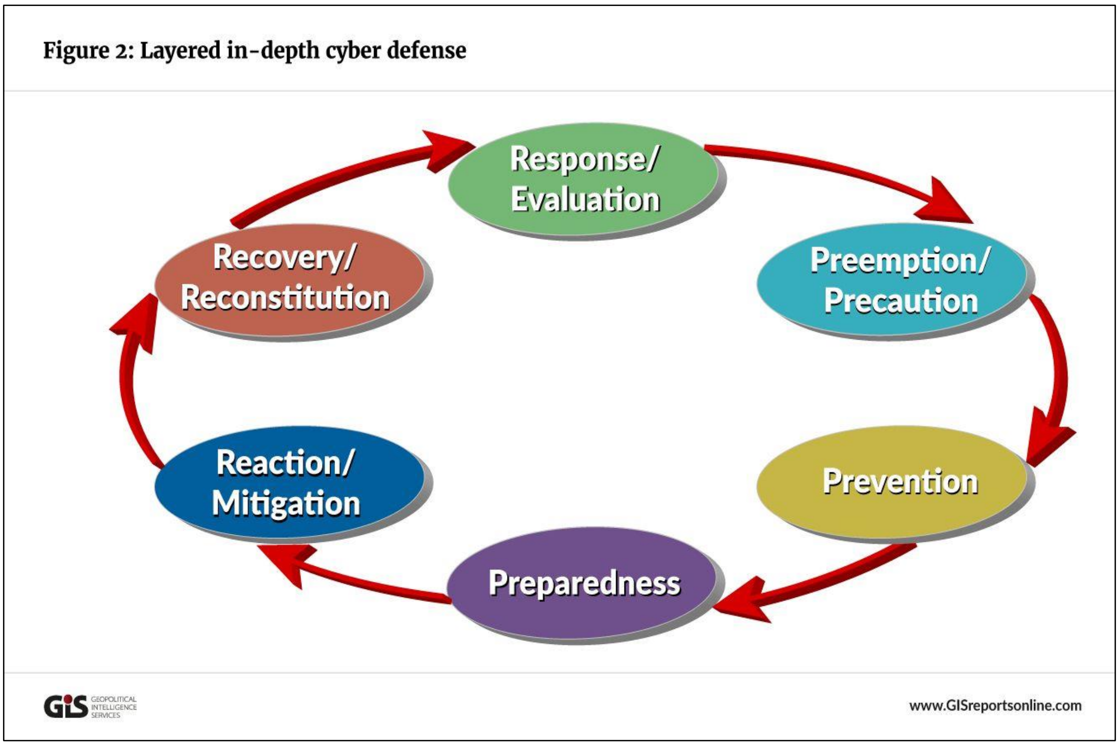
282 See Chris Baraniuk, 'Hackers 'Could Target Electricity Grid' via Solar Panel Tech', www.bbc.com, 8 August 2017. See also Michael Rühle/Lukas Trakimavicius, 'Cyberattacks are the New Challenge for Renewable Energy', Politico, 18 July 2017.

283 See Hannah Kuchler, 'Wind Farms and Factory Robots at Risk from Hackers, Experts Say', FT, 30 July 2017.

284 See idem, 'Companies Test Defences against Cyber Crime Threat', FT, 7 January 2018; Ashley Arbuckle, 'Incident Readiness and Response, an Evolution in Cyber Risk Mitigation', www.securityweek.com, 16 January 2018; Scott Stewart, 'The Weakest Link in the Cybersecurity Chain Is Sitting at the Keyboard', Stratfor.com, 19 October 2017; Stefan Mouille, 'Cybersecurity Act: Five Outcome-Based Principles from the Digital Security Industry', 2 February 2018 (https://www.linkedin.com/pulse/cybersecurity-act-five-outcome-based-principles-from-digital-mouille/ accessed on 3 February 2018); Susan Hennessy, 'Deterring Cyberattacks. How to Reduce Vulnerability', Foreign Affairs, 16 October 2016; John Drzik, 'Cyber Risk Is a Growing Challenge. So How Can We Prepare?', World Economic Forum, 17 January 2018; Brad Brown et.al., 'To Survive in the Age of Advanced Cyberthreats, Use 'Active Defense', McKinsey Insights, November 2017; Harald Bauer et.al., 'How CEOs Can Tackle the Challenge of Cybersecurity in the Age of the Internet of Things', ibid., June 2017; Jason Chol et.al., 'Hit or Myth? Understanding the True Costs and Impact of Cybersecurity

Effective cyber resilience strategies begin with making security a business and organisational priority as the top management. They also include reviewing critically the overall security architecture of companies and organisations in the light of the introduction of new disruptive technologies and changing business models and companies' cultures. Even by taking into account that some technology trends such as blockchain, AI '*transactive energy*' peer-to-peer-trading and other innovations will enhance cyber defence and cybersecurity.[285] But they are not silver bullet solutions. As full prevention of sophisticated cyberattacks (i.e. APTs) is impossible, a layered '*defence-in depth'*-concept and resilience system for CIs and ICS, based on physical, organisational, electronic and cryptographic layers, need to include the elements as highlighted in the following figure.

Figure 30: Layered In-Depth Cyber Defense Concept



Source: FU/GIS 2018

In addition, digital energy security also needs to build on two other key concepts beyond resilience: cyber hygiene (a basic set of precautions and monitoring to enhance awareness)

Programs', ibid., July 2017, and George Beebe, 'How to Deter Russian Cyber Attacks', The National Interest, 12 July 2017.

285 To AI see for instance, Dom Galeon, 'How Artificial Intelligence is Making Nuclear Reactors Safer', Futurism-News, 23 November 2017 (https://futurism.com/researchers-training-ai-make-nuclear-reactors-safer/).

and ‘*security of design’* by incorporating safety and security objectives and defined standards as part of a technology and system architecture already in the design phase.[286]

Given the rising cyber threats to CIs, China’s plans for investment in key national infrastructures across the world and the increasing overall importance of CEIs for the rest of CIs and the overall political as well as social-economic stability of highly industrialised countries has led to a review of control, ownership and legal frameworks for future foreign investments in Western CEIs. The introduction of cross cutting national security requirements for continuing government approval of the ownership and control of CIs (i.e. telecommunications, transportation, water supply and energy) in UK, France, Germany, the Baltic States, and Australia gives the governments a political veto for national security as a paramount objective.[287] Lithuania already adopted in 2012 a law to prevent that foreign entities and investors from owning major energy and other infrastructures that do not support Vilnius’ trans-Atlantic alliance and EU membership commitments.[288]

The EU has also strengthened the transnational efforts for cyber defence relying on strengthening resilience, deterrence and defence for a stronger cybersecurity for the EU by various means, including an EU-wide ‘*Directive on Security of Network and Information Systems (NISD)*’ in 2016 and giving the EC cyber security agency ‘*ENISA*’ (European Union Agency for Network and Information Security) more institutional power and human resources to enhance its capabilities.[289]

Ultimately, governments, industries as well as businesses and the public need to be aware that any new technology can be used for offensive crime-related purposes as well as strengthening defence and resilience in the cyberspace in an ever escalating cyber arms race. Smart grids, for instance, enable a re-architecture of grids to be interconnected to the internet. They allow multiple power to flow, including to reroute around downed substations and enable the much more resilient grids for a rapid recovery to grid outages. But at the same time, their internet-connection and SCADA-systems makes them more than ever vulnerable to cyberattacks.

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286 See IEA, ‘Digitalisation & Energy’, p. 128.

287 In Germany, for instance, the government has clearly given the preference that the share of 20% of the ownership transmission grid company ‘50Hertz’ has been sold to the Belgian Majority Owner Elia instead to the Chinese company ‘State Grid Company of China (SGCC) – see Klaus Stratmann, ‘Die Bundesregierung kämpft um 50Hertz’, Handelsblatt, No. 39, 23-25 February 2018.

288 See also Nick Butler, ‘Energy Security Focus Turns National’, FT, 3 October 2017 and Brenda Shaffer, ‘Energy Security is No Monkey Business’, Atlantic Council, 9 June 2016.

289 See ‘Operational Considerations for Responding to the Threat of Cyberattacks on Critical Energy Infrastructure’, European Commission/Strategic Energy Technologies Information System (SETIS), SETIS Magazine, Brussels, May 2018 (https://setis.ec.europa.eu/setis-reports/setis-magazine/digitalisation-of-energy-sector/operational-considerations-responding; accessed on 16 June 2018).

While the blockchain–technology, as another example, is widely seen as an important technology strengthening cyber defence of industries and governments, the infrastructure of blockchain that records cryptocurrencies transfers as digital money have been used by hackers for stealing processing power illicitly for this very energy-intensive procedure of '*mining*' them over the last year. Companies around the world have been surprised and shocked by the '*cryptojacking schemes*', which can slow down computers and increase server bills. Those cyberattacks rose more than 600% in the first quarter of 2018. Some experts have already warned that the theft of computing power processing and '*mining*' of cryptocurrencies have become much more profitable than that of data. Many companies are again not aware of those profits made by hackers as their cyberattacks are often undetected in companies whose computing power is being leached.[290] The expansion of virtual cryptocurrencies itself (such as Bitcoin), which have a total value meanwhile of hundreds of billions of US$, can be explained at least partially by their preferred use of cyber hackers, who blackmail companies to pay a ransomware in cryptocurrencies as they are anonymous (at least until it is exchanged for conventional money) and much harder to trace than credit card payments in conventional currencies.[291] Cyber hackers have also shifted their attacks from the exchanges to the users with phishing attacks to steal their personal details and private keys for their digital accounts.[292]

5.3 The Need for Advanced Battery Storage Technologies

For its expanding fleet of EVs, Tesla has built the world's largest battery Gigafactory in Nevada, which has started its production last January, and is currently building another one in Australia.[293] It hopes to produce 500,000 car batteries or 35 GWh annually by the end of this year. The factory will be fully powered by clean energy and include battery recycling. Battery costs have declined by 73% since 2008 to US$230 per kilowatt hour (kWh) in 2016.

In 2017, battery prices fell by 35%. Some industry forecasts suggest that the cost of EVs will fall to match those powered by combustion engines by 2022 when battery costs will have further fallen to US$100/kWh.[294] But some other experts suggest rather a slower fall

290 See Chloe Cornish/Hannah Kuchler, ''Cryptojackers' Steal Computer Power to Mine Digital Coins', FT, 8 April 2018, and Hannah Murphy, 'Cryptojacking Malware on the Rise, Says McAffee Report', FT, 27 June 2018.

291 See also Hannah Kuchler, 'Bitcoin Fuelling Rise in Cyberattack Ransom', FT, 8 December 2013.

292 See also Jemima Kelly, 'Hackers Target New Cryptocurrency Investors,', FT, 12 July 2018.

293 See also Sarah Kimmorley/Paul Cogan, 'Tesla is Going to Build the World's largest Lithium ion Battery in Australia', Business Insider, 7 July 2017.

294 See also F. Umbach, 'Four Implications of Electric Mobility', GIS, 2 November 2017.

of the future battery costs.[295] But a new generation of batteries is forthcoming. SK Innovation (a Korean battery producer), for instance, is introducing next December its NCC-811 batteries which will extend the driving range of EVs up to 500 km and plans to introduce another one by 2020 with a 700 km range. Toyota is developing ultra-fast charging solid-state EV batteries (instead of lithium-ion based), which will double the range of current EVs, charging them only in minutes than hours and are no fire hazard. It hopes to commercialise them by the early 2020s.[296] In the U.S. a team of the North-western University has developed a cheaper lithium-iron-oxide battery that can power smartphones and car batteries eight times longer.[297] Meanwhile, also the building of a fast EV battery charging infrastructure in Europe makes progress alongside much shorter charging times.[298]

Another problem is the lack of recycling capacities.[299] At present, about 90% of lead-acid batteries used in conventional gasoline cars are recycled – compared with less than 5% of lithium batteries. An estimated 11 m tons (mt) of spent lithium-ion battery packs will be discarded till 2030. But recycling processes are technically challenging and expensive. For making battery recycling economically profitable, the utilisation rates of recycling facilities must be sufficiently high. For the first generation of EV batteries to reach the end of life, present timely investments are insufficient to have the much needed recycling infrastructure in place.[300]

China and the EU have already introduced rules that will hold carmakers responsible for recycling their batteries. But while the cost of fully recycling a battery is also falling, the value of the recycled raw materials is often still a third of that. A more attractive option is

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295 See Michael Lynch, ‘Electric Vehicle Prospects: Bad Analogies are Worse than no Analogies‘, Forbes, 21 August 2017, and Gerard Reid, ‘Why the Future of Batteries is Lithium and Why Their Impact will be Bigger than You Think’, www.energypost.eu, 15 December 2017.

296 See Bertel Schmitt, ‘Ultrafast-Charging Solid-State EV Batteries around the Corner, Toyota Confirms‘, Forbes, 25 July 2017; ‘Aufladen in weniger als zehn Minuten‘, FAZ, 4 November 2017.Melissa Shaw, ‘Toshiba Unveils ‚Game Changing‘ EV Battery that can Charge in 6 Minutes‘, Rare Earth Investing News, 25 October 2017; Shim Woo-Hyun, ‘SK Innovation to Produce EV Batteries with 100 km Extension of Driving Range‘, Korea Herald, 31 August 2018; Eric Brandt, ‘Honda Claims ist Electric Cars will Change in 15 Minutes by 2022‘, 26 November 2017 (http://www.thedrive.com/sheetmetal/16365/honda-claims-its-electric-cars-will-charge-in-15-minutes-by-2022; accessed on 29 November 2017), and Brian Westenhaus, ’EV Range Set to Triple with New Lithium Battery Breakthrough‘, Oilprice.com, 20 December 2017.

297 See Kyree Leary, ‘This Inexpensive Battery Could Revolutionize the Clean Energy Industry’,6 January 2018 (https://futurism.com/battery-revolutionize-clean-energy/; accessed on 9 January 2018).

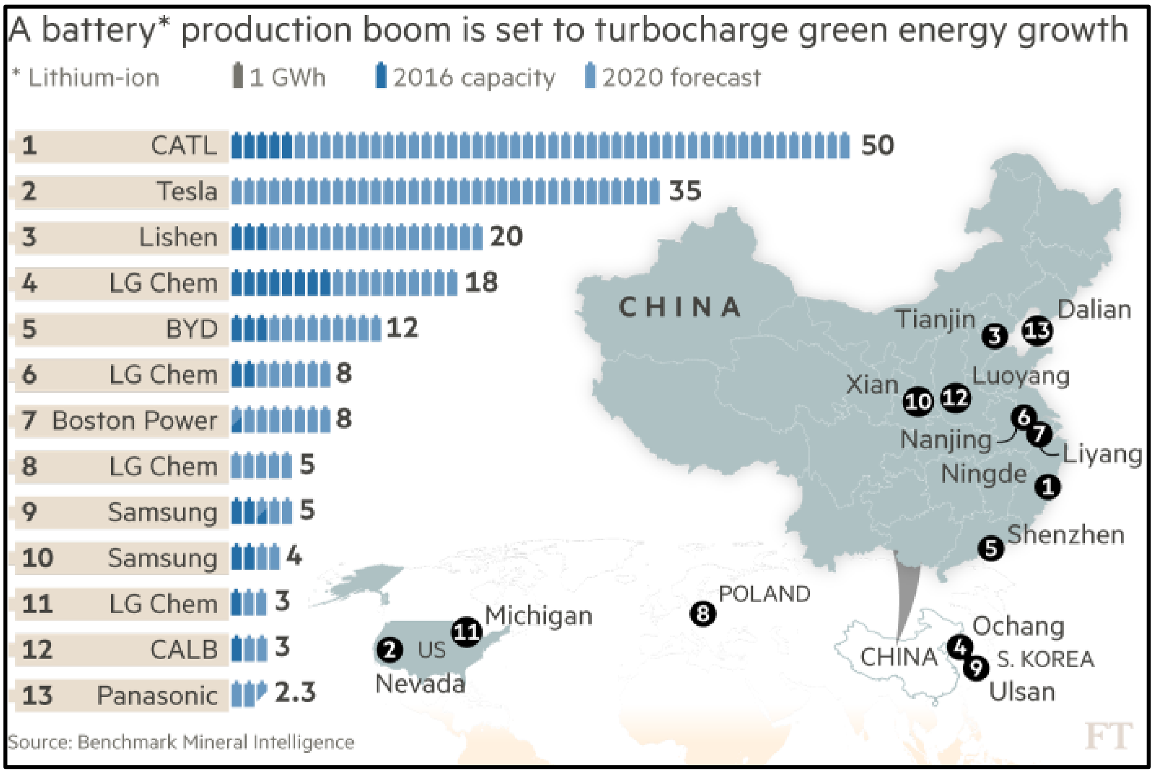
298 See also Stefan Knupfer/Jesse Noffsinger/Shivika Sahdev, ‘How Battery Storage Can Help Charge the Electric-Vehicle Market’, McKinsey Center for Future Mobility, February 2018.

299 See also ’Battery Recycling Technology Essential to the Electric Vehicle Revolution‘, Investing News, 1 November 2017; Henry Sanderson, ‘Rise of Electric Cars Poses Battery Recycling Challenge‘, FT, 3 September 2017; Joey Gardiner, ‘The Rise of Electric Cars Could Leave Us with a Big Battery Waste Problem‘, The Guardian, 10 August 2017; Echo Huang, ‘China’s Booming Electric Vehicle Market Is About to Run into a Mountain of Battery Waste‘, 28 September 2017 (https://qz.com/1088195/chinas-booming-electric-vehicle-market-is-about-to-run-into-a-mountain-of-battery-waste/; accessed on 29 September 2019).

300 See Harry Sanderson, ‘Electric Car Growth Sparks Environment Concerns‘, FT, 7 July 2017.

the re-use of car batteries for home and other energy storages rather than recycling. These batteries can still have up to 70% of their capacity, when they end their usual lifetimes in electric cars.

Figure 31: The Worldwide Leading Companies of Battery Production



Source: FT 2017

China not only matters as the world's largest EV market but is also as the globally largest battery producer with 59% in 2018 to 73% by 2021.[301] It would create new critical dependencies of the European carmakers on China for years if not decades to come due to the unwillingness to create an own battery production in Europe.[302] In addition, as metal prices for years have been determined by China's industrial demand, the world stocks of industrial metals have become very dependent on China's future of industrial and technological developments as well as raw material demand. As these prices have currently recovered, the rising Western and global dependence on the development of China's EV and battery market is added by their equally rising dependence on REEs and other CRMs under Chinese control. While it is the world's largest lithium consumer, for instance, China is also the fourth-largest lithium producer as well as the worldwide largest producer of refined

301 See 'The Supply of Cobalt Has Emerged as a Potential Risk to the Pace of Growth in Electrified Transport over the Next Few Years', Bloomberg NEF, 21 May 2018 (https://about.bnef.com/blog/e-buses-surge-even-faster-evs-conventional-vehicles-fade/), and 'Lithium Forecast & Lithium Stocks to Buy', Resource Investing News, 2017, p. 4.

302 See also Gerard Reid, 'The Bosch Solar Complex: European Companies Should not Give up on Batteries just because They Failed in Solar', www.energypost.eu, 11 April 2018.

cobalt and up to 82% of the global graphite production – two other raw materials for car batteries.

For Europe and the U.S., the geo-economic and geopolitical challenge of the worldwide electrification of the transport sector results from the fact that their car producing companies have missed the technological revolution as 20 of the 30 largest worldwide battery producers are currently located in Asia (China, Japan and South Korea) and in particular China.[303] As future car manufacturing plants have numerous competitive advantages to be located near vast battery gigafactories or vice versa, the chosen locations of the battery gigafactories will considerable shape geography and geo-economics of the auto industry for the next decades. They have numerous advantages towards those car construction plants, having no gigafactory in their direct neighbourhood and rely on long-distance imports from Asia. The extended supply chain of those gigafactories also guarantees a large number of skilled jobs in the future.[304] Bloomberg New Energy Finance (BNEF) has predicted an overall global investment of US$548 bn in battery capacity by 2050 – with two thirds at the grind level and one-third for installed behind-the-meter by households.[305]

Worldwide, the number of battery megafactories has increased from 25 in 2017 to more than 40 in 2018.[306] In this context, it is very alarming for European governments as its car-makers invest seven times more in EV production in China than at home.[307] A European car battery value chain alone could be worth of an estimated 250 bn Euros by 2025. Therefore, the European Commission has launched a '*European Battery Alliance*' in October 2017 to stimulate European companies to build battery factories.[308] For critical experts, it doesn't make sense as Europe comes too late and won't be able to compete with Chinese and other Asian competitors. Instead, it should invest in research and development of next-generation solid-state EV batteries. Moreover, in order to avoid losing market shares in the global competition of the battery race, Chinese, Korean and Japanese battery companies

303 See AT Kearney, 'Überspannung im Batteriemarkt für Elektrofahrzeuge', Düsseldorf 2017.

304 See also Nick Butler, 'Batteries are the Next Frontier of Industrial Competition', FT, 21 May 2018.

305 See Karel Beckmann, 'Battery Boom will Transform Energy'- but will Europe Get Left behind', www.energypostweekly.eu, 26 June 2018, p. 2.

306 See Priscila Barrera, 'Simon Moores: We're in the Midst of a Global Battery Arms Race', Investingnews.com, 11 June 2018.

307 See Karel Beckmann, 'Battery Boom will Transform Energy', p. 6.

308 See European Commission, 'Strategic Action Plan on Batteries. Annex to the Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, 'Europe on the Move. Sustainable Mobility for Europe: Safe, Connected and Clean', Brussels, 17.5.2018 COM(2018) 293 final. See also Carole Mathieu, 'The EU Battery Alliance. Can Europe Avoid Technological Dependence?', IFRI, Paris, 20 February 2018, Aurélie Faure-Schuyer, 'The European Battery Alliance: Ambitions and Requirements', CEPS-Commentaries, Brussels, 27 April 2018, and Sam Morgan, 'Blossoming Batteries Boosted by EU-Plan', EURACTIV.com,23 May 2018..

are already building or considering further larger investments in new battery production facilities in Europe.[309]

Meanwhile, energy storage needs and battery storage solutions have become ever more important for households, utilities as well as other industrial customers. At the same time, battery costs fell 15% per year between 2012 and 2017 - a total drop of 75% in just five years. The balance-of-system (BOS) costs (other hardware, soft costs and engineering, procurement, and construction/EPC) have dropped even by more than 25% per year over that period. The installed per-kilowatt-hour cost of an energy-storage system could further decline by 55-70%by 2025 and break through the US$100 per-kilowatt-hour mark already by 2020.[310]

Furthermore, experts expect that further radical improvements of lithium batteries will also allow to use them for trucks, busses, and increasingly also for air and sea transport.[311] Energy utilities have already begun to build utility grade lithium-ion batteries for large industry storage systems and grid-scale energy storage applications.[312] Batteries are also becoming an electricity storing option for other industries, including as a build-in option for wind and solar farms. The costs for such a stationary use could fall by another 66% by 2030, according to a study of the International Renewable Energy Agency (IRENA).[313] With these perspectives, battery storage will become another disruptive technology for various industries.[314] They will allow a more rapid growth of RES and replacing traditional coal and other fossil-fuel power generation.[315]

5.4 Rising Dependencies on Raw Material Supply Security

As the transition to a non-fossil fuel age and related climate change mitigation efforts as well as Sustainable Development Goals are dependent on '*green technologies*' and non-

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309 See also Karel Beckmann, 'Should Europe Buy or Build Batteries? Or Have the Asians to Build Batteries in Europe?', Energypostweekly.eu, 20 June 2018.

310 See David Frankel/Sean Kane/Christer Tryggestad, 'The New Rules of Competition in Energy Storage', McKinsey&Company, June 2018.

311 See Gerard Reid, 'Why the Future of Batteries is Lithium and Why Their Impact will be Bigger than You Think'.

312 See Megan Geuss, 'Two Energy Powerhouses Join together to Make Big, Grid-Tied Batteries', 11 July 2017 (https://arstechnica.com/information-technology/2017/07/two-energy-powerhouses-join-together-to-make-big-grid-tied-batteries/; accessed on 17 July 2017), and Simon Bennett/Luis Munuera, 'Commentary: Who Wants to be in Charge', IEA, 21 November 2017.

313 See 'Battery Costs for Stationary Energy Could Fall by 66 pct by 2030 – Study', Reuters-Inside Power, Gas & Carbon, 6 October 2017, and John Massey, 'Battery Storage is Becoming a Built-in Product Feature', www.energypost.eu, 25 August 2017.

314 See also David Frankel/Amy Wagner, 'Battery Storage: The Next Disruptive Technology in the Power Sector', McKinse&Company, June 2017.

315 See Soila Apparicio, 'Battery-Backed Solar Power to Undercut Coal in China by 2028, Report', Climatechangenews.com, 3 July 2018.

renewable Critical Raw Materials (CRMs). As a World Bank report of 2017 concluded, the clean energy shift and clean technologies “*are in fact MORE material intensive in their composition than current fossil-fuel-based energy supply systems*”.[316]

Figure 32: Matrix of Metals and Energy Technologies Explored (World Bank 2017)

	Wind	Solar photovoltaic	Concentrating solar power	Carbon capture and storage	Nuclear power	Light-emitting diodes	Electric vehicles	Energy storage	Electric motors
Aluminum	X	X	X	X		X		X	X
Chromium	X			X	X	X			
Cobalt				X	X		X	X	
Copper	X	X		X	X	X	X		X
Indium		X			X	X	X		
Iron (cast)	X		X			X		X	
Iron (magnet)	X								X
Lead	X	X			X	X			
Lithium							X	X	
Manganese	X			X			X	X	
Molybdenum	X	X		X	X	X			
Neodymium (proxy for rare earths)	X						X		
Nickel	X	X		X	X	X	X	X	
Silver		X	X		X	X	X		
Steel (Engineering)	X								
Zinc		X				X			

Source: World Bank 2017

As the world’s leading holders of reserves and producers of CRMs for renewable energy resources such as neodymium for advanced magnets of wind power stations or for silicon production, they might benefit economically and geopolitically from the switch from carbon and fossil fuels to renewables and may even become new ‘*renewable superpowers*’.[317] In Latin America, Chile, Brazil, Peru, Argentina and Bolivia could benefit from the rising supply of CRMs due to their reserves of lithium, nickel, manganese, copper, iron ore, silver and zinc. Africa could benefit from its reserves of platinum, manganese, cobalt, bauxite and chromium. But such a development does not only depend on attractive mining and extraction conditions but also political stability and ‘*social licenses for sustainable*

[316] World Bank, ‘The Growing Role of Minerals and Metals for a Low Carbon Future’, Washington D.C., June 2017, p. XXII.

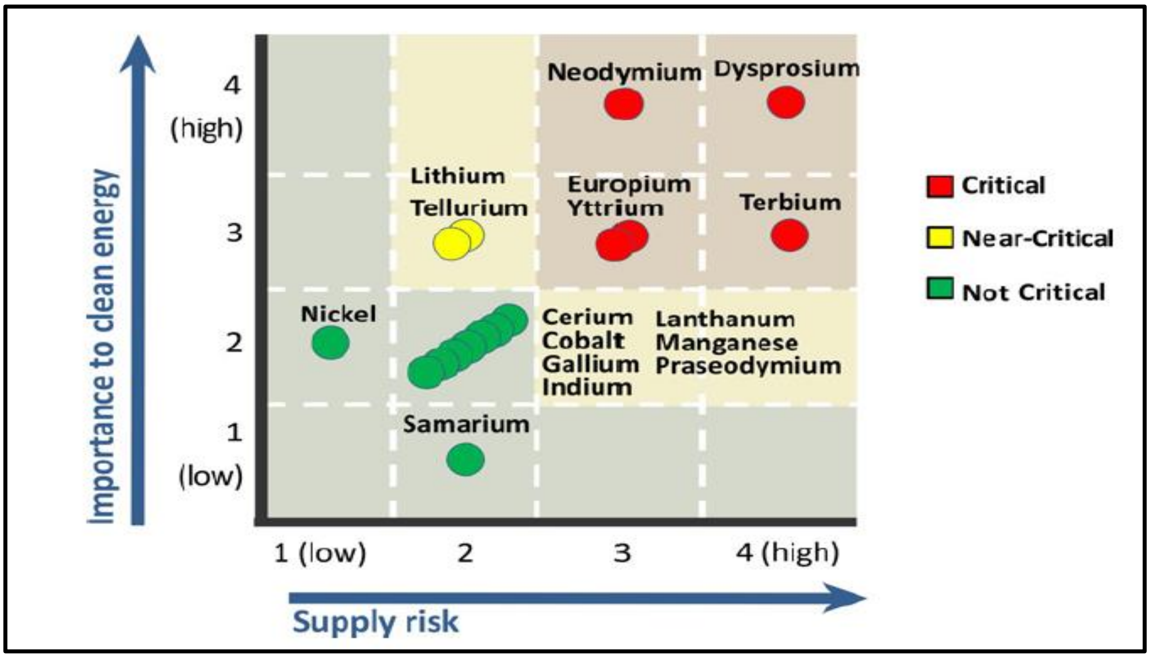
[317] See also Andrew Barron, ‘Meet the New ‘Renewable Superpowers’: Nations that Boss the Materials Used for Wind and Solar’, www.energypost.eu, 26 February 2018.

sourcing', higher environmental standards, human and social rights as well as promoting affordable and clean energy.[318]

In contrast to fossil fuels, those CRMs don't need to be continuously supplied though the replacement cycle for more modern and traditional powerful systems might be shorter than replacing a power plant with the 30-40 years of their lifecycle.

With the fastening of development of new electric cars, the world's critical raw material supply demand will further grow and become a '*disruptive source*' for EVs and other technology developments. They require not just more Rare Earth Elements (REEs[319]), but also other CRMs such as lithium, cobalt, nickel, and graphite.[320]

Figure 33: (Medium Term 5–15 years) Criticality of Raw Materials to Clean Energy



Source: U.S. Department of Energy 2011

Rare Earths

In recent years, internationally efforts have been strengthened to diversify imports of REEs and increase investments for opening new REEs mines around the world as well as '*urban mining*' like recycling of rare earths and other materials from used electronic devices.

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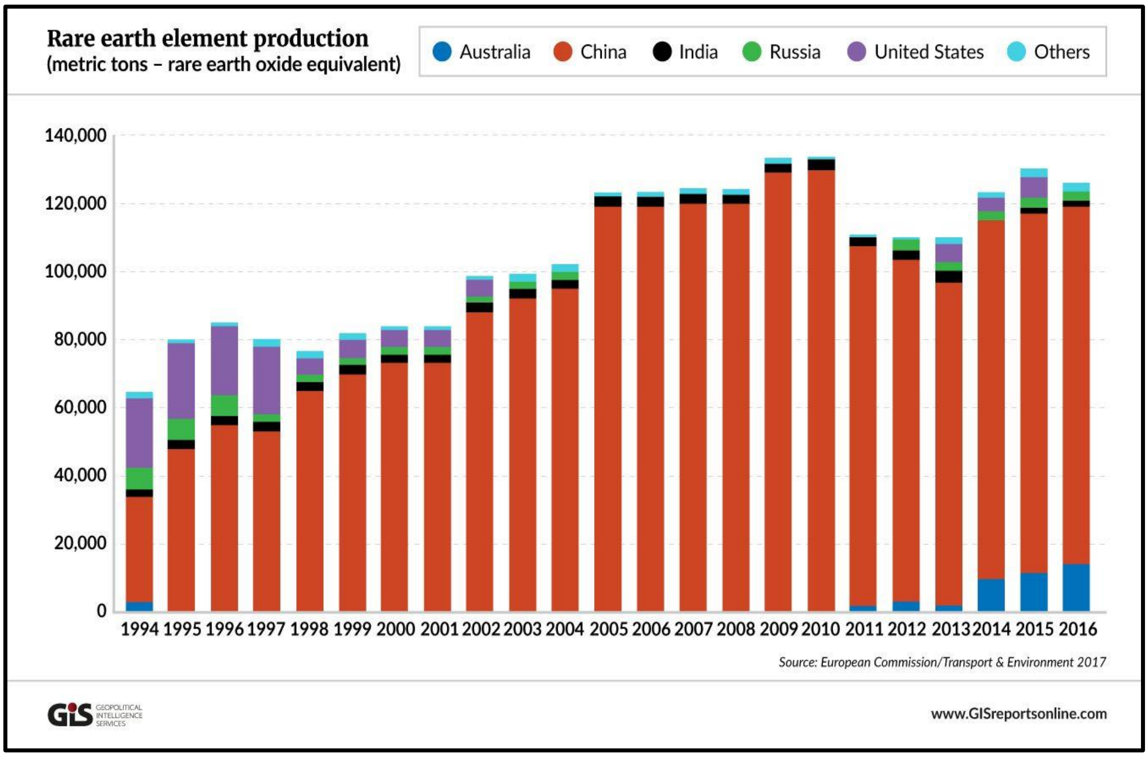
318 See also World Bank Group, 'The Growing Role of Minerals and Metals for a Low Carbon Future', pp. XIII ff. and 26 ff.

319 The REE *Neodymium Iron Boron* is used for permanent magnets (NdFeB) of high-performance electric motors. Those magnets also use other REEs such as *Praseodymium (Pr)* and *Dysprosium*.

320 See also European Commission, 'Electric Vehicle Life Cycle Analysis and Raw Material Availability', Priscilla Barrera, 'Cobalt Demand Set to Soar as EU Outlines Electric Car Plans', Cobalt Investing News, 8 November 2017; idem, 'Cobalt Set to Surge as UK Plans to Ban Fossil Fuel Cars by 2040', ibid., 26 July 2017, and Henry Sanderson, 'Electric Vehicle Ambitions Spark Race for Raw Materials', FT, 24 October 2017.

China's export cut and use of near '*technology minerals*' for political ends in 2011 have sent even a more troubling message to the world as Beijing might not be prepared and politically willing to assume the regional and global responsibilities that grow with that status. Although Beijing has given up its export ban in 2015, the renationalizing trends in China and its overall focus on disrupting technologies for its arms race with the U.S., Japan and Europe does not suggest that China might never use its de facto production and export monopoly of REEs in the future. Even with opening of new mines in other countries, including in the U.S. and Europe, China can always undercut the price of REEs as it did in the 1990s when Beijing deliberately reduced the prices of REEs to cause the bankruptcy of the Western and many international mines in order to gain the worldwide monopoly status for REEs.[321] In the short-term perspective, the worldwide demand is expected to increase as the demand for magnets based on Neodymium Iron Boron is expected in 2020 some 14 times higher than in 2015.[322]

Figure 34: Rare Earth Element Production (1994–2016)



Source: GIS 2018/European Commission/Transport & Environment 2017

As China has scaled back its car subsidies, it has become unclear how fast the worldwide electric mobility – and, therewith, the production of batteries and their CRM demand - will

321 See Paul McLeary, 'DoD, White House Likely to Fight Chinese Monopoly on Rare Earths Minerals', Breakingdefense.com, 18 May 2018, and Jude Clemente, 'Trade War with China Exposes U.S. Mineral Import Problem', Forces, 11 July 2018.

322 See European Commission, 'Electric Vehicle Life Cycle Analysis and Raw Material Availability', p. 8.

further grow.[323] But the mining and exploration of REEs will also remain difficult in the future as they are not found in high concentration to allow profitable economic extraction. The global reserves of REEs are estimated at around 80 mt, whereas the average production per year has been around 135,000 t during the last years. In 2015, around 50% of the global REE demand came from magnets of permanent electric motors of EVs.[324]

Supply diversification efforts have proved to implement as rather difficult. Despite long lead times of more than 7 years, technology innovation in mining and production helped to restore commercial competitiveness, to reduce the overall demand, and to push environmentally acceptable solutions in the worldwide supply of REEs.[325] Yet, China still accounts for more than 80% of REE supply (105,000 mt in 2017) and over 66% of global demand. REE prices are increasing again due to the global demand for new emerging disruptive technologies.[326]

Figure 35: Rare Earth Production and Reserves in 2015 (in metric tons)

Rare earth production and reserves in 2015 (in metric tons)

Country	*Production*	*Reserves*
China	105,000	55,000,000
Brazil	0	22,000,000
Australia	10,000	3,200,000
India	N/A	3,100,000
United States	4,100	1,800,000
Malaysia	200	30,000
Russia	2,500	(listed in other countries)
Thailand	2,000	N/A
Other countries	N/A	41,000,000
Total	124,000	130,000,000

N/A = not available
*Includes key metals necessary for some low-carbon technologies, including neodymium

Source: USGS, World Bank

GIS GEOPOLITICAL INTELLIGENCE SERVICES www.GISreportsonline.com

Source: GIS 2018

323 See Henry Sanderson, 'Easy Electric Car Trade Expected to Lose Power in 2018', 11 December 2017

324 See European Commission, 'Electric Vehicle Life Cycle Analysis and Raw Material Availability', p. 6.

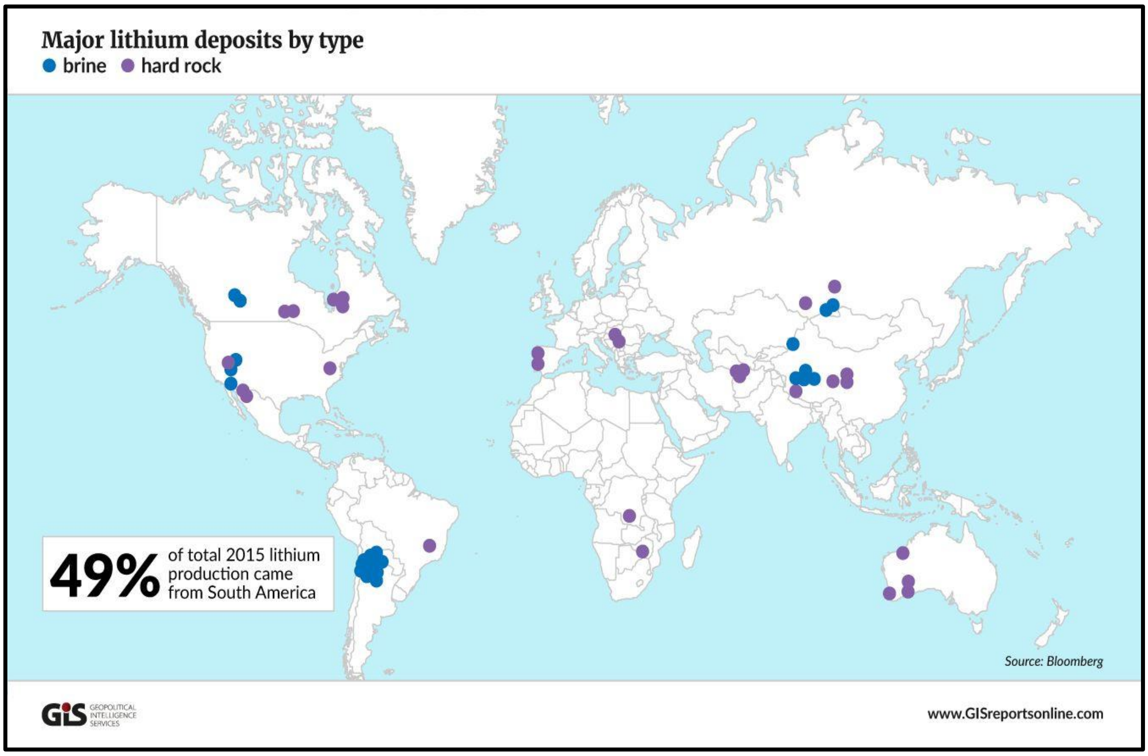
325 See also 'GIS Dossier: China Dominates the Rare Earths Supply Chain', GIS, 7 February 2018; Chris Lo, 'The False Monopoly: China and the Rare Earths Trade', Mining-Technology.com, 19 August 2015 and James Vincent, 'China can't Control the Market in Rare Earth Elements because They aren't all that Rare', The Verge.com, 17 April 2018.

326 Neodymium and Praseodymium, representing 14% of the global REE demand in 2017, are expected to increase to over 24% by 2027 - see Melissa Shaw, 'Rare Earths Outlook 2018: Diversifying Supply and Spotlight on NdPr', Rare Earth Investing News, 11 December 2017, p. 2.

Lithium

In 2015, small lithium-ion batteries used in smartphones, electronic toothbrushes and other electrical appliances already consumed about US$2 bn of metals and minerals. Batteries in EVs are much bigger, will last for only 8–10 years, and will account for 90% of the future lithium-ion market by 2035.[327]

Figure 36: Rare Earth Production and Reserves in 2015 (in metric tons)



Source: GIS 2018

Global lithium demand has been estimated to increase fourfold by 2035, while the demand of other essential raw materials for batteries like cobalt might double. A report of the World Bank projected in 2017 that the worldwide metal demand could double and lithium increase by more than 1,000% by 2050.[328] Lithium reserves are estimated at around 14 mt. Lithium is mined on six continents, but largely produced in the '*lithium triangle*' (already called '*the new Middle East'* if batteries replace oil) of Chile (about half of the world's reserves), Argentina and Bolivia with 49% of the global production. It's produced from continental brines with lower costs compared to pegmatities (or hard-rock ore) like in Australia, the world's largest lithium producer, and sedimentary rocks. For brines in Chile, the extraction can impact water supply as one of the major environmental concerns. Bolivia holds the world's largest lithium deposit, which contains 50-70% of the world's known

327 See also F. Umbach, 'Four Implications of Electric Mobility'.

328 See Henry Sanderson, 'Environment a Risk from Clean Energy Switch, says World Bank', FT, 18 July 2018.

reserves. But given its state control and the more complex are costly production and refining, it has yet to become a leading producer.[329]

Figure 37: The Worldwide Lithium Production

Worldwide lithium production

Country	Production 2016	Change year to year	Reserves
United States	Unknown, but rapidly increasing	–	38,000 tons
Argentina	5,700 tons	58%	2 million tons
Australia	14,300 tons	1.4%	1.6 million tons
Brazil	200 tons	Flat	48,000 tons
Chile	12,000 tons	14.2%	7.5 million tons
China	2,000 tons	Flat	3.2 million tons
Portugal	200 tons	Flat	60,000 tons
Zimbabwe	900 tons	Flat	23,000 tons
Total	**35,000 tons**	**11.1%**	**14 million tons**

Source: Dr. F.Umbach based on various sources

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Source: GIS 2018/Dr. Frank Umbach based on various sources

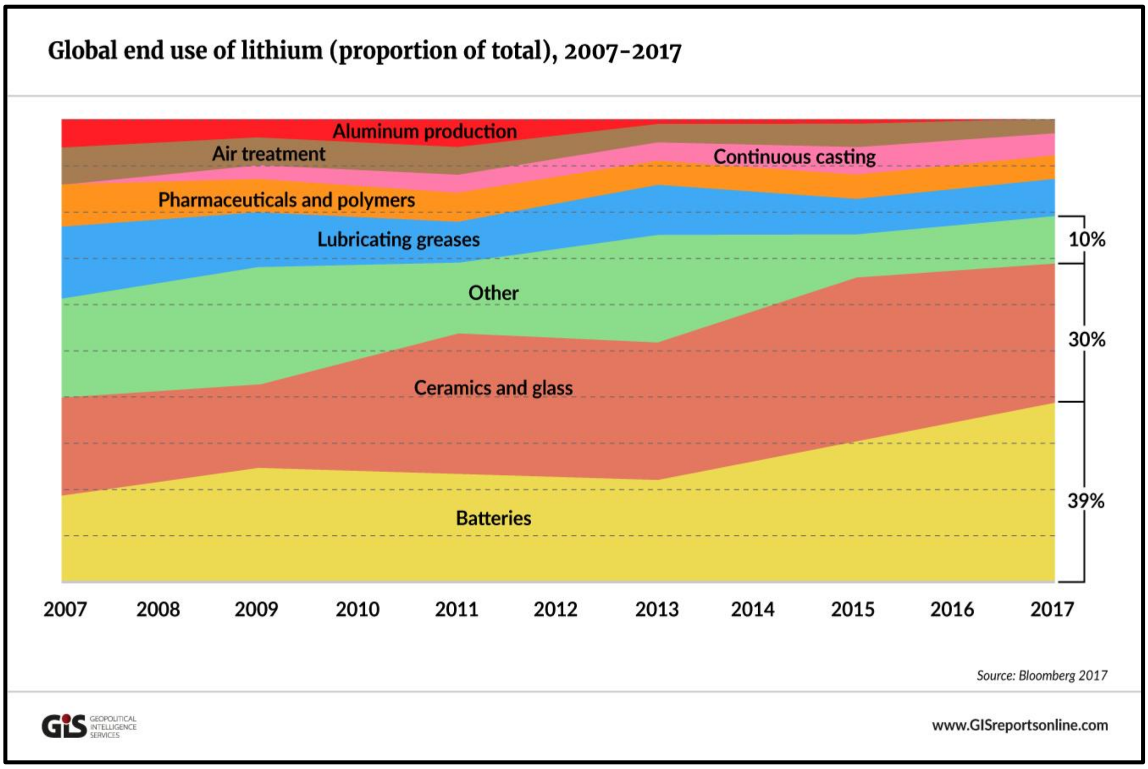
Following China's announcement of also phasing out ICEs by 2030, lithium demand may grow up to 785,000 t per year by 2025, amounting to a 26,000 t shortfall from anticipated supply. Others estimated to need enough lithium to feed 35 plants of the size of Tesla's '*Gigafactory*'. Depending on three different scenarios that EVs will acquire a market share of 8%, 13% or even 25% by 2025 of an average growth rate, lithium mining production needs to increase between 260% and 600% within 10 years. Total investments in new lithium and other mines for the worldwide battery expansion have been calculated at US$350-750bn by 2030.[330] In 2017, the total lithium cell demand was estimated at 100 GWh. At present, the combined planned capacity of 26 megafactories of battery cells, either already in production and being planned, will expand the worldwide capacity up to 344.5

329 See also Ben McLellan, 'Politically Charged: Do You Know Where Your Batteries Come from?', www.energypost.eu, 11 August 2017; 'Types of Lithium Brine Deposits', Lithium Investing News', 9 August 2017, and Lithium: Powering a Global Revolution', Stratfor.com, 20 October 2017.

330 See Didier Julienne, 'Will the World Suffer a Lithium Crisis?', Paris Innovation Review, 5 December 2017; Priscilla Barrera, 'Another Win for Lithium as Ford prepares to Launch Fully Electric Cars in China', Lithium Investing News, 23 August 2017; idem, 'Lithium to Get boost after China Eyes Ban on Fuel Car Sales', ibid., 11 September 2017; idem, 'Can Lithium Demand Producers Keep up with Electric Vehicle Batter Demand?', ibid., 9 August 2017, and 'Lithium Forecast & Lithium Stocks to Buy', ibid., p. 5 ff.

GWh by 2021. By 2025/2026 the surging demand will push those capacities between 400-750 GWh.[331] For many lithium experts, security of supply is still too much underappreciated and the electric car demand may also cause supply challenges in the years ahead.[332]

Figure 38: Global End Use of Lithium (2007-2017)



Source: GIS 2018

In 2016, the price for lithium jumped almost 30%, of lithium carbonate even by 300% due to China's rising demand and an acute shortage of spodumene (a mineral rock which allows lithium to extract from and mainly to be found in Australia), qualifying it as one of the best performing commodities.[333] In 2017, lithium prices increased only by a modest 35%.[334] Prices are expected to average US$13,000 a ton between 2017 and 2020 compared with US$9,000 a ton in 2015-2016. While new lithium projects are expected to come to the market, it remains to be seen whether they are available in time, the rising

331 See 'Rise of the Lithium-ion Battery Megafactories: What Does 2018 Hold?', Lithium Investing News, 12 December 2017, and 'Lithium Forecast & Lithium Stocks to Buy', Resource Investing News, 2017, p. 2 and 7.

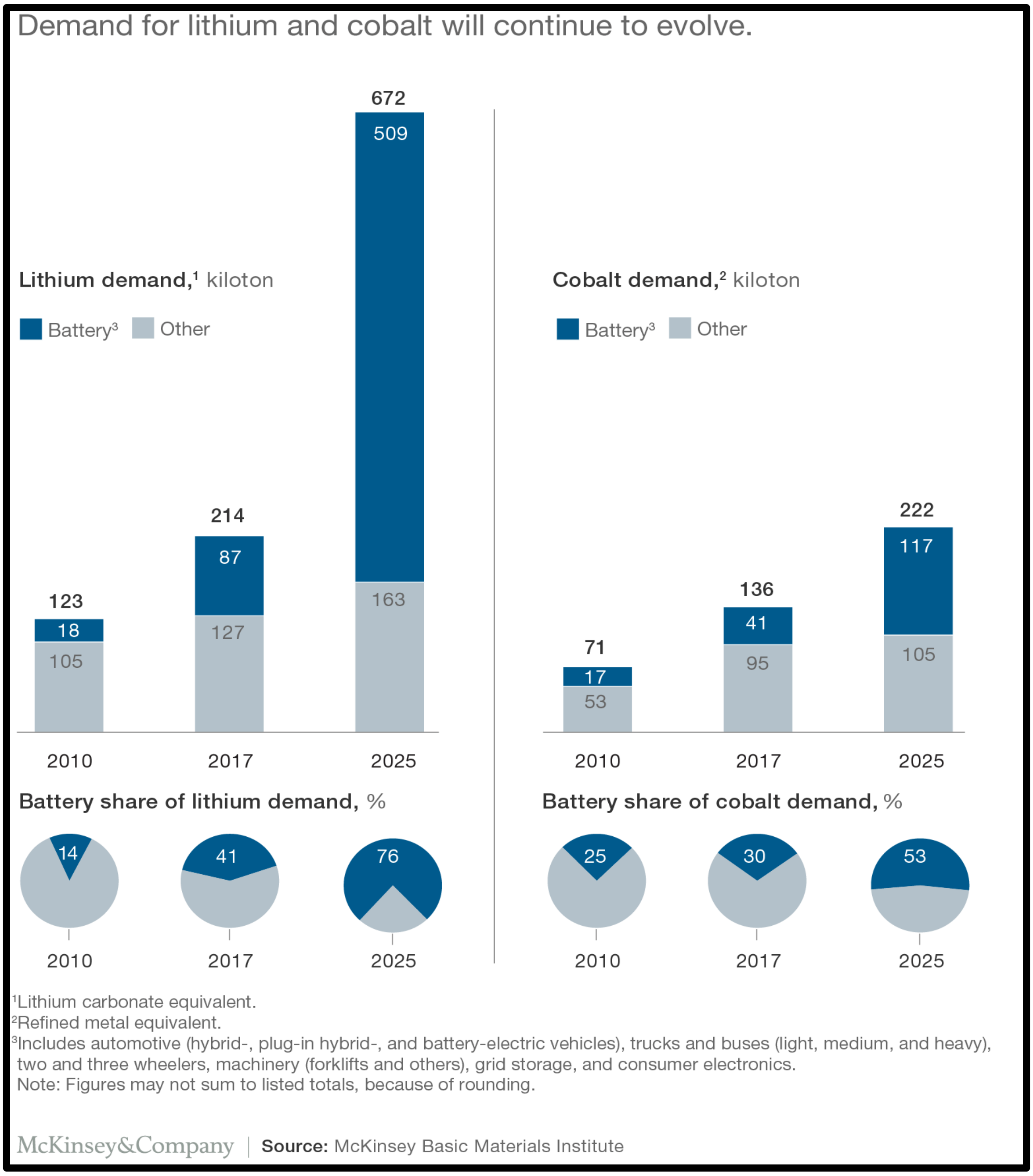
332 See 'Lithium Forecast & Lithium Stocks to Buy', p. 6; Jessica Shankleman et.al., 'We're Going to Need More Lithium', Bloomberg, 7 September 2017; Gregory Brew, 'Could the Battery Boom Lead to a Lithium Shortage?', Oilprice.com, 22 August 2017; 'A Vote on the future of Chilean Copper and Lithium', Stratfor.com, 5 December 2017, and Henry Sanderson, 'Electric Car Demand Sparks Lithium Supply Fears', FT, 9 June 2017

333 See Peter Stewart, 'Lithium Battery Demand Soars While Supply Lags Behind',www.interfaxenergy.com, NGD, 9 August 2017.

334 See Henry Sanderson, 'Easy Electric Car Trade Expected to Lose Power in 2018'.

global demand or gets overpriced with the expected fourfold rise by 2025. Some industry experts have warned that it needs to raise another US$7-9 bn by 2025/2026.[335] Tesla's new giant gigafactory might benefit from new, unexpected discoveries of rich lithium sources in the McDermitt caldera located in the Western part of the U.S. between Oregon and Nevada, only a couple hours away from its gigafactory.[336]

Figure 39: Projected Demand Growth of Lithium and Cobalt (2010-2015)



Source: McKinsey & Company 2018

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335 See 'Lithium Forecast & Lithium Stocks to Buy', p. 11.

336 See Alasdair Wilkins, 'Tesla Could be Near all the Lithium It Needs for its Car Batteries', 28 August 2017 (https://www.inverse.com/article/35618-tesla-gigafactory-lithium-supervolcano; accessed on 30 August 2017).

Australia and Argentina are expected to profit at most in the forthcoming years from the global lithium demand growth. Whether Bolivia with the world's largest untapped lithium reserves will be able to benefit for the growing worldwide demand remains uncertain due to the lack of a pro-business and investment climate, the lack of technical know-how of the Bolivian mining companies as well as its need - as a landlocked country - to cooperate with neighbouring states having harbours and access to the world markets by sea.[337]

China has recently strengthened its efforts to control the entire global supply chain of lithium from owning international mines to production up to manufacturing of batteries and EVs. In May, the Chinese company Tianqi Lithium Corp. purchased a large share of Chilean lithium giant SOM. 35 Chinese companies are already active in the DRC and have established the Union of Mining Companies with Chinese capital in June to facilitate their bilateral cooperation. Another Chinese company has recently opened the world's largest new battery manufacturing facility. Chinese companies have already increased their control of the worldwide lithium-ion manufacturing capacity from 50% in 2013 up to 60% in 2018. While the U.S. will be able to compete at least to some extent with China, albeit also remain dependent on Chinese battery supplies and sales, it can rely on increasing own lithium reserves on its continent. The EU, by contrast, has neither own larger lithium reserves nor established any battery manufacturing capacity up to now. As a result, Germany and the EU have become increasingly protective of its technology know-how and automotive sectors. But as a U.S. analysis has warned: "*Ultimately, if Chinese domination of the Continental market becomes too strong, Europe may have little option but to continue to work with Beijing*."[338] Thereby, the bilateral dependency could become ever more asymmetric and unbalanced at the expense of the EU.

Cobalt

Cobalt is another critical raw material for lithium-ion batteries of EVs. Such batteries already consume 42% of the metal and 80% of refined cobalt demand, dominated by China as the world's largest refiner of cobalt. Like REEs, cobalt does not occur alone in the Earth crust, but it is associated with copper and nickel production. It is rarely found as a native metal, but rather as a by-product of nickel, copper and lead. Cobalt sources can mostly be found as by-products follows: 37% from nickel mines; 61% from copper mines and 2% from primary cobalt mines.[339] In combined average, less than 10% occurs as a primary product.[340]

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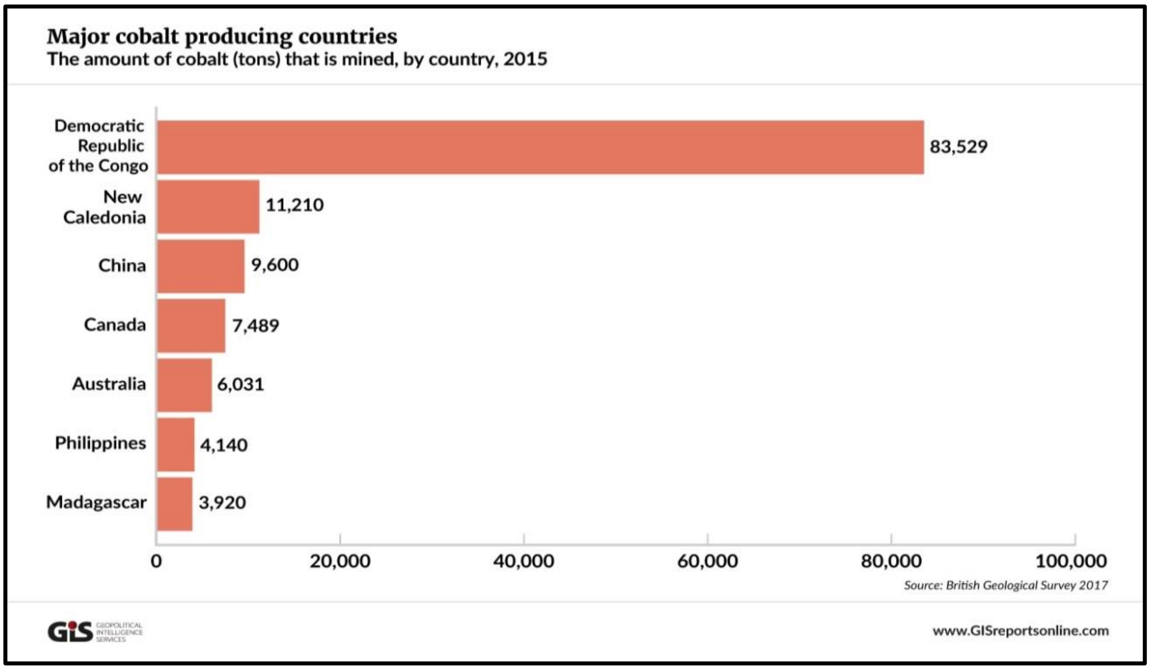
337 See 'Lithium: Powering a Global Revolution', Stratfor.com, October 2017, and Marcelo Azevedo et.al., 'Lithium and Cobalt: A Tale of two Commodities', McKinsey & Company, Metals & Mining, June 2018.

338 See 'How China is Muscling In on Lithium-Ion Batteries', Stratfor.com, 5 July 2018.

339 See Nicole Rashotte, 'Will Cobalt Supply Meet Growing EV Battery Demand?', Cobalt Investing News, 6 June 2018.

340 See Marcelo Azevedo et.al., 'Lithium and Cobalt: A Tale of two Commodities', p. 5.

Figure 40: Major Cobalt Producing Countries



Source: GIS 2017

Its demand for the rising EV production is expected to increase from 46,000 t in 2016 to 76,000 t in 2020 and more than 90,000 t by 2030.[341] Other forecasts have projected a demand increase of 60% between 2017 and 2025.[342] The three largest estimated reserves of nearly 5 mt are located in Democratic Republic of Congo (DRC), Australia and Cuba. The global supply will remain tight in the short-term perspective as it depends by more than 50% mining in the DRC – an African country plagued by decades of violent conflicts, instability, bad governance, human rights abuses, child labour and widespread corruption.[343] Some 30% of revenues from cobalt exports by mining companies have simply disappeared between 2013 and 2015. The deficit of supply experienced in 2016 might triple by the end of this year. By 2026, cobalt in lithium-ion batteries might have tripled from today. Lithium-ion batteries contain about 11 kg of cobalt in average.[344]

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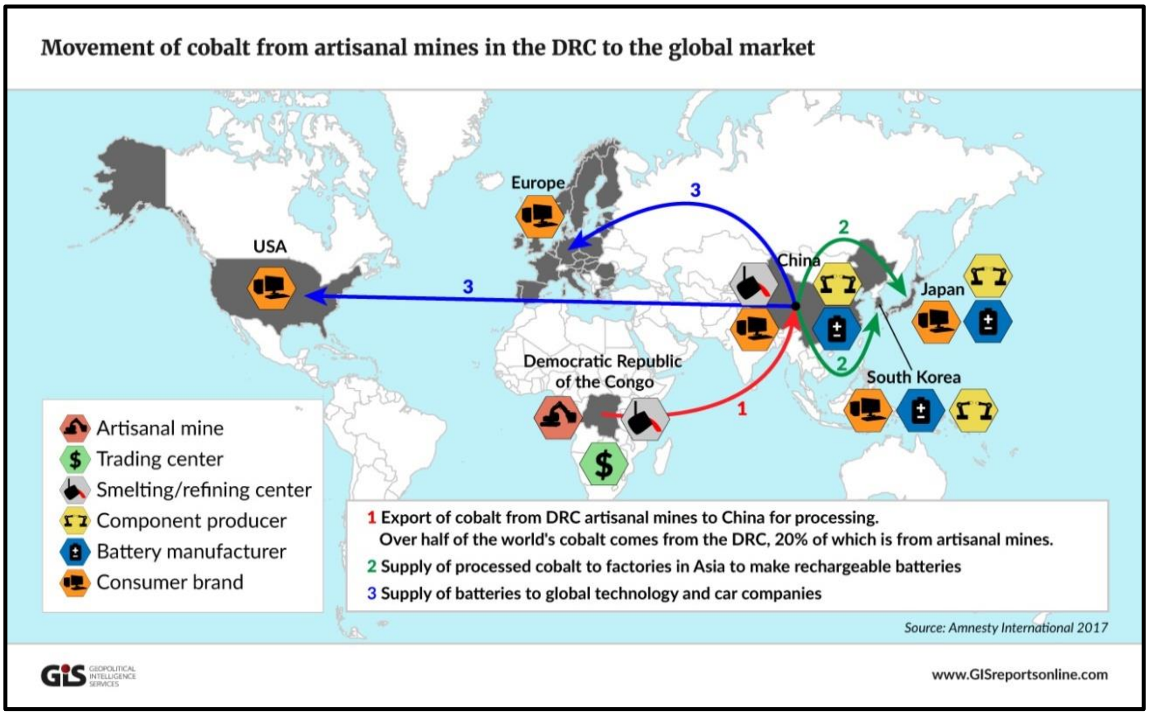
341 See European Commission, 'Electric Vehicle Life Cycle Analysis and Raw Material Availability', p. 8; Henry Sanderson/Neil Hume, 'Cobalt Stand-off Key to Future of Electric Vehicles', FT, 17 October 2017 and 'Cobalt Market Forecast and Cobalt Stocks to Buy', Resource Investing News 2018, p. 2.

342 See Marcelo Azevedo et.al., 'Lithium and Cobalt: A Tale of two Commodities', p. 3.

343 See also 'Cobalt Market Forecast and Cobalt Stocks to Buy', p. 4, Priscilla Barrera, 'EV Makers 'not Doing Enough' to Tackle Human Rights Abuses in Cobalt Supply Chains', Cobalt Investing News, 16 November 2017; 'The Critical Need for Cobalt Supply Diversification', ibid., 20 September 2017; David Pilling, 'Clean Electric Cars are Built on Pollution in Congo', FT, 26 July 2017; Bernd Freytag, 'Blackbox Batterie', FAZ, 12 August 2017, S. 19 and Henry Sanderson/Cloe Cornish, 'Amnesty Warns on Use of Child Labor in Cobalt Mining', FT, 15 November 2017.

344 See 'Cobalt Market Forecast and Cobalt Stocks to Buy', p. 2, and Neil Hume/Henry Sanderson, 'Copper and Cobalt Markets at Risk of Supply Disruptions', FT, 30 April 2018.

Figure 41: Global Cobalt Trade



Source: GIS/Amnesty International 2017

In 2017, cobalt prices have boomed exponentially by about 127%, hitting US$75,000 per ton at the beginning of 2018 from US$32,500 at the beginning of the previous year 2017.[345] Some analysts have predicted a 30-fold increase of the global cobalt demand by 2030. New production of cobalt outside Congo appears still years away, complicated by international demands for more transparency and responsible mining of '*ethnically sourced*' cobalt.[346]

Other Critical Raw Materials

Graphite reserves are estimated at around 250 mt. Its demand by anode manufacturing of batteries has been calculated to reach 250,000 t in 2020 and 1.6 mt by 2030.[347] A worldwide supply of Nickel has not been seen as problematic for the global expansion of EVs with a total global production of 2.5 mt Nickel in 2016 as the current worldwide

345 See Henry Sanderson, 'Easy Electric Car Trade Expected to Lose Power in 2018', idem, 'Cobalt Miners Play a Strong Hand in Price Setting', FT, 7 December 2017.and 'Cobalt Market Forecast and Cobalt Stocks to Buy', p. 7.

346 See also Priscilla Barrera, 'EV Makers Join Forces to 'Drive Sustainability' in Cobalt Mining', Cobalt Investing News, 29 November 2017.

347 European Commission, 'Electric Vehicle Life Cycle Analysis and Raw Material Availability', p. 8; Siv Padhy, '10 Top Graphite-Producing Countries', Graphite Investing News, 23 October 2017, and 'Battery Demand Beginning to Boost Graphite Prices', ibid., 31 October 2017.

reserves are estimated around 78 mt. However, it needs to be taken into account that only 50% of global nickel supply is usable for EV batteries.[348]

The Swiss mining giant Glencore, one of the world's largest miner and commodity trader, has projected an additional demand of 2 mt of copper, 1.2 mt of nickel and 260,000 to cobalt.[349] Palladium prices have also increased to a new record at the end of 2017 since 2001.[350] By contrast, the global platinum demand might fall as the auto industry is the largest consumer of platinum.[351]

Constrained International Counterstrategies for Stabilizing Supply Security of CRMs

While from a geological perspective, sufficient quantities of CRMs, available in the earth crust, the real supply of CRM is often dependent on few mining companies in few (often politically unstable) producer countries. REEs are only scarce because their production in other deposits of the world has been uneconomic and unprofitable to extract.[352] Their future supply security depends largely on timely investments, likewise dependent on adequate investment conditions, and alternative strategies such as:

- Diversification of Imports and new Supply Options;
- Reduced use
- Substitution;
- Re-Cycling and Re-use.[353]

Using these strategies for reducing the rising imports of CRMs might allow a reduction on imported CRMs in the longer-term perspective. These options are also an integral part of the development of '*circular economies*' as a response strategy for using CRMs more economically, efficiently and environmentally by reducing their mining demand in order to strengthen their security of supply.

348 See European Commission, 'Electric Vehicle Life Cycle Analysis and Raw Material Availability', p. 6; Neil Hume, 'Nickel Rebound Gathers Pace on Electric Car Boom', FT, 24 October 2017; Melissa Shaw, 'Half of the Global Nickel Supply Suitable for Electric Car Batteries', Nickel Investing News, 1 November 2017, and idem, 'Nickel Outlook 2018: Price gains and Growing Battery Boom', ibid., 7 December 2017.

349 See Neil Hume/David Sheppard, 'Glencore Sees Rich Benefits in Battery Growth as Debts Fall', FT, 10 August 2017, and John Authers, 'Metals Prices are Saying a Global Recovery is Afoot', FT, 1 September 2017.

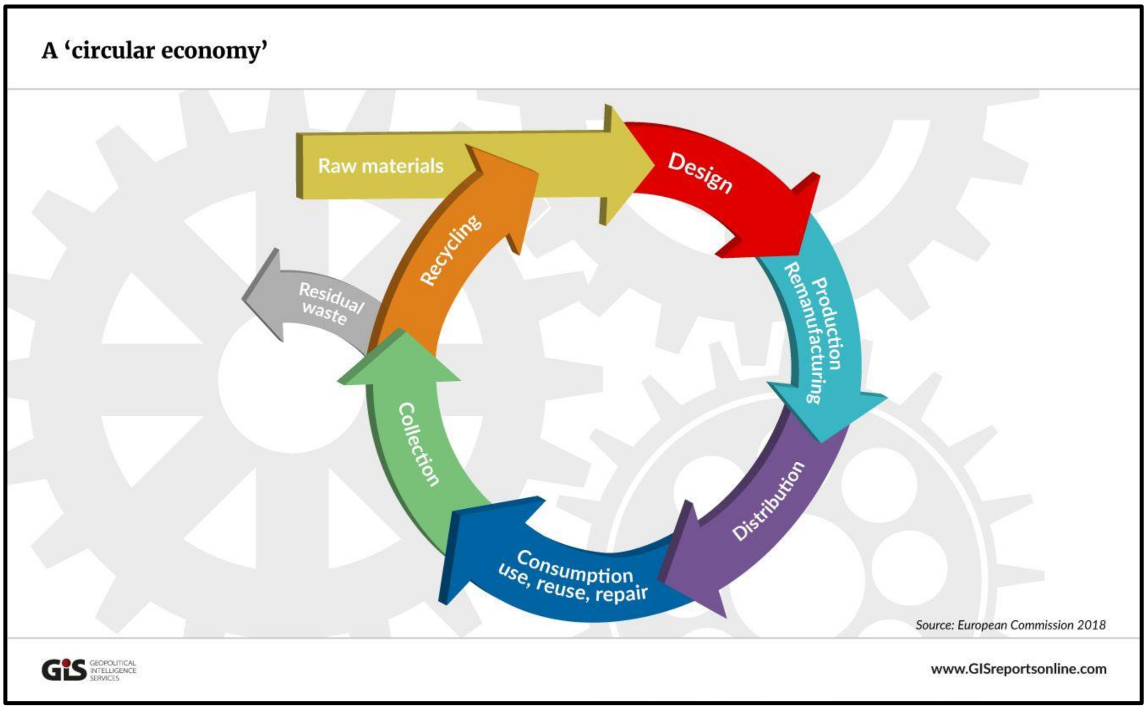
350 See also Melissa Shaw, 'Palladium Futures End at Highest Point in 16 Years', Palladium Investing News, 8 November 2017, and Henry Sanderson, 'Palladium Hits $1,000 for First Time since 2011', FT, 16 October 2017.

351 See Siv Padhy, 'Will Paladium be Impacted by Electric Cars?', Platinum Investing News, 18 October 2017.

352 See 'A Scramble for the Minerals Used in Renewable Energy is Under Way', Economist, 15 March 2018.dc

353 To recycling see also Luis A. Tercero Espinoza, 'The Contribution of Recycling to the Supply of Metals and Minerals', Polinares Project, European Commission/European Research Area, Polinares Working Paper No. 20, March 2012.

Figure 42: Elements of a 'Circular Economy'



Source: GIS/European Commission 2018

Diversification of Imports and Supplies

After the China-Japan Rare Earth conflict in 2010/11, Japan, the U.S. and the EU have strengthen their efforts to diversify their imports and by opening new mines. But those efforts have often been not really profitable during the last years with declining prices for CRM (2012-2016) and - with few exceptions – have not really broaden the global supply basis for REEs.

But the U.S. Department of Energy has funded research for developing a cost-effective method of extracting REEs from coal in order to guarantee domestic supply. Researchers of the University of Kentucky have claimed in 2017 to be able to provide a 98% pure REE concentrate from a coal source. Their technology is being tested at a mobile rare earth pilot project since last spring. As rare earth mining was non-existing in the U.S. during the last two years and giving the dependence of its defence industry on REEs, the pilot project has been given high support by the U.S. Department of Energy as President Trump has also promised to revive its coal industry.[354]

354 See Melissa Shaw, 'US DOE Funding Research to Extract Rare Earths from Coal', Rare Earth Investing News, 23 October 2017; idem, 'Researchers Find Cost-Effective Way to Extract Rare Earths from Coal', ibid., 21 November 2017, and John Seliciano, 'Coal Industry could be in Store for a 'Rare Earth' Reboot', Washington Examiner, 13 June 2017.

In April 2018, Japan declared to have found large REE deposits of 16 mt of rare earth oxides on the sea bottom in its Exclusive Economic Zone (EEZ) some 2,000 km southeast of mainland Tokyo. The discovered deposits are assumed to be sufficient to meet global demand for centuries: equivalent to 780 years' worth of yttrium supply, 620 years of europium supply, 420 years of terbium supply and 730 years of dysprosium supply. Japanese researchers have developed a new extraction technology for REE from the mud. Whether the Japanese discovery will have any impact on global supply and prices will be dependent on how soon extraction can begin and expand competitively.[355]

Reduced Use of CRMs in Key Technologies

Efforts to reduce cobalt dependency appear still outweighed by the magnitude of EV growth. Tesla has announced at the beginning of May 2014 that it has achieved a significant reduction of cobalt content per battery pack while increasing nickel content and being still able to maintain superior thermal stability. While this technological progress will certainly reduce Tesla's cobalt demand and have some influence on the supply-demand balance of this raw material, most other EV makers are expected to use rather nickel-manganese-cobalt (NMC) batteries with a higher cobalt content.[356] Volkswagen, for instance, will invest €70 bn in EVs to electrify 300 different car models by 2030, including batteries. But up to now, it can't guarantee its cobalt supply for at least five years as it couldn't negotiate sufficient supply contracts with mining and trader companies.[357]

The use of costlier REES have also been reduced with cheaper and sometimes better solutions or applying modern control software and power electronics made of silicon, the worldwide most abundant solid element. Those efforts have also promoted '*urban mining*' like recycling of REEs and other materials from used electronic devices. Tesla's lithium batteries, like its motors, use no REEs at all. Lighter carbon for fiber passenger department reduces the overall weight of cars and, therefore, need fewer batteries and less REEs. Siemens has considered a technology that eliminates the REE dysprosium in its wind turbines. Another example is a newly developed magnet of Toyota. The world's first heat-

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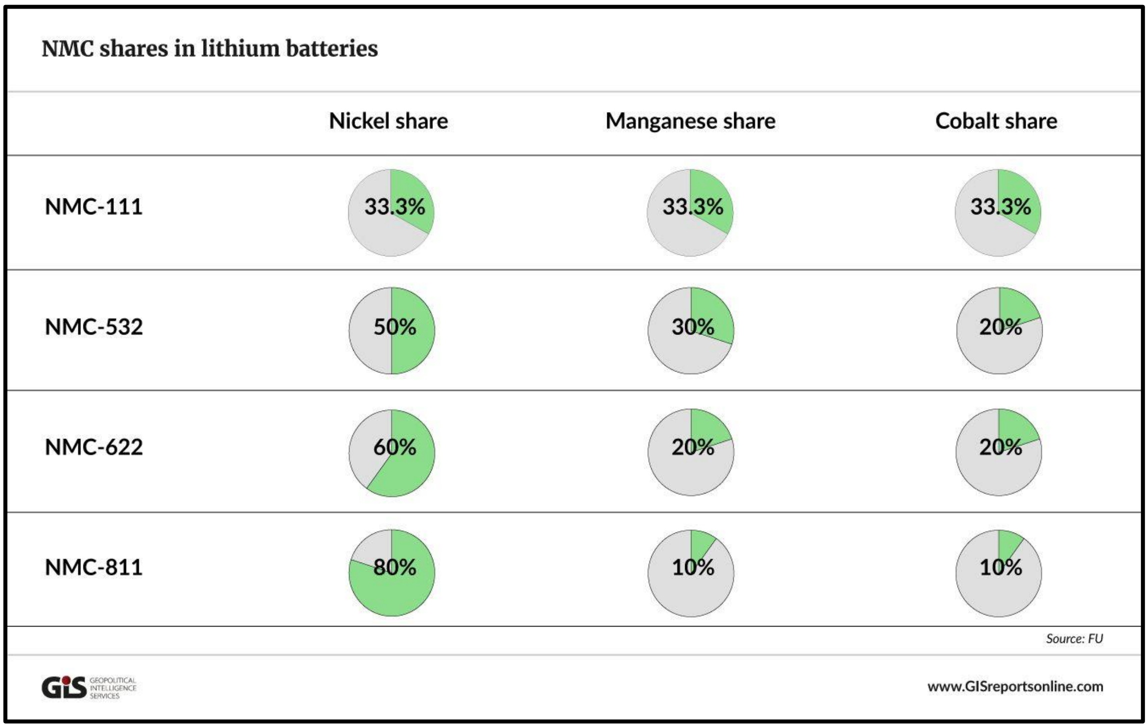
[355] See Yui Shuzo, 'Centuries' Worth Supply of Rare Earths Found in Japanese Waters', The Mainichi, 11 April 2018; Yutaro Takaya et.al., 'The Tremendous Potential of Deep-Sea Mud as a Source of Rare Earth Elements', Nature-Scientific Reports, No. 8/2018, 10 April 2018; Hudson Lockett, 'Rare Earths Discovery Boots Japan Extractors, Machinery Makers', FT, 11 April 2018; Charlotte McLeod, 'Japan Holds 'Semi-Infinite' Supply of Rare Earths, New Research Shows', Rare Earth Investing News, 12 April 2018, and Karel Beckmann, 'The OPEC of the Future – World Faces 'Fundamental Shift in Resource Demands', Energypost-weekly.eu, 18 April 2018.

[356] See Priscilla Barrera, 'Tesla to Reduce Cobalt Use in EV Batteries to 'Almost Nothing', Cobalt Investing News, 3 May 2018.

[357] See 'Cobalt Market Forecast and Cobalt Stocks to Buy', p. 5,; Priscilla Barrera, 'Volkswagen Struggles to Reach Long-Term Cobalt Supply Deals', Cobalt Investing News, 27 November 2017, and Henry Sanderson/Neil Hume, 'VW Fails to Secure Long-Term Cobalt Supply for Electric Vehicles', FT, 15 October 2017.

resistant magnet has replaced its costly heavy REE of neodymium portion by the lower-cost REEs of lanthanum and cerium.[358]

Figure 43: Nickel-Manganese-Cobalt Shares in NMC-Batteries



Source: GIS 2018/Dr. Frank Umbach

A new battery generation will certainly reduce Tesla's future cobalt demand and also have some impact on the supply-demand balance of this CRM, most other EV makers are expected to use still rather NMC-batteries with a higher cobalt content. NMC-811 batteries with a lower cobalt share of just 10% will reach a market share only by just 25% by 2026 and only marginally impact the global rise of the cobalt demand in the mid-term perspective.

Substitution

Options for substitution are presently often limited (with the exception of coking coal) or even impossible (for phosphate rock). While substitutes are in principle available for many applications, they are often generally less effective and efficient and/or demand more energy in return. For some REEs (i.e. HREEs), for instance, no material replacement has been found, such as for Neodymium that enhances the power of magnets at high heat and is crucial for hard-disk drives, wind turbines, and the electric motors of hybrid cars. While in principle, wind turbines can be built without rare earths, REEs reduce the per megawatt

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358 See Nicole Rashotte, 'New Toyota Magnet Could Cut Electric Vehicle Motor Costs. Rare Earth Investing News, 21 February 2018.

cost of wind energy and improve its competitiveness through conservation of other materials such as steel and copper. While some international efforts to reduce the demand of REEs are successful (as highlighted above), the reduced use of REEs in certain products and its slowdown of the overall demand rise might enhance their global supply security by preventing their widespread shortage, the overall demand rise as a key CRM will continue.

While new nickel projects with cobalt as a by-product outside of the DRC might also contribute to a supply solution for the rising cobalt demand, it will take some more years having some impact. A worldwide supply of Nickel has not been seen as problematic for the global expansion of EVs with a total global production of 2.5 mt Nickel in 2016 as the current worldwide reserves are estimated around 78 mt. However, it needs to be taken into account that only 50% of global nickel supply is usable for EV batteries.

At present, there is no short-term alternative to using cobalt in EV batteries either for stabilizing the battery and preventing fire and explosions, while at the same time conserving battery strength and extending battery life. Analyses suggest that we need at least another 5 years of research for finding an alternative to cobalt in batteries. It is presently the most important CRM from a strategic and cost viewpoint to further developing lithium-ion batteries.

Recycling Options and Re-use of CRMs

Forced by regulations, the older lead-and nickel based batteries have a life-end-recycling rate of 99% in Europe and North America. The high recycled content of lead batteries is more than 85%. In the future, new EVs may only be sold in the EU if they may be re-used, recovered and recycled in line with its 'end-of-life vehicles (the '*ELV-Directive'*)'. Some companies have already begun investing of used EV batteries in Europe.

But many recycling options are often constrained due to poor data on both current and future recycling rates and insufficient profitability and commerciality for industry businesses. Smart phones and other electronic devices, for instance, have up to 70 different CRMs. But it is commercially still not profitable to recycle them. Recycling is often constrained due to poor data on both current and future recycling rates and insufficient profitability and commerciality. Worldwide, only few CRMs (Vanadium, Tungsten, Cobalt and Antimony) have a higher recycling rate. Of the 9 added CRMs up to 27 to the EU-list of defined CRMs in 2017, the recycling rates of all 9 CRMs are currently low or non-existent due to failing technologies or being commercially not profitable. The overall trend of miniaturisation of electronics is generally making disassembly of components, and, therewith, more challenging than ever. Large-scale recycling is expected to be more efficient only beyond 2025.

Recycling of cobalt in batteries is presently unattractive if it is not extended to the other CRMs like lithium and graphite. Advanced recycling options are currently 10-15 years away from being a viable source. Even for cobalt, international efforts to reduce their dependency by recycling appear still outweighed by the magnitude of the projected EV and cobalt growth. The present potential of recycling of cobalt and other CRMs is largely insufficient to meet their demand growth.

Recycling of lithium in batteries is still rather low as most of the batteries are unused in second life applications or sold to refurbishers in Asia. But given the overall demand rising and with much more lithium batteries after their multiple purposes reaching their end of their lifetime, recycling rates may go up from presently 3-5% up to 58% in the coming years.[359]

Challenges and Implications for Developing Countries as Producers of Critical Raw Materials

The more the world will expand '*green technologies*' and becoming dependent on a rising and stable supply of CRMs, the more the international focus will be on their environmental standards and energy efficient production methods.[360] Cobalt extraction causes major concerns in regard to environmental damage, workers health and safety, water supply problems and child labour. Similar problems are also acknowledged in regard to the lithium-ion supply chain.[361]

In addition to enhancing their productivity, mining companies are already increasing renewables in their energy mix of production and trying to reduce the environmental impacts. But some of the largest mining companies do still not publish any emissions targets on their own.[362]

While in developed countries, the environment might get cleaner with EVs and an expanded battery use for EVs and RES, the opposite might be true in the developing countries, which produce the CRMs for the rich world. Environmental and social costs are increasing with expanded mining of these critical raw materials. These countries may face even more water

359 See Hans Eric Melin, 'New Report on Recycling and Second Life of Lithium-ion Batteries', LinkedIn, 21 June 2018 (https://www.linkedin.com/pulse/new-report-recycling-second-life-lithium-ion-batteries-melin; accessed on 28 June 2018).

360 See also Henry Sanderson, 'Electric Car Growth Sparks Green Concern', FT 7 July 2018, and Priscilla Barrera, 'RCS Global: The Importance of Responsible Sourcing in the Lithium-ion Battery Industry', Cobalt Investing News,23 October 2017.

361 See Harrison Mitchell/Nicholas Garrett, 'Keeping Clean Technology Clean', FT, 14 September 2017.

362 See Nathan Flasher, et.al., 'Productivity across the Global Mining Sector is Starting to Improve', McKinseq & Company, Metals & Mining, June 2018, and Sibren de Jong et.al., 'Strengthening Stability and Sustainability. Mapping Opportunities in the Governance of Natural Resources', The Hague Centre for Strategic Studies (HCSS), The Hague 2017.

shortages, rising emissions and toxic pollution and other environmental problems, and have to cope with human rights abuses, international labour standards and rights as well as to prevent any child labour. Supply chains from mining to end products are often not fully transparent despite many efforts to improve industry practice for responsible and ethical sourcing. But international certification schemes such as the '*OECD Due Diligence Guidance'*[363], conflict free sourcing and '*sustainable mining*' initiatives offer instruments for more transparency and international collaboration to increase environmental, social and labour standards in developing countries.[364]

Given the numerous challenges of the future supply security of CRMs, more international cooperative is needed on a regional and a global level to avoid new antagonistic conflict patterns and geopolitical rivalries. Internationally, wide-ranging institutional governance architecture with multi-stakeholders already exists. A Dutch-study identified worldwide 144 multi-stakeholders in 2017, which deal with natural resources and raw materials. But the global governance architecture is characterised by an overall fragmentation and a lack of coordination between the numerous organisations, institutions and forums.[365]

While most studies do not predict a major supply side problem of CRMs for the global markets, they mostly agree that the supply of them need to be closely monitored as short-term supply constraints and price volatility can always occur, when the market for EVs, robotics and AI increases too quickly or instabilities in major producer countries disrupt production and supplies.[366]

But the problem of lead times for opening new mines are often overlooked. In average throughout the world, those lead times take at least 7 years. In Western countries is more than 10 years and can even take 20 years: 10 years from a successful exploration to political and industrial consent on all levels, and another 10 years to build out the infrastructure to make the mine operational. In today's world and the public acceptance challenge for a '*social license to operate*' even on local levels, given especially environmental, social and reputational issues, it has become ever more challenging to find investors for those long-term projects. In sum: Minerals and CRMs have become scarce - but politically rather geologically.[367]

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363 See OECD, 'A Global Standard: Towards Responsible Mineral Supply Chains', 1 August 2014.

364 See also Rocky Mountains Institute, 'Sunshine for Mines: Toward Sustainable Mining', July 2017, and Joshua S. Hill, 'Renewables Could Create 'Groundbreaking' Decarbonisation Effort for Mining Industry',27 July 2017 (https://cleantechnica.com/2017/07/27/renewables-create-groundbreaking-decarbonisation-effort-mining-industry/; accessed on 31 July 2017).

365 See Sibren de Jong et.al., 'Strengthening Stability and Sustainability'.

366 See European Commission, 'Electric Vehicle Life Cycle Analysis and Raw Material Availability'.

367 See also Robert Spencer, 'So You Thought a Clean, Low Carbon World Would Require Few Materials Right?', Linkedin, 8 November 2018 (https://www.linkedin.com/pulse/so-you-thought-clean-low-carbon-world-would-require-few-spencer/; accessed 20 November 2017).

5.5 Decarbonisation Efforts and Digitalisation Threatening Traditional Oil and Gas Producers: Political Stability versus Decarbonisation

„We are on an irreversible pathway to renewable energy [..] those who don't embrace the clean-energy transition will be the losers in the future"

Miguel Arias Canete, EU Commissioner for Climate and Energy Policies [368]

"It seems clearer, though, that the losers of the [energy] transition are those countries blessed with ample fossil fuel reserves and that bet on these resources for too long, without developing alternative economic activities."

Daniel Scholten/Rick Bosman, 'Geopolitics of Renewables'[369]

The present focus on the global climate warming mitigation efforts after the Paris Agreement in December 2015[370] is largely directed on decarbonisation of the national and global energy mix (by expanding and replacing fossil fuels with RES) and enhancing energy efficiency as well as conservation.[371] These efforts are supported primarily in the major industrialised countries (OECD), which are – together with China, India and Brazil – the world's largest energy consuming countries. At present, 175 countries out of 197 have ratified the Paris Agreement, which entered into force on November 4, 2016.[372] Worldwide, 169 countries have already submitted their first '*Nationally Determined Contributions (NDCs)*', in which commit their decarbonisation plans for their energy mix and CO_2-reduction measures.[373] At the same time, a global divestment movement away from fossil fuels increased its popularity as 1,400 international outperformed so-called '*black funds'* by more than 14% in 2014. But the NDCs vary considerably in scope, ambition and real commitment and will mitigate global warming just to 2.7 °C. Moreover, the worldwide campaign for decarbonisation cannot be and is not restricted to coal, but also includes to phase-out the oil and gas production worldwide. But the present decarbonisation efforts for a '*global Energiewende*' are - regardless of U.S. President Donald Trump's declared withdrawal from the Paris Agreement on Climate Change - insufficient to achieve the goal

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368 Quoted following 'Clean Power Is Scaling up the Global Geopolitics of Energy', p.3.

369 Daniel Scholten/Rick Bossman, 'The Strategic Realities of the Emerging Energy Game – Conclusions and Reflections', p. 314.

370 See United Nations Framework Convention on Climate Change (UNFCC), 'Paris Agreement- Status of Ratification' (http://unfccc.int/paris_agreement/items/9444.php; accessed on 5 July 2017).

371 See also IEA, 'WEO 2017', pp. 281 ff.

372 See 'Paris Agreement - Status of Ratification' (https://unfccc.int/process/the-paris-agreement/status-of-ratification; accessed on 24 April 2018).

373 See UNFCC, 'NDC-Registry (interim' (http://www4.unfccc.int/ndcregistry/Pages/Home.aspx; accessed on 24 April 2018).

for reducing the worldwide emissions by more than 80% by 2050 and decreasing global warming below the agreed 1.5-2°C target.[374]

Another reason for the insufficient strategy of climate mitigation is that the present global decarbonisation efforts are almost exclusively of economic, technical and technocratic-theoretical nature as highlighted by the recommendations of the '*Energy Transition Commission*', an independent group of climate and energy experts (incl. from international energy companies), in April 2017.[375] They often completely overlook, disregard or at least underestimate the multi-dimensional (geo-)political implications and national interests of major fossil fuel producer countries as well as their present (unwanted) overreliance on oil and gas rent. As long as their strategic interests and the fact of their heavy dependence on hydrocarbon export revenues are not taken into account and brought realistically in compliance with worldwide decarbonisation efforts for a '*global Energiewende*', global warming mitigation below the 2°C-target will be even more unrealistic and could even result in higher global warming as long as they don't see a realistic alternative development strategy for their non-diversified economies.

The dramatic decline of the worldwide oil and gas prices between 2014 and 2017 indicates that – in contrast to the previously forecasted '*peak-oil*'-scenario - oil and gas are no longer a scarce resource. The newly anticipated worldwide demand growth is largely being balanced by low-cost production from OPEC-countries, and US shale plays. Given the need for more radical decarbonisation efforts for achieving the 2°C target, many fossil fuel investments can indeed lead and end in '*stranded reserves*' and '*stranded assets*' as the result of the '*carbon bubble*'. It will hurt in particular high-cost producers and countries highly dependent on higher oil export revenues for their state budgets. Disruptive4technologies and larger geo-economic, as well as geopolitical shifts, produce winners and losers.[376]

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374 See also 'IEA Finds CO_2 Emissions Flat for Third Straight Year Even as Global Economy Grew in 2016', 17 March 2017 und David Hone, 'The Drivers Behind Flattening CO_2-Emissions', www.energypost.eu, 1 May 2017; Justin Gillis, 'Carbon in Atmosphere Is Rising, Even as Emissions Stabilize', NYT, 26 June 2017; David G. Victor, 'Prove Paris Was More than Paper Promises', Nature, Vol. 548, 3 August 2017 und 'Analysis: Just Four Years Left of the 1.5C Carbon Budget', Carbon Brief, 5 April 2017; Michael Bastasch, 'Report: $12.7 Trillion Needed to Meet Paris Climate Accord's Goal', Daily Caller, 15 June 2017, and Sergey Paltsev u.a., 'Scenarios of Global Change: Integrated Assessment of Climate Impacts', Massachusetts Institute of Technology (MIT), Cambridge, MA, February 2016.

375 See Energy Transitions Commission, 'Better Energy, Greater Prosperity. Achievable Pathways to Low-Carbon Energy Systems', April 2017. Another example can be seen in the 'Oil and Gas Climate Initiative (OGCI)' of the worldwide 10 largest oil majors, which will invest around 1 bn in the next decade for the development of innovative technologies with lower carbon emissions –see Ed Crooks, 'Business Leaders Back Transition to Low-Carbon Energy System', FT, 25 April 2017; Stuart Hazeldine, 'Oil Companies' Climate Initiative Lacks Initiative', www.energypost.eu, 9 November 2016 und Andrew Ward, 'Oil Groups 'Not Investing Enough' in Green Energy', FT, 18 November 2016.

376 See also Nick Butler, 'Winners and Losers in the Age of Energy Abundance', FT; 26 February 2018, and 'The Middle East and Russia are Ill-Prepared for a Low-Carbon Future', Economist, 15 March 2018.

For any transition period, energy supply security is not guaranteed without political stability in oil and gas producing countries. The interplay and nexus of oil prices and geopolitics, resulting in falling energy export revenues for state budgets and companies, was once the beginning of the end of the Soviet Union and its socialist empire when the oil prices dropped 3.5 times, and Saudi Arabia's production increased fourfold since 1986. The rapidly falling oil prices between 2014 and 2017 have already affected many state budgets, which are heavily dependent on high oil and gas revenues.[377] In this context, '*fiscal breakeven prices*' of oil matter more than the global oil price itself as it describes the minimum price per barrel that the country needs in order to meet its expected spending needs while balancing its budget (see figure 44).[378]

At present, some oil producers such as Venezuela are already on the brink of an economic collapse - long before any real decarbonisation will fundamentally change the world's energy mix - as their economies are often not very diversified.[379] As typical rentier states, fastening decarbonisation of the world's energy system may even result in larger regional social-economic and political instabilities, which could undermine regional peace and stable as well as positive economic development much needed particularly in countries with rapidly increasing populations such as in the Greater Middle East and Africa. In the mid-term perspective, those unwanted and unintended impacts of the decarbonisation policies could be aggravated by the electrification of the transport and heating sectors as well as the digitalisation, automatisation, big data, artificial intelligence and other technology innovation such as '*digital oil fields*'. They could further destabilise many oil and gas producing countries when a reduced global oil demand would decrease oil prices again. While Arab countries can produce oil for just US$10-12 per barrel, they need more than US$60 per barrel to balance their state budgets.

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377 See also Andrey Movchan/Alexander Zotin/Vladimir Grigoryev,'Managing the Resource Curse. Strategies of Oil-Dependent Economies in the Modern Era'. Carnegie/Moscow Center and British Embassy Moscow, April 2017; Elena Chirkova, 'How Institutions Affect Development of Resource-Based Economies', Carnegie/Moscow Center and British Embassy Moscow, April 2017; Natural Resource Governance Institute, '2017 Resource Governance Index'; Anthony H. Cordesman, 'The 'OPEC Disease'. Assessing the True Impact of Lower Oil Export Revenues' (Washington D.C.: CSIS, September 2016), and The Hague Centre for Strategic Studies (HCSS), 'The Geopolitical Impact of Climate Mitigation Policies. How Hydrocarbon Exporting Rentier States and Developing Nations Prepare for a More Sustainable Future', The Hague (Netherlands), April 2017

378 See Brad W. Setser/Cole V. Frank, 'Using External Breakeven Prices to Track Vulnerabilities in Oil-Exporting Countries'. Council on Foreign Relations, New York, July 2017.

379 See also F. Umbach, 'Geopolitische Auswirkungen des Ölpreisverfalls – Gewinner und Verlierer', Europäische Sicherheit und Technik (ES&T), December 2017, pp. 21-24.

Figure 44: Fiscal Breakeven-Prices in US-Dollar of Oil Producing Countries (Spring–Summer 2017)

Oil Producers	Fiscal Breakeven-Oil Prices
Nigeria	139$
Bahrain	84$
Angola	82$
Oman	75$
Saudi Arabia	74$
Russia	72$
Kazakhstan	71$
Gabon	66$
Azerbaijan	66$
Iraq	61$
Abu Dhabi, United Arab Emirates (UAE)	60$
Republic of Congo	52$
Qatar	51$
Kuwait	45$

Source: Nick Cunningham, 'Did the Arab Spring Disarm OPEC?', The Energy Collective', 3 August 2017.

Those wide-ranging impacts could already be observed In the midst of the 1980s when Saudi Arabia increased its oil production four-times within few years. It resulted in a comparable dramatic fall of the oil prices – in combination with its lack of missing economic competitiveness, insufficient diversification and high defence expenditures – and fuelled the disintegration and, ultimately, the collapse of the Soviet Union.[380]

In contrast to the Soviet Union and Russia, Europe and the West as net oil-importing countries could reduce their dependencies on oil and their oil import dependence of the politically unstable Middle East and the Gulf region. But how are prepared the leading Arab countries in the Gulf region?

380 See also Neil Barnett, 'Deploying the Saudi Oil Weapon against Russia', Centre for Policy Studies (CPS)-Pointmaker, March 2014.

5.5.1 Saudi Arabia

The Saudi price strategy and its unwillingness to agree for a freeze of oil prices have been explained by defending its market share, particularly in the oil-hungry Asia-Pacific region, and to test the robustness as well as the breakeven price for US shale production. It was hoping to collapse or at least to shrink significantly the supposed higher-priced US oil production.[381]

When Saudi Arabia has pushed its OPEC-partners for joining the cartel's production cut last November, Iraq, Libya, Iran and some other countries have been engaged in intensive discussions with Riad to be excluded from those cuts as their production has decreased over years due to wars and sanctions. Iraq and others even insisted to raise their oil production and exports further to help to fight Islamic militants at a time when the other OPEC members have to live up to their agreed national oil production cuts.[382]

While it is no longer the world's largest oil producing country, Saudi Arabia is still the world's lowest cost-producer for as little as US$ per barrel and resilient enough to survive oil prices even below US$30-40 per barrel (though still hurting its state budget) for a longer time in contrast to many higher-oil cost producers. It kept its production at presently around the 10 mb/d. But the oil and gas industry still accounts for 40% of its GDP, 77-88% of its government revenue and 90% of its exports.[383]

Thus Riad appears to be able - much better than other higher cost oil producers - to sacrifice short-term costs for long-term strategic objectives. But even Saudi Arabia has been hurt by its own oil price war as it was already running a budget deficit of US$98 bn (16% of its GDP) in 2015 and a US$87 bn in 2016 when it was forced to cut government salaries by 20% and reduce public funding. By 2020, the deficit could even reach US$380 bn. Hence the currency reserves of the Saudi Central Bank decreased from US$737 bn in 2014 to US$555 in 2016 and US$488 bn in the spring of 2018.[384] The current financial breakeven price for Saudi Arabia is currently estimated at US$65 per barrel.[385]

Saudi Arabia and the other oil producers are currently benefitting from higher oil prices from shrinking inventory surplus, strong worldwide demand and geopolitical tensions and seek to maintain them for the much hyped Aramco's Initial Public Offering (IPO) to raise the

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381 See also F. Umbach, 'The Geopolitical Impact of Falling Oil Prices', GIS, 19 November 2014 and idem, 'The Future of OPEC", ibid., 29 November 2016.

382 See Khalid Al Ansary/Sam Wilkin, 'Iraq Confirms Oil-Output Cut Even as Scheduled Exports Rise', Bloomberg.com, 10 January 2017.

383 See also Zvi Mazel, 'Saudi Arabia's Royals are Readying a Revolution from Above', GIS, 20 July 2018.

384 See Al Arabia, 'Saudi Comfortable with Foreign Reserves Level: Central Bank', 14.11.2016 and Nicholas Cunningham, '$100 Oil is Back on the Table', www.energypost.eu, 23 April 2018.

385 See Anjli Raval, 'Oil Cash Set to Boost Saudi Arabia's Sovereign Wealth Fund', FT, 9 March 2018.

valuation of its giant oil company. In contrast to many other Saudi companies being hindered by state control stifling innovation and new economic opportunities, Aramco is considered as operating like a Western private company with efficient, killed and highly educated employees as well as finishing projects on time and budget. It has oil reserves at about 260 billion barrels (bb) – equalizing around 70 years' worth of production at present output levels, out-competing any publicly listed international competitor.[386] The Saudi price strategy risks an overtightening of the oil market, which will boost the U.S. shale oil production even more and also increase the investment in electric mobility, undermining and constraining the future oil demand.[387] Furthermore, it also has to cope with the depleting old oil fields, which are costly to replace as past experiences have highlighted over more than a decade at costs running up to tens of billion US$.[388] It plans to invest US$300 bn in projects to maintain its spare oil production capacity and exploration as well as the production of conventional as well as unconventional gas.[389]

Saudi Arabia and his crown prince Mohammed bin Salman have outlined a '*Vision 2030*' in April 2016[390], which has recognised the global energy megatrends. The '*revolution from above*' includes the plan to sell off 5% of Saudi Aramco, the world's biggest oil company, to raise US$2 trillion for the country's public investment fund. Higher oil prices and crude oil revenues shall also bolster the US$230 bn '*Public Investment Fund'* to promote the country's transformation program.[391] The crown prince and his supporters want to reform his country and make it more economically more independent from its overreliance on oil exports. He seeks to diversify its economy in order to prepare it for an end of the oil age.[392] While many observers and regional experts are sceptical whether the timeframe is realistic[393], in contrast to most other oil and gas producers worldwide, he has a longer-term political vision, strategies and the financial resources for such a comprehensive and ambitious reform of the Saudi state, its economy and population.

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386 See Stanley Reed, 'An Oil Giant is Taking Big Steps. Saudi Arabia Can't Afford for It to Slip', NYT, 16 June 2018.

387 See Tsvetana Paraskova, 'Is OPEC Underestimating U.S. Shale?', Oilprice.com, 19 April 2018 and Anjli Raval, 'Oil Prices and Saudi Arabia's Perennial Goldilock Problems', FT, 11 April 2018.

388 See also Amy Myers Jaffe, 'Could a U.S.-Russia Oil Showdown be Coming?', Council on Foreign Relations, 18 December 2017.

389 See also Wael Mahdi/Bruce Stanley, 'The Next Entrant in the Shale Revolution? OPEC's Saudi Arabia', Bloomberg, 7 March 2018, and Cyril Widdershoven, 'Technical Problems in Saudi Arabia Could Wipe out the World's Oil Glut in Weeks', Oilprice.com, 18 July 2017.

390 See Mohammad bin Salman bin Abdulaziz Al-Saud, 'Vision 2030' (http://vision2030.gov.sa/en; accessed on 20 January 2018).

391 See also Anjli Raval,'Saudi Arabia's Existential Crisis Returns as US Shale Boom Anews', FT, 19 March 2018.

392 See also Peter Waldman, 'Saudi Arabia's Plan to Extend the Age of Oil', Bloomberg Markets, 13 April 2015, and Carole Nakhle, 'Saudi Arabia's Eonomic Reform', GIS, 22 June 2016.

393 See also Norah Alajaji, 'Letter from Riad', Carnegie Europe (Judy Dempsey's Strategic Europe), 30 June 2017; Ahmed Al Omran, 'Saudi Arabia Edges More Women into Work', FT, 1 September 2017.

The rather low oil price until last autumn has also decreased Saudi Arabia's GDP-growth, estimated by the IMF for 1.9% in 2017.[394] At the same time, the domestic political pressure has increased as the enthusiasm has already declined and the criticism has grown. In the view of conservative circles, the reforms of the Saudi society go too far as they are threatening the state-religious foundation of the country. But in the view of the younger generation and well-educated women, the reforms are insufficient.[395] As the result, a part of the initiated reforms of Riad's '*National Transformation Plan*' has already revised and been postponed into the later years of 2025-2030.[396] In November 2017, a government purge of 300 tycoons, princes and former government officials to tackle fraud had taken place to receive back some net US$100bn after the detained agreed to settlements.[397]

Although Riad has learned from failures of its hitherto much more moderate reforms, the outlined privatisation and the objective to decrease the rising income inequalities, to fight corruption, and to dismantle monopolies are dependent on complete new transparency and unknown accountability as well as clear responsibilities and the use of sanctions in its economy.[398] In consequence, the reform vision demands a new Saudi model for its relationship between the state and its society with an unknown result of future success at a time when its economy has fallen into recession in 2017.[399] The finance ministry has revised the target to balance the state budget from 2020 to 2023.[400]

Furthermore, Riad's role of an oil producer acting unilaterally within OPEC as the world's '*swing producer*' and '*central bank of global oil supply*' has been questioned and has undermined OPEC's role as a price cartel. Since 2014, Riad is less willing to play that role due to both economic and geopolitical factors as, alongside the reduced U.S regional engagement, Saudi Arabia is facing Iran as its geopolitical rival in the Middle East. Given the disagreements even between the monarchies of the Gulf Cooperation Council about the conflicts in Yemen, Syria, and Qatar, the diverging geopolitical interests of OPEC's individual member countries have eroded trust within the cartel. It makes it more difficult to enforce collective decisions that are mutually beneficial in their shared short- and long-term

394 See Zainab Calcuttawala, 'IMF: Saudi's Oil GDP to Fall 2% on Back of OPEC Cuts', Oilprice.com, 21 July 2017.

395 See Norah Alajaji, 'Letter from Riad', and Ahmed Al Omran, 'Saudi Youth Anxious to See Progress on Prince's Reform Plan', FT, 27 July 2017.

396 See also Jason Bordoff, 'The Saudi Arabian Reform Slowdown and the Oil Price Dilemma', FT, 11 September 2017; Karen Gilchrist, 'Saudi Arabia Is Reportedly Revising its Ambitious Plans to Change its Economy', CNBC.com, 7 September 2017, and Imad Al-Khayyat,'Saudi Economy Merits Beyond a Hasty Review', Forbes, 3 May 2017.

397 See Simeon Kerr/Andrew England, 'Wealthy Saudis Sit on Cash as Purge Casts Shadow over Investment', FT, 24 July 2018;

398 See also Ahmed Al Omran, 'Saudi Arabia Edges More Women into Work'.

399 See also Danila Bochkarev/Jan Hanrath, 'Envisioning the Future', Iranian and Saudi Perspectives on the Post-Oil Economy', CARPO-Brief No. 7, 18 April 2017, here p. 5 f.

400 See Ahmed Al Omran, 'Saudi Arabia Unveils Record $261bn Budget', FT, 19 December 2017.

interests. Despite the higher-than expected oil prices this year, it has still to cope with the largest budget deficit among OPEC's five largest producers. A decline of just one dollar in average oil prices of US$69 per barrel this year might balance off any financial benefit of boosting its oil exports by more than 500,000b/d. Four of these five largest oil producers of OPEC still need an oil price of more than US$70 per barrel to cover the government's spending targets.[401]

Saudi Arabia has no interest that Iran increases its economic power through rising oil revenues in order to dominate the region. A further escalation of the bilateral conflict cannot be excluded as the traditional conflict between Sunnis and Shiites has been added by new economic and security dimensions. The conflict between Saudi Arabia and its allies with Qatar has indicated that neighbouring countries are increasingly drawn into this widening bilateral conflict between Riad and Teheran.[402] In this context, Riad has also supported the U.S. to cancel the nuclear deal with Western powers as the newly adopted sanctions will constrain Iran's future oil exports.[403]

Last May, OPEC and Russia agreed to push through an oil production crease o around 1 mb/d to stabilise the international oil price after the unexpected cuts of oil supplies of around 2.8mb/d in Venezuela, Libya and Angola. They also reacted due to President Trump's criticism and the overall fear that the higher oil prices would hurt the worldwide economic development.[404] But assuming forthcoming U.S. sanctions against Iran, the global market could have to cope with the loss of another 2 mb/d of Iranian oil exports. Reportedly, OPEC's spare capacity is presently just 2.02 mb/d, it would leave almost no spare capacity on OPEC's side for any other geopolitical crisis causing the disruption of oil supplies on the global oil market if Saudi Arabia would rise its production up to 12 mb/d. Moreover, it is uncertain whether such higher production rates could really be implemented in such short time and sustained for any longer time.[405]

While Saudi Arabia and some other Gulf states are promoting and expanding RES, those efforts are undertaken due to decrease domestic oil as well as gas resources and thus free

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401 See Mohammed Aly Sergie, 'Saudi Dilemma: Output Boost could Hurt its Oil-Based Economy', WorldOil.com, 19 June 2018.

402 See also David Sheppard, 'Oil Traders will Find Middle East Power Struggle Harder to Ignore'.

403 See also Anjli Raval, 'Saudi Arabia's Existential Crisis Returns as US Shale Booms anew', FT, 19 March 2018.

404 See Rania El Gamal, 'Saudi-Russian Axis Rules Oil Markets as Trump Fights Iran', Reuters, 28 June 2018; Anjli Raval, 'Saudi Arabia's Next Oil Move in Spotlight after Trump Call', FT, 3 July 2018.

405 See John Kemp, 'Could Saudi Arabia Replace all the Barrels Lost from Iran Sanctions?', Reuters, 9 July 2018; Cyril Widdershoven, 'Can Saudi Arabia Prevent the Next Oil Shock?', www.energypost.eu, 2 July 2018.

them for exports - and not because of supporting the global climate mitigation policies and any real decarbonisation strategies.[406]

5.5.2 Iran

Before the 1979 Islamic Revolution and the eight-year war with Iraq, Iran was one of the most dynamic economies in the world and the most developed one in the region. Iran's per capita GDP was even higher than that of the Soviet Union, though its industrialisation was badly planned and in effective. It has the largest population in the region with almost 80 m people.[407] With 60% of its total exports and less than 50% of budget revenues, its overall dependence on oil is lower than in most other Gulf countries it is even more striking when the US$850 for per capita of oil exports (due to its large population) are compared with Saudi Arabia's about US$ 10,800 per capita of oil export revenues.[408]

Those differences matter as Iran – like Saudi Arabia and other Arab countries – is facing a high youth unemployment, a rapid population growth, an underrepresentation of women in workforce, a public sector able to increase the high numbers of university graduates, rising environmental problems and pollution, widespread corruption as well as failing transparency and accountability.

Iran is a sleeping giant of energy producers as it has the worldwide the fourth largest proven oil (9.3%) and second-largest conventional gas reserves (17.2% of the world's total – after Russia with 18.1%).[409] Oil has not only been the main driver of Iran's economy and its primary source of income but has also been seen as a major instrument for its energy diplomacy as well as geopolitical influence and interests.[410] The nuclear agreement between Iran and six world powers in 2015 has opened the prospect for major Western investment in its oil and gas sector, allowing it to raise also its present oil export from 2.6 mb/d and to generate significantly higher export revenues in the future.[411] Its crude oil

406 See also 'The Middle East and Russia are Ill-Prepared for a Low-Carbon Future'.

407 To Iran's oil and gas sector development in the pre- and post-revolutionary period see Kalina Damianova, 'Iran's Re-emergence on Global Energy Markets: Opportunities, Challenges & Implications', EUCERS-Strategy Paper 7 (London: EUCERS/King's College, 2015), pp. 42 ff. and Alexander Zotin, 'Iran: The Fruits of Isolation', in: Andrey Movchan/Alexander Zotin/Vladimir Grigoryev,'Managing the Resource Curse. Strategies of Oil-Dependent Economies in the Modern Era', pp. 80 ff.

408 See also Danila Bochkarev/Jan Hanrath, 'Envisioning the Future', Iranian and Saudi Perspectives on the Post-Oil Economy', p. 4; 'How to Do Business in Iran? – Successfully', Think Act/Roland Berger, 2015; KPMG, 'Off to Iran? What You should Know before You Enter the Market', 2016, and idem, 'Entering the Iranian Market'-Opportunities and Risks', January 2016.

409 See BP, 'Statistical Review of World Energy 2018', June 2018.

410 See also Sara Vakhsouri, 'Iran's Energy Policy after the Nuclear Deal' (Washington D.C.: Atlantic Council, November 2015).

411 See also Monavar Khalaj/Anjli Raval, 'Iran's Oil Gains at Risk as Trump's Nuclear Deadline Nears', FT, 2 May 2018 and Najmeh Bozorgmehr, 'Iran Hopes for $50bn in Investments as Sanctions Lifted', FT, 17 January 2016.

production has increased from 3 mb/d in 2014 to presently almost 4 mb/d. In the first half of 2018, it exported some 2.2 -2.4 mb/d. Teheran has planned to raise production up to 4.8 mb/d by 2021. Some 40% of the 187 existing fields and discoveries have yet to be developed.[412]

Despite facing new U.S. sanctions and confronted with proxy wars in Syria and Yemen following the escalation of its bilateral relations with Saudi Arabia and its Gulf allies since the 2011 Arab Spring, Iran has planned to rapidly increase its oil production from currently around 3.7 million barrels per day (mb/d) to around 5 mb/d and its gas production from presently more than 800 million cubic meters per day (mcm/d) to nearly 1.37 billion cubic meters per day (bcm/d) by 2021. In 2017, Teheran negotiated both with Western IOCs as well as state-owned Russian and Chinese oil and gas companies to develop 27 oil and gas projects with an overall worth of US$200 bn.[413] In total, it needs another US$200 bn for its upstream and downstream projects.[414] It has also worked out a more flexible and less risky contractual framework of the Iran Petroleum Contracts (IPC) and other more attractive conditions for foreign investments.[415] Iran hopes not only to significantly increase its oil and particularly gas exports to the world markets (both to Europe and Asia) but also to function as an regional energy transportation hub for Caspian and Central Asian oil and gas exports via Iran to the world markets.[416]

In 2017, it accepted an oil price of around US$55 per barrel and has agreed in principle to an oil production cut between OPEC and non-OPEC countries.[417] But its principle support has been dependent on the exemption from any production cuts or constraints itself as long as it can expand its oil and gas production. As it was fully able to benefit from the rising oil prices until 2014 as a result of the Western sanctions, it also had much less problems to adopt lower oil prices until 2017.[418]

The signing of the South Pars Phase 11 development contract with France's Total in 2017, China's Petroleum Corp. and Iran's Petropars company after persistent domestic criticism

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412 See also Christopher Adams/Anjli Raval, 'Iran Nuclear Deal Primes Market for Rising Oil Exports', FT, 6 April 2015

413 See also Henry Foy, 'Russia and Iran Sign $30bn Energy Agreements', FT, 1 November 2017.

414 See ibid.

415 See also Anjli Raval, 'Iran Prepares to Open up to Foreign Oil Companies', FT, 1 November 2015.

416 See also Micha'el Tanchum, 'A Post-Sanctions Iran and the Eurasian Energy Architecture. Challenges and Opportunities for the Euro-Atlantic Community' (Washington D.C.: Atlantic Council, September 2015). In context see also F. Umbach/Slawomir Raszewski, 'Strategic Perspectives for Bilateral Energy Cooperation between the EU and Kazakhstan - Geo-economic and Geopolitical Dimensions in Competition with Russia and China's Central Asia Policies', Konrad-Adenauer-Foundation/EUCERS, Berlin-Astana, EUCERS-Strategy Paper No.8, February 2016.

417 See also Keith Weir, 'Iran Says $55 Oil Price Suitable, Sees Supply Cut Extension', Reuters, 6 May 2017.

418 See also Brad W. Setser/Cole V. Frank, 'Using External Breakeven Prices to Track Vulnerabilities in Oil-Exporting Countries', pp. 15 ff.

(for offering foreign companies lead roles) and delays (i.e. sanctions over 13 years) was both a very important political and economic achievement, as the consortium can recover more than 280 bcm of gas and 450 mb of condensate, with first gas planned by 2021.[419]

Both its short-and longer-term strategic objective is to become a major player with rising exports in the global oil and gas market, generating hard currency for modernizing and diversifying its economy and strengthening its military power as well as geopolitical influence in the wider '*Greater Middle East'*. But its support of regional terrorism as well as geopolitical conflicts with the U.S. and Saudi Arabia are causing major uncertainties for the much needed foreign investments and the realisation of the rapid expansion of its oil and gas production as well as exports. Given the deepening of the mutual mistrust between Teheran and Riad during the last years with proxy wars in Yemen and Syria, the regional geopolitical rivalries could further escalate to an open military conflict.

Hardly surprising that Iran, supported by Venezuela and Iraq, has recently – unsuccessfully - tried to resist Saudi Arabia's efforts to raise OPEC's oil production and had criticised the related pressure of U.S. policies that OPEC is not an "*American organisation to receive its instructions from President Trump*". In contrast to Saudi Arabia and some other OPEC-members, Iran as OPEC's presently third largest oil producer is currently not really in the position to raise its oil production at short-notice, and, therefore, would lose market shares and has to cope with lower export revenues.[420]

The U.S. withdrawal from the international deal over Iran's nuclear program after its deadline of May 12 will also challenge Teheran's oil and gas plans as well as a result in higher global oil prices. Since lifting the international sanctions in January 2016, Iran has hardly revitalised its oil and gas industry as U.S. secondary sanctions remained in place. They have limited Iran's access to international banks as well as their services and constrained processing payments. The increase of its oil exports from 2.8 mb/d in January 2016 to its high of 3.83 mb/d in August 2017 is largely been explained by unusual high field pressure of previously shut down wells and by using the stored oil in tankers parked in the Persian Gulf, and not by new and higher oil production. About 70% of Iran's oil production comes from fields which are already 50 years or more in production.[421]

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419 See also '10 Facts about the Gas Fields Iran Is Offering to Foreigner', www.naturalgaseurope.com, 3 December 2015, and Peter Stewart, 'Iran Threatens Big Rise in Oil and Gas Output and Exports', www.interfaxenergy.com, NGD, 12 July 2017.

420 Quoted following Anjli Raval/David Sheppard/Kathrin Hille, 'Iran to Resist Saudi-Led Push to Increase Oil Output', FT, 20 June 2018.

421 See Ellen Wald, 'Sanctions or Self-Sabotage? The Story of Iran's Oil Industry', www.energypost.eu, 25 June 2018.

New U.S. sanctions to create "*unprecedented financial pressure*"[422] on Iran could cut its oil exports by 500,000 to 1 m b/d, depending on the political support of Russia, China and some other Asian oil importers. China, India, Japan and South Korea import almost 65% of Iran's oil exports. [423] As long as Russian and Chinese companies are investing in Iran's upstream sector and oil as well as gas infrastructures, Teheran has some leverage over their policies.[424] Teheran might also speculate that Beijing's announced 25% tax on U.S. oil imports in Chinas as a retaliatory measure in context of the escalating U.S.-Chinese trade war will make China even more dependent on Iran as Beijing has to move away from its oil imports from the U.S.[425]

While Iran has also benefitted from the recent rise of oil prices, other businesses have been hurt by them. But the higher oil prices have already undermined some larger businesses in Iran. They are also not in the U.S. interests either, highlighting contradictions in U.S. oil and security policies.[426] Meanwhile, Iran's hardline and powerful Revolutionary Guards have threatened to close the vital Strait of Hormuz if the U.S. is threatening the national economy and political stability of Iran. While this threat has been made in the past repeatedly, it has never really implemented this threat since the Iran-Iraq war (1980-88), as it would block the regional oil a LNG exports and lead to much more dangerous escalation with severe global impacts as 30-35% of the global maritime oil trade moves through this strait.[427]

Iran hopes to balance the conflictual relations with the U.S. by having signed a collaboration agreement with Russia on "*strategic cooperation on the energy sector*" of last November, totalling up to US$30bn.[428] But this Russian-Iranian cooperation in the energy sector also has its limits as Russia has simultaneously also become more dependent on its collaboration with Saudi Arabia and any newly agreed oil production cut between OPEC- and non-OPEC countries.[429] Similar investment contracts Iran has also signed with China as part of its '*Belt and Road-Initiative*' since 2016.

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422 Quoted following Michael Peel, 'US Rejects Europe's Hopes of Relief from Iran Sanctions', FT, 15 July 2018.

423 See Anjli Raval/Najmeh Bozorgmehr, 'Iran Eyes Asia Buyers to Protect Oil Exports from U.S. Sanctions', FT, 16 July 2018.

424 See Peter Stewart, 'Iran-Saudi Tensions may Limit OPEC's Options', www.naturalgas.com, NGD, 20 June 2018, p. 6 and Verity Ratcliffe, 'Energy Battle Lines Drawn on US-Iran Divide', ibid., 27 July2018, p. 3 . But the Russian-Iranian relations are also guided by increasing competing strategic interests and have their own limits – see also Azadeh Zamiriad, 'Pragmatisch, taktisch, opportun: Die russisch-iranische Allianz im Nahen Osten', Russland-Analysen, No. 356, 8 June 2018.

425 See Mahsa Rouhi, 'Can China Save the Iran Nuclear Deal?', IISS, London, Blog, 9 July 2018 (https://www.iiss.org/blogs/analysis/2018/07/china-save-iran-nuclear-deal; accessed on 14 July 2018).

426 See Ed Crooks, 'Playing with Fire: Iran Deal Looms over Rising Oil Price', FT, 27 April 2018.

427 See Anjli Raval/Najmeh Bozorgmehr, 'Iran Eyes Asia Buyers to Protect Oil Exports from U.S. Sanctions'; David Sheppard, 'Trump Face-off with Iran Creates Huge Oil Supply Risks', FT, 24 July 2018, and 'Why Iran is Threatening to Close the Strait of Hormuz', Stratfor.com, 5 July 2018.

428 See again Henry Foy, 'Russia and Iran Sign $30bn Energy Agreements'.

429 See also Nikolay Kozhanov, 'The Limits of Russian-Iranian Cooperation', Chatham House, London, 27 November 2015.

The renewed conflict between Iran and the U.S. after President Trump withdrew the U.S. from the '*Joint Comprehensive Plan of Action (JCPOA)*' on 8 May 2018 may open some more beneficial investment opportunities for Russia and China in Iran, but could also further complicate their bilateral relationships with the U.S., which are already conflictual.[430] Meanwhile, the Trump administration has claimed that more than 50 international companies have indicated to withdraw their business engagement (mostly in the energy and financial sectors) in Iran.[431] But Russia has just declared to invest some US$50 bn in Iran's oil and gas sectors.[432]

Beyond the escalation of the U.S.-Iranian relations, all newly planned Iranian projects and official energy plans suggest that Iran – like most other – oil producing countries – still sees no alternative to the development and expansion of its oil and gas sectors for the country's economic and political stability. Like other oil producing countries, it views the global decarbonisation efforts rather as a potential threat to the country's future and supports the expansion of renewables for domestic consumption basically as an instrument for freeing more oil and gas resources for exports rather than contributing to the global efforts for climate change mitigation and a transition to a low carbon energy system.

5.5.3 Iraq[433]

When Saudi Arabia has pushed its OPEC-partners for joining the cartel's production cut last November, Iraq, Libya, Iran and some other countries have been engaged in intensive discussions with Riad to be excluded from those cuts as their production has decreased over the years due to wars and sanctions. Iraq and others even insisted to further raise their oil production and exports to help to fight Islamic militants at a time when the other OPEC members have to live up to their agreed national oil production cuts.[434] Between 2014 and 2015, Iraq had already increased its oil production by almost 700,000 b/d – more than the total oil output in Egypt or Malaysia.[435] But also in 2015, Iraqi oil production has grown by another 660,000 b/d, benefitting from capital investments and relative

430 See also Verity Ratcliffe, 'U.S. Action on Iran Opens the Door for Russia', www.naturalgas.com, NGD, 22 June 2018, p. 3; Simon Theobald, 'After U.S. Withdrawal, Iran Embraces China', East Asia Forum, 5 June 2018.

431 See Katrina Manson, 'US Claims 50 Companies Plan to Quit Iran to Avoid Sanctions', FT, 2 July 2018.

432 See Henry Foy, 'Russia Ready to Invest $50bn in Iran's Energy Industry', FT, 13 July 2018.

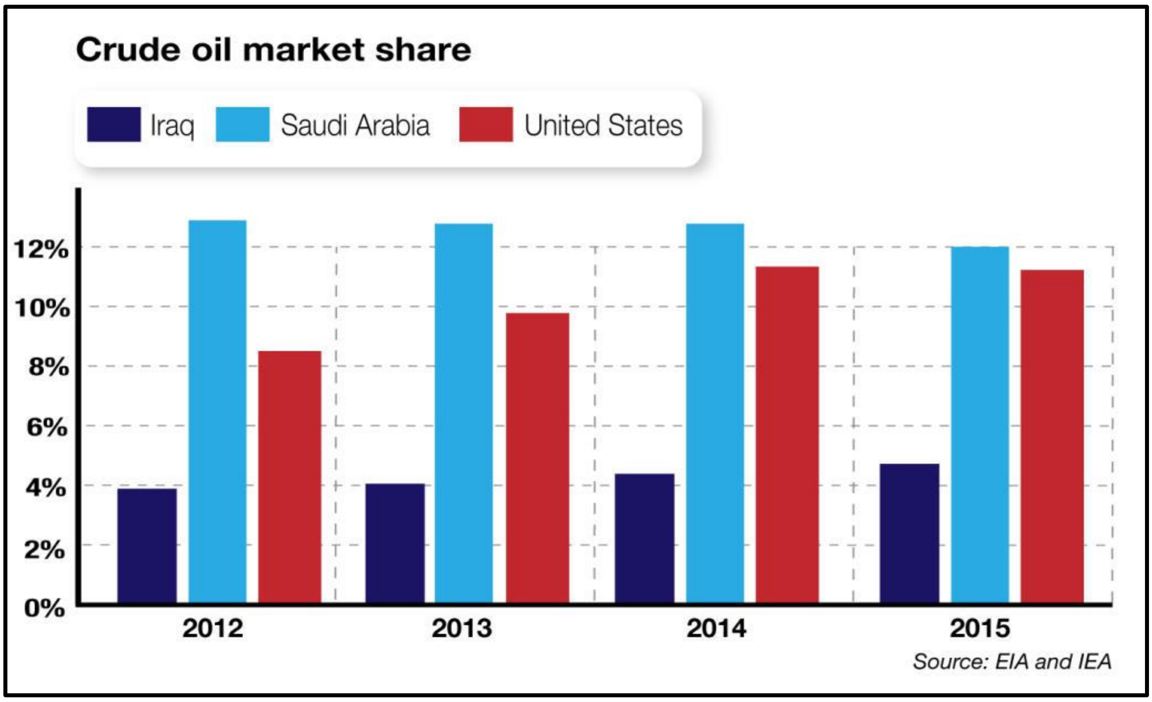
433 This chapter is based on a previous study by the author – F. Umbach, 'The Future of Iraq Gas and EU Energy Security", Pflueger Consulting/Roland Berger Consulting, Berlin, July 2017, but has been revised and up-dated.

434 See Khalid Al Ansary/Sam Wilkin, 'Iraq Confirms Oil-Output Cut Even as Scheduled Exports Rise', Bloom-berg.com, 10 January 2017.

435 See also Carole Nakhle, 'Iraq Oil Dilemma: to Freeze or Not to Freeze', GIS, 14 April 2016.

political stability between 2012 and 2014.[436] Before 2013, Iraq was even hoping to expand its production up to an unrealistic 12mb/d by 2017, but then had reduced the oil production target to (an still equally unrealistic) 9 mb/d by 2018[437] whereas the IEA projected a 6.1 mb/d by 2020, which has meanwhile revised downwards to 5.4 mb/d by 2022 and longer-term 7.1 mb/d by 2040.[438] While global oil production moved up by 3.3 mb/ between 2014 and 2016, 1.1 mb/d of it were added by a single country: Iraq.[439] It was able to increase its market share - largely at the expense of Iran. Thus within OPEC, contrary to previous assumptions, it was not Iran becoming the 'wild card' within OPEC, but rather Iraq by causing new controversies about compliance and the level of national production curbs. However, it appears rather unrealistic that such an oil production growth in 2014-2016 can be repeated by Iraq in the forthcoming years regardless of any newly agreed production cuts between OPEC and non-OPEC members.

Figure 45: Crude Oil Market Shares of Iraq, Saudi Arabia and U.S. 2012–2015



Source: GIS 2016

In contrast to Iran and Libya, which have been exempted from the oil production curbs, Iraq as the second-largest oil producer of OPEC (since 2012 replacing Iran) had also reduced its oil production from 4.61 mb/d last December by 215,000 barrels per day (b/d) since

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436 See IEA, 'WEO 2016', p. 138 f. To the data problem see also Carole Nakhle, 'Iraq: OPEC's Wild Card', GIS, 22 November 2016.

437 See Guy Chazan, 'Storm Clouds Threaten Iraq's Striking Oil Revival', FT,8 July 2013.

438 See IEA, 'WEO2016',,pp. 137 ff. and Nawar Alsaadi, 'Is an Iraqi Production Slowdown Inevitable?', Oilprice.com, 3 April 2017.

439 See Nawar Alsaadi ibid.

January 2017.[440] But with Saudi Arabia over-complying its agreed cut by 486,000 b/d to a ceiling of 10.058 mb/d, Iraq appears to have failed to comply with the cuts in 2017.[441] It has produced around 4.4 mb/d last year.[442]

The agreed production cuts between OPEC and 11 non-OPEC-members by 1.8 mb/d last November have not automatically translated into the reduction of oil exports on the oil producer side. Thus Iraq was able to even increase its exports despite the fact that it has - compared with other oil producers – only limited storage capacity. Other oil producers have used excess stockpiles in their oil storage sites, albeit the inventories have also declined already since last summer - four months ahead of the agreed production cut between OPEC and non-OPEC states – to raise their exports during the last months.

Iraq has officially backed the recent joint Saudi-Russian proposal for extending oil output cuts of OPEC and non-OPEC countries for another nine months, albeit it could increase its oil production as its oil industry still recovers from the past wars and sanctions.[443] OPEC's second-largest oil producer Iraq has promised to cuts its production by 210,000 b/d to a level of 4.351 mb/d, while Iran (No. 3 of the cartel) was allowed to raise its production to 3.797 mb/d.[444]

In the first quarter of 2017, Iraq's oil production was 36% higher compared with 2014.[445] But without any negotiated oil production cut in the U.S. and by granting Iran, Libya, Nigeria and others exemptions for not cutting their production, Bagdad may experience more pressures not to live up to the agreed OPEC production curbs. As a result, the oil prices could further decrease and reduce the oil revenue for its state budget.[446]

While Saudi Arabia has been forced to compromise with Baghdad by allowing Iraq to raise its oil exports despite the agreed production cut, it has not strategic interest that Iraq becomes another important swing producer threatening Riad's historical leadership role in OPEC. Their bilateral relations are also tense due to other complicating interests and factors.[447]

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440 Initially, Iraq has agreed to reduce its production by 160,000 b/d – see ibid. To the higher reduction figure see Arthur Berman, 'OPEC Production Cuts and the Long Road to Market Balance', Oilpro.com, 20 April 2017.

441 See Tsvetana Paraskova, 'OPEC Deal Backfires: Saudi Lose Market Share to Iran, Iraq', Oilprice.com, 1 May 2017.

442 See Ajli Raval/David Sheppard, 'OPEC Eyes Output Cut Compliance Ahead of Supply Curb Extension', FT, 24 May 2017.

443 See 'Iraq to Back OPEC-Led Output Cut Extension', FT, 22 May 2017and Ahmed Rasheed/Ernest Scheyder, 'Saudi Arabia, Iraq Agree Oil Output Cut Needs Nin-Months Extension', Reuters, 22 May 2017.

444 See Tsvetana Paraskova, 'OPEC Deal Backfires: Saudis Lose Market Share to Iran, Iraq', Oilprice.com, 1 May 2017.

445 See Mohamed Mostafa, 'Iraq's Oil Production up 36% in 2017: Official', Iraqi News, 15 May 2017.

446 See also F. Umbach, 'The Future of OPEC', GIS, 29 November 2016.

447 See Luay J.Al-Khatteb, 'Natural Gas in the Republic of Iraq', p. 23.

Against the background of these recent developments of the global oil markets and an extended OPC oil production cut until next year, as it has been agreed again within OPEC (.e. Saudi Arabia) and 11 non-OPEC oil producers (i.e. Russia), Iraq needs to review its previous '*Integrated National Energy Strategy (INESS)*'.[448] In light of a rapidly changing global oil and gas, markets to fasten it has the development of its natural gas sector and to expand RES. This would also allow freeing more oil and gas resources for future exports.

According to the latest annual '*BP Statistical Review of World Energy 2018*', Iraq has around 3.5 trillion cubic meters (tcm) natural gas reserves, which equalise to 1.8% of the world's conventional gas reserves.[449] However, given the traditional Iraqi focus on its oil sectors, larger parts of the country need still to be analysed geologically and sufficiently be explored. Its potential gas resources, which can be technically exploited, might be much larger. According to the INES-report of 2012, a comprehensive exploration could more than double its gas reserves up to the 280 trillion cubic feet (tcf or 7.5-7.9 tcm[450]). Many existing non-associated '*free gas*' fields (up to 4.5 tcm), particularly in Iraq's western region, have not been explored at deeper levels. As a result, Iraq may have worldwide one of the five largest conventional gas reserves.[451]

The Kurdish (KRG) Ministry of Natural resources (MNR) has estimated higher potential gas reserves in Kurdistan of up to 200 tcf (or 2.8 bcm) than the federal government's stated reserves of 165 tcf for the region. Most promising fields are in the North (Khor Mor and Chemchemal) and are believed ten times as much as those controlled by Baghdad's federal Ministry of Oil (MOO).[452] Energy companies have even more optimistic, estimating that Kurdistan holds 3.3 tcm of gas and 50 bn barrels (bb) of oil in potential reserves, added by 821 bcm and 11 bb of proven reserves.[453]

Future Iraqi gas exports are facing not only competition by other LNG suppliers in an already oversupplied market at least till 2025, but also growing competition with in the region. The Middle East could significantly increase its gas production by another 400 bcm year to the global market (comparable with the U.S.) by 2040. The Middle East is expected to become the second-largest consuming gas region (presently the third largest).[454] But

448 See Iraq Prime Minister Advisory Commission, 'Integrated National Energy Strategy (INES). Final Report, Bagdad, 25 September 2012.

449 See BP, 'Statistical Review of World Energy 2018', p. 26; Iraq Prime Minister Advisory Commission, 'Integrated National Energy Strategy (INES)', p. 13 and Luay J.Al-Khatteb,'Natural Gas in the Republic of Iraq', p. 8.

450 See also IEA, 'Iraq Energy Outlook'. World Energy Outlook Special Report', Paris, 9 October 2012,p. 69.

451 See Iraq Prime Minister Advisory Commission, 'Integrated National Energy Strategy (INES)', p. 41.

452 See Luay J.Al-Khatteb,'Natural Gas in the Republic of Iraq', p. 10.

453 See Verity Ratcliffe, 'Kurdistan to Offer 20 Blocks in Licensing Round', www.interfaxenergy.com, NGD, 6 December 2016.

454 See IEA, 'WEO 2016', p.171.

such an expansion of gas production is dependent on the future regional security and stability, and alongside uncertain sufficient investments, attractive investment regimes and related regulatory conditions.[455]

During the last two years and particular since the appointment of Jabbar al-Luaibi a Iraq's oil minister in August 2016, Iraq has made some important progress by diversifying its energy mix, implementing new environmental legislation, enhancing energy efficiency in an updated RES and energy strategy and exploring new contract models for foreign investors in a more pragmatic way.[456]

While the world is shifting its future energy investments in the energy sector increasingly to natural gas and renewables, Iraq's energy policies have paid their main attention still on a rapid rise of its oil production. This is understandable as Iraq's total government revenues for its state budget were still generated by 93% per cent by crude oil export revenues in 2014.[457] Iraq's overall economy is very much interlinked with its energy sector (around 45% of GDP dependent on oil export revenues), Eight million of Iraq's population dependent on government salaries and pensions[458]. The dramatic oil price decline by (temporarily) up to 60% until 2016 has further complicated the economic, political and social situation in Iraq in addition to the country's wars and sanctions.

As a result of the declining oil prices, Iraq earned already around US$35 bn (2015) less from its oil exports, leaving only US$49 bn of oil export revenues for the state budget and increasing the state deficit to unsustainable levels even despite a significant increase of its crude oil volumes from 2014 to 2016.[459] While public finances have declined, public spending has increased - especially for the military. But despite being so dependent on oil export revenues as a typical rentier state, the oil and gas sector is not labour-intensive. The direct employment is currently not more than 2% of its national workforce. In its state-owned oil and gas companies with their production, refining, processing and distribution subsectors only 100.000 (of altogether 125.000 by including service companies and some others) are directly employed.[460] A quarter of the population lives in poverty as the 'oil wealth' had not reached large parts of the population, even not when the oil prices were above US$100 per barrel. With a population growing from 32 million today to 40.4 million in 2025 and 56.3 million in 2050, each year another 500,000 young people join the

455 See ibid., p. 185 f.

456 See also 'Reform Eludes Iraq's Oil Sector', Stratfor.com, 20 April 2017.

457 See Energy Information Administration (EIA), 'Country Analysis Brief: Iraq', Washington D.C., 28 April 2016, p. 1.

458 See EU-Iraq Energy Centre (EUIEC)/Pflüger International, 'Iraq's Energy Sector. Addressing Challenges and Leveraging Opportunities', p. 15.

459 See EIA, 'Country Analysis Brief: Iraq', p. 1.

460 See also IEA, 'World Energy Outlook 2016', Paris 2016, p. 111.

workforce, and most of them are currently not able to find a job.[461] This Iraq sees its economic future and political stability still in the expansion of its oil and gas industry. The expansion of renewables serves primarily not just to cope with its rapid electricity demand growth, but to free oil and gas resources for higher exports and hard currency inflows, too.

5.5.4 Russia

In October 2016, Russia's President Vladimir Putin himself has rejected the idea that the hydrocarbon era is ending and the need to phase-out hydrocarbons in Russia's and the world's energy mix. Instead, he has re-assured old and new energy partners at the World Energy Congress in Istanbul:

> "We are encouraging the exploration of new oil and gas fields and continue investing in production even in today's difficult economic conditions. There should be no doubt in your minds that our country will be a reliable energy supplier on the global markets. Russian energy exports are a guarantee for the successful functioning of many countries' economies."[462]

These Russian energy policies are in line with its official climate policies. While the Kreml recognises climate change as such, but it is not linked with the primary anthropogenic factor as the main driver of climate change. Therewith, it is fully in line with U.S. President Trump's basic assumptions of climate change.[463]

In the past, 80% of the energy revenues came from oil. They covered around 40% of the Russian state budget. In 2014, Russia's state budget was calculated still on prices of around US$117 per barrel.[464] In 2015, Russia's Finance Ministry expected that the low oil price would cost the country at least 2% of its GDP and that its oil sector would lose around US$4bn by any further oil price reduction of US$10 per barrel. It still needed an oil price of around US$65-75 per barrel to cover its production costs and to generate enough export revenues for its state budget. In June 2017, Russia's Economic Ministry declared that it is "*actually ready to live forever at oil prices $40 or below*".[465] At that year, oil and gas accounted for 16% of Russia's GDP, 52% of the federal government's revenue and 70% of the county's exports.[466] Other estimates indicate that energy accounts for 66% of Russia's

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461 See Amatzia Baram, 'Iraq's Struggle Against Poverty and Violence Despite its Oil Wealth', GIS, 2 June 2014.

462 Quoted following 'World Energy Congress in Istanbul', Kremlin.ru, 10 October 2016.

463 See Alexej Kokorin/Anna Korppoo, 'Russia's Ostrich Approach to Climate Change and the Paris Agreement', CEPS-Policy Insights, No. 2017/40, November 2017.

464 See also F. Umbach, 'Rosneft and Russia Pay the Price of West's Energy Sanctions', GIS, 1 December 2014.

465 Quoted following Tsvetana Paraskova, 'Russia's Rosneft Expects $40 Oil in 2018', Oilprice.com, 11 September 2018.

466 See Olga Samofalova, 'Are Russia's Oil Wells Truly in Danger of Driving up?, Vzglyad/Russia Beyond its Headlines, 30 March 2017.

exports, bolstered by a complex web of decreased taxes and duties and state incentives for its oil and gas industry.[467]

As the world's second-largest energy producer, Russia did not diversify its economy during the past decade of high oil and gas prices. It has just begun to address the manifold challenges with longer-lasting low oil and gas prices, but not with declining oil and gas exports as the result of a declining world oil demand and global decarbonisation efforts.

Russia's officially proclaimed future energy policies are still based on best-case scenarios ignoring the world's long-term energy megatrends. Russia rather still vies with Saudi Arabia and the U.S. for the title of the world's biggest oil producer. But it cannot ignore that its aging oil fields will be rapidly depleting after 2025. It also explains the Kremlin's support for collective oil production cuts with OPEC since 2015 as it didn't have really to decrease its own production. But it is also rather unable to raise its production significantly after its record of 11.1 mb/d in 2014 and almost 11.2 mb/d at the beginning of July this year.[468] The Russian Finance Ministry sees a balanced long-term oil price level of US$50-60 per barrel and has recently warned of another price collapse in contrast to others projecting rather new price spikes above US$ 100 per barrel, particularly of an escalating U.S.-Iranian conflict and a scenario of an Iranian blockade of the Hormuz Strait as threatened by Teheran.[469]

Russia still has the world's largest unconventional oil resources (i.e. the Bazhenov-oilfield[470]), accounting for some 20% of its remaining recoverable oil reserves.[471] But only exploration could prove whether they can be drilled in a competitive way with lower oil prices. For those explorations and a larger production of its unconventional oil reserves, it needs Western technology cooperation, particularly with U.S. oil companies. But any joint oil cooperation is prohibited in regard to deep water oil field development, Arctic shelf field development, and Scavenger oil field development, including shale oil and gas projects. But the Western sanctions have rather mid- and long-term negative impacts and have not

467 See also Henry Foy, 'Russian Oil Industry Proves its Resilience', FT, 5 June 2018.

468 See ibid., and David Sheppard, 'OPEC and Russia Poised to Roll over Oil Output Cuts', FT, 9 May 2017; James Marson, 'Russia Bets on Shale Oil to Defend its Spot as Top Producer of Crude', Wall Street Journal, 29 December 2017, and Tsvetana Paraskova,'Russian Oil Production Soars to 11.193 Million Bpd', Oilprice.com, 7 July 2018.

469 See Irina Slav, 'Russia's Finance Ministry Warns of Another Price Collapse', Oilprice.com, 9 July 2018.

470 It might be the world's largest unconventional oil field, whose territory is stretching over more than 1 million square meters and might contain oil reserves of at least 20 bn tons. The production costs have been estimated at least US$55-60 per barrel – see Viktor Katona, 'When Will Russia Run Out of Oil?', Oilprice.com, 4 April 2017 and Kenneth Rapoza, 'When Russian Finally Hopes on Shale Bandwagon, OPEC Is Finished', Forbes, 29 August 2017.

471 The estimates of the EIA in the U.S. on those Russian shale oil reserves have varied during the last years and have been downgraded to the worldwide second-largest (74.6 bb compared with 78.2 bb in the U.S.) – see Kenneth Rapoza, 'When Russian Finally Hopes on Shale Bandwagon, OPEC Is Finished'.

stalled Russia's Arctic exploration activities in the short-term thanks Chinese investments, its prudent currency policies by weakening the Rubble and recently by the increasing oil price.[472] So far, Russia's Arctic Shelf region may hold as much as US$20 trillion worth of oil and gas resources and is expected to provide around 20-30% of Russia's oil production in 2050.[473] The dramatic oil price decline had much more short-term impacts as many high cost conventional oil and gas projects in the Arctic, and onshore shale oil projects have become unprofitable and, therefore, have been frozen since 2014.[474] The discovery of new oil and gas fields have significantly declined in 2015 and 2016 compared with the pre-sanction period.[475] As Western financing of Russian oil and gas projects have become much more difficult or impossible, China has partly replaced Western banks and offered Chinese loans, though they are often criticised as very expensive.[476] The longer the Western sanctions will be in place, the higher will be the accumulated impacts. They are jeopardizing Russia's future oil and gas production as well as modern pipeline infrastructures, undermining its market shares, limiting its export revenues, and threatening the stability of the Russian economy.[477]

Russia's oil and gas production and exports are the foundation for restoring Russia's great power status. Putin's power elite is intimately interlinked with Russia's oil and gas elite, all coming from the '*siloviki*' (its secret services and other power ministries). But its economic growth has remained marginal, though it has proved better than anticipated in the West. Any real reform policy is elusive with costly geopolitical ambitions (Ukraine, Syria etc.). Russia's government policies are still focused on balancing the state budget deficit and other short-term concerns at the expense of much needed long-term structural reforms.

During the last decade, Gazprom, Rosneft and Novatek already invested more than US$100 bn in new oil and gas fields on the Yamal Peninsula and the offshore Arctic waters. Another US$150 bn will be spent by 2025. Despite the dramatically fallen global oil and gas prices and offshore Arctic oil and gas projects being considered as the world's most costly ones, the Russian government has strongly supported and subsidised the development of new oil and gas fields in Yamal and its territorial waters.[478] Given the

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472 See also Henry Foy, 'Russian Oil Industry Proves its Resilience'.

473 See Henry Foy, 'Russian Oil Groups Brave Cold of Western Sanctions to Explore Arctic', FT, 19 April 2017.

474 See Igor Yushkov, 'Sanctions vs. Cheap Oil: What is More Dreadful for Russia's Fuel & Energy Complex', Russian Council on International Affairs, 26 April 2017

475 See see Viktor Katona, 'When Will Russia Run Out of Oil?'.

476 Novatek, for instance, has sold 20% to the CNPC and 9.9% to the Chinese Silk Road Fund in its Yamal LNG-project, and only having provided reassurance for the workload of the Chinese enterprises that it could obtain a 9.3 bn Euro and9.8 bn Yuan (ERO: 1.33 bn) loan –see Igor Yushkov, 'Sanctions vs. Cheap Oil: What is More Dreadful for Russia's Fuel & Energy Complex'.

477 See Tatiana Mitrova, 'Where are Western Sanctions Leading the Russian Oil and Gas Industry', Carnegie Moscow Center, 25 July 2018.

478 See also F. Umbach, 'The Myth of Cheap Russian Gas', GIS, 5 September 2017.

regional permafrost, long winters, and temperatures down to minus 50 degrees Celsius and summer times, when 80% of Yamal's territory is covered by lakes, swamps and rivers, the drilling and production is much more complicated and expensive. The exploitation also needs much more energy compared with its old low cost gas fields. In addition, some of the gas volumes of these new fields need to be highly processed before it can be used and exported.

Yet, production costs at US$63-70 per barrel should be still cheaper than those of its tight oil reserves as far estimated US$80-90 per barrel.[479] In August 2017, Russian scientists and domestic oil service companies have claimed that they have developed a new '*thermochemical fracturing*' technology as an alternative to the hydro-fracking one in the U.S. Reportedly, it will allow an increase of oil production between 1.7-6 times of the traditional drilling.[480]

Russian companies have increased their investments during the last three years in ongoing and new offshore oil and gas projects as well as the expansion of Sovcomflot's maritime fleet with cutting-edge LNG tankers. For environmentalists, those new commercial prospects are rather a dangerous development for both the Arctic region as well as the future worldwide decarbonisation efforts. New research results indicate that two-thirds of Russia's permafrost landscape might melt by the end of this century. It represents a serious threat to civilian and military infrastructures and facilities, including oil and gas drilling sites, pipelines, powerlines, roads, train connections, airports and residential settlement. Methane gas leakages are increasing and have already lead to a growing number of explosions much earlier than previously been assumed. The Yamal Peninsula has the world's biggest concentration of natural gas fields. They are increasingly threatened as those explosions can occur "*anywhere*" as local officials and newspapers have noted. They have warned that Moscow's ability to extract oil, gas and mineral resources from the region or maintain military facilities will be compromised and threatened far sooner than anyone had expected.[481]

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479 See Viktor Katona, 'Can Russia Develop Its Shale Reserves?', Oilprice.com, 5 September 2017, and Igor Yushkov, 'Sanctions vs. Cheap Oil: What is More Dreadful for Russia's Fuel & Energy Complex'.

480 See Tsvetana Paraskova, 'Russia Claims to Have Invented Alternative to Fracking', Oilprice.com, 17 August 2017.

481 See S.E.Chadburn et.al., 'An Observation-Based Constraint on Permafrost Loss as a Function of Global Warming', Nature Climate Change, 10 April 2017; Henry Fountain, 'More permafrost than Thought may be Lost as Planet Warms', 11 April 2017; 'Warnings of new Artic Explosions at some 700-plus Sites in Yamal due to Thawing Permafrost', Siberian Times, 4 July 2017; '7,000 Underground Gas Bubbles Poised to 'Explode' in Arctic', ibid., 20 March 2017; Anna Liesowska, 'Danger of Methane Explosions on Yamal Peninsula, Scientists Warn', ibid., 22 September 2015; Stephanie Pappas, 'Oozing Methane Blasts Hokes in Siberian Tundra', 6 July 2017 (https://www.livescience.com/59705-oozing-methane-blasts-craters-in-siberian-tundra.html; accessed on 30 September 2017); Tibi Puiu, 'Thousands of Methane-Filled Bubbles are Waiting to Explode in Siberia', 10 July 2017 (https://www.zmescience.com/science/news-science/methane-

Despite being hurt by the dramatic oil price decline until 2016, Rosneft has continued its worldwide expansion by new investments in oil and gas fields inside and outside Russia, including highly unstable countries like Iraq and Venezuela.[482] The reduced hard revenues from oil exports for the Russian state budget have been largely balanced off with an expansion of its oil production by 6% between 2013 and 2016 – albeit at the expense of its older fields which might deplete even more rapidly.[483]

In contrast to most other countries in the world, Russia's political-economic elite perceives climate change less as an environmental and economic threat, but rather as an opportunity for its future economic development. The melting of the Arctic ice opens new offshore oil and gas production (up to 25% of the world's remaining conventional oil and gas reserves) as well as new sea-lanes for commercial shipping.

The draft Russian energy strategy up to 2035 replaced the previous '*optimistic*' targets of 4.5% by 2020 and 5% by 2030, with a "*more realistic*" target of 2.2% in 2020 compared with the 2009 energy strategy. While the potential for RES (i.e. wind power) access for at least 11.3% by 2030 according to a report IRENA (more than twice of Russia's official forecast of 5%), political and other vested headwinds, appear still greater.[484] But symptomatically, Russia still consumes much more energy per unit of GDP than the world's leading economies.[485]

Given Russia's problems to significantly increase its present oil production due to the Western sanctions and to prevent any new U.S.-Saudi oil alliance, it is forced to maintain its

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lakes-siberia-0432423/; accessed on 5 October 2017); BEC Crew, '7,000 Huge Gas Bubbles Have Formed under Siberia, and Could Explode at any Moment', 21 March 2017 (https://www.sciencealert.com/7-000-huge-gas-bubbles-have-formed-under-siberia-and-could-explode-at-any-moment; accessed on 6 October 2017); Olga Dobrovidova, Melting Glaciers Threaten to Inundate Russia's Far North and Siberia', Russia Beyond the Headlines (RBTH), 14 March 2017; Ben Guarino, 'Russian Scientists Find 7,000 Siberian Hills Possibly Filled with Explosive Gas', Washington Post, 27 March 2017; Will Stewart, 'Terrifying! More than 7,000 Underground Methane Gas Bubbles are about to Explode in the Arctic', Daily Mail, 21 March 2017, and Stephen Blank, 'Putin's Arctic Dream Evolving into Nightmare', Eurasia Daily Monitor, 26 March 2018.

482 See 'Russia's Energy Firms Seek to Whether the Economic Storm', Stratfor.com, 11 February 2015; Henry Foy, 'Rosneft Results Hit By Production Cuts in Crude', FT, 4 August 2017; Katya Golubkova/Gleb Gorodyankin, 'Despite new U.S. Sanctions, Russian Oil Traders Say It's Business as Usual', Reuters, 29 August 2017, and F. Umbach, 'Rosneft and Russia Pay the Price of West's Energy Sanctions'.

483 See Henry Foy, 'Russian Oil Groups Brave Cold of Western Sanctions to Explore Arctic'.

484 See idem, 'Russia Struggles to Unleash Clean Energy Potential', FT, 7 May 2017; 'Life after Oil', St. Petersburg International Economic Forum (SPIEF)', 17 June 2016 und Denis Chukanov, 'Renewable Energy and Decentralized Power Generation', SWP-Comments 45, Berlin, November 2017.

485 See Alexej Kokorin/Anna Korppoo, 'Russia's Ostrich Approach to Climate Change and the Paris Agreement', pp. 4 ff., and Alexey Kokorin, 'Russia's Post-Climate Policy: Slow Progress and Problems', Russian Analytical Digest, No. 185, 20 June 2016.

collaboration with Saudi Arabia regards to oil production levels and production cut.[486] However, Moscow is concern that the present high oil prices will only lead to higher U.S. oil production and decreasing market shares of Russia.[487]

Russian economic experts believe that Russia will only break with its '*resource curse*' when oil and gas prices will further drastically decline and oil and gas revenues won't be relevant any longer for its political-economic elite.[488] The Russian billionaire and former Russian foreign trade minister, Petr Aven, warned in 2016 ,

> "…that petrostates … have used their oil rent to enjoy Western-style consumption without subscribing to the Western values that made it possible. Now they are at risk of ending up like the producers of natural rubber after the invention of synthetic latex – dependent on a commodity that no longer generates a rent because of its scarcity but just sells as a certain mark-up to production cost. […] 'The full enjoyment of Western comforts and technologies will no longer be compatible with a negation of its values and institutes. Only those countries that embrace modernisation and carry it further than they did in the previous oil downcycle can hope not be relegated to a historical footnote."[489]

Indeed, Russia's future economic development is still at risk to fall back toward some kind of '*petro-stagnation*' with a further decline of its average income, painful cuts to social expenditures and mounting structural problems. The country is still ill-prepared for any low-carbon future[490] - even less than Saudi Arabia and some other Gulf states, which are diversifying their economies, though Russia may benefit from the world rising dependence on CRMs supplies.

5.5.5 Venezuela

Venezuela is currently considered as the most vulnerable OPEC member state as it needs an oil price of around US$110 per barrel to cover its state budget targets and to repay its debts of US$18.5bn until the end of 2017. Oil exports have generated 96% of its total export revenues. Income has fallen more than 50%. These facts constrain its ability to

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486 See James Henderson/Ahmed Mehdi, 'Russia's Middle East Energy Diplomacy', Foreign Affairs, Snapshot, 20 June 2017, and Nicolas K. Gvosdev, 'Russia's Hand Is Visible Everywhere in the Middle East', National Interest, 12 September 2017.

487 See also Viktor Katona, 'Is Russia Running out of Patience with OPEC?', Oilprice.com, 7 June 2018; Julian Lee, 'Russia's OPEC Bear Hug Probably Won't Last', Bloomberg, 16 October 2016, and Martin Tillier, 'Is Oil about to Collapse?', ibid., 10 December 2017 .

488 See Anna Andrianova/Andre Tartar, 'Oil Must Go to $40 and Stay There to Buy Russia Some Reform', Bloomberg, 18 July 2016.

489 Quoted following Leonid Bershidsky, 'Putin Should Heed this Russian's Warning on Oil', Bloomberg, 20 May 2016.

490 See also Pavel K. Baev, 'Russia is Steered Back toward Petro-Stagnation', Eurasia Daily Monitor (EDM), 10 October 2017; 'The Middle East and Russia are Ill-Prepared for a Low-Carbon Future', and 'The Ende of Carbon Fuels? A Symposiumof Fuels', The International Economy, Spring 2018, pp. 10-21 (here pp. 12-13).

finance its expensive social programs and food supply as well as consumer goods by subsidizing their imports.[491]

But the real reason and origin of its political-economic and social crisis needs to be recognised not in the dramatic oil price fall, but rather in the failing socialist economic policies of its former President Hugo Chavez during his presidency (1999 to 2013). As a typical rentier state, oil exports served the financing of an ever expanding corruption, populistic measures and a systemic inherently mismanagement of his economic policies, which had been increasingly renationalised. With the dramatic oil price decline at latest, Venezuela's economic policies proved no longer been sustainable. Rapidly growing inflation of up to 700%, exploding crime and violence as well as a further decline of the GDP in 2017 to just a third compared with 2013 have made the country to one of the poorest in Latin America. At the time of his death in 2013, the country had a budget deficit of 14% of its GDP, despite the fact that the country has worldwide the largest oil reserves. But these oil reserves are largely heavy oil, which can hardly produce economically at lower oil prices.[492]

Last year, Venezuela produced just 1.9 mb/d compared with 3.5 mb/d at the beginning of Chavez's presidency in 1999, of which 2.5 mb/d were exported.[493] Since the beginning of the year, its oil production has further declined to just 1.1-1.2 mb/d in June 2018 below its agreed target level within OPEC due to the lack of maintenance, investment and technical expertise. Each month this year, Venezuela had been losing some 50.000 b/d - being in "freefall".[494] As long as the Maduro regime will remain in power, the prospects are grim for restoring any higher oil production as the conditions of the producing fields will further deteriorate.[495] At the end of 2018, its oil production might fall to just 1.2 mb/d or even falling below the psychologically important threshold of 1 mb/d.[496] Furthermore, Venezuela's heavy crude oil may also face more competition and constraints because its oil production creates six times as much as GHGE as oil from Saudi Arabia.[497]

In the meantime, the U.S. administration has increased the political pressure by enhancing its sanctions on Venezuela's President Nicholas Maduro. Washington also banned any

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491 See also Luis Colasante, 'Venezuela's National Oil Company on its Last Legs', Oilprice.com, 18 July 2017and F. Umbach, 'Geopolitische Auswirkungen des Ölpreisverfalls – Gewinner und Verlierer', p. 24.

492 See Keith Johnson, 'How Venezuela Struck it Poor', Foreign Policy, 16 July 2018; CPS, 'Venezuela – No Room for Apologists', Centre for Policy Studies, London, Economic Bulletin No.98, 6 September 2017; Bulant Gökay, 'Venezuela Crisis Is the Hidden Consequence of Saudi Arabia's Oil Price War', The Conversation, 10 August 2017 und 'The Implosion of the Venezuelan Thugocracy', FT, 4 May 2017.

493 See Nick Butler, 'Why the Oil Market Should not Misread Venezuela', FT, 28 August 017 and Robert Rappier, 'How Venezuela Ruined Its Oil Industry', Forbes, 7 May 2017.

494 John Paul Rathbone, 'Venezuela's Oil Decline Reaches New Depths', FT, 1 May 2018, and Nick Cunningham, 'Venezuela Forced to Shut Down Production as Operations Fall Apart', Oilprice.com, 17 June 2018.

495 See Nick Buttler, 'It is Venezuela's Crisis that is Driving the Oil Price Higher', FT, 26 March 2018.

496 See John Paul Rathbone, 'Venezuela's Oil Decline Reaches New Depths'.

497 See also Ed Crooks, 'The Week in Energy: Big Oil and Climate Risk', FT. 4 March 2018.

involvement in restructuring Venezuela's debts and new bonds or shares issued by the Maduro government or its state-owned oil company PDVSA.[498] But these policies have driven Venezuela even more into the arms of China and Russia.[499] The Russian state-owned oil company Rosneft has already granted Venezuela's state-owned energy company PdVSA a larger credit in 2016 and received 49.9% shares of Citgo Petroleum Corp., the U.S. refinery and business arm of the Venezuela's state-owned oil company.[500] However, Venezuela's oil industry remains heavily dependent on the U.S. oil industry. While the U.S. imported around 500,000 b/d from Venezuela, the country also imported 80,000-100,000 b/d of oil and refined oil products from the U.S. as its heavy crude oil has hardly any alternative (due to its non-payment) than exporting it in the U.S. for making it '*diluent*' (naphta or light crude for pipelines and tankers to bring the oil to the markets).[501]

Confronted with over US$50bn in debt, Venezuela could indeed become the first oil producing country in the history, which could end in a complete state bankruptcy. But China and Russia have so far cooperated more closely last year by supporting Venezuela financially, economically and with military weaponry to prevent the economic-political collapse of Venezuela due to common geopolitical interests towards the U.S.[502] The fate of the Maduro government and the future of the country depend more than ever on the role of the military with its manifold political and economic interests, being involved in drug trafficking and profiteering from widespread corruption as well as illegal and legal food and medicine imports under the government's aid programs.[503]

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498 See also Jonathan Wheatley, 'Venezuela Stopped Bond Payments in September ', FT, 9 April 2018.

499 See also Michael Shifter/Ben Raderstorf, 'Venezuela after the Constituent Assembly', Foreign Affairs, 1 August 2017 and Joseph S. Tulchin, How not to Resolve the Venezuelan Crisis', GIS, 11 August 2017.

500 See also Liam Denning, 'Venezuela's Perfect Storm for Oil May be About to Break', Bloomberg, 21 July 2017; Kathrin Hille, 'Moscow Seeks to Extend Influence inUS Back Yard', FT, 1 September 2017, and Henry Foy, 'Rosneft Seeks to Ease Fears over Venezuela Loans', FT, 19 March 2018.

501 See also John Dizard, 'A Venezuelan Oil Embargo would Wipe out Maduro & Co', FT, 23 March 2018, and David Sheppard, 'Ways the US can Hit Venezuela Oil with Sanctions', FT, 1 August 2017.

502 See also Tyler Durden, 'Venezuela Will be the First Sovereign Oil Producer to See an 'All-Out Collapse'', Zero Hedge, 23 July 2017.

503 See also John Polga-Hecimovich, 'Global Outlook 2017: Venezuela', GIS, 20 January 2017.

6 Conclusions and Strategic Perspectives

The worldwide energy sector stands at the crossroads by coping with unprecedented changes and challenges of the digitalisation, new forms of mobility, autonomous driving and AI. In contrast to the past, most of the new technologies and digitalisation are drivers developed outside of the energy sector itself but might have unprecedented impacts on energy markets and traditional energy industries. For the incumbent energy industry, these changes offer both new benefits as well as risks.

The fastening digitalisation of the energy sector is adapting to the widespread use of new '*information and communication technology (ICT)*'. It will have disruptive impacts on the energy sector as established energy industries have to cope with new consumption patterns, providers and platforms (also coming from outside of the energy sector). They will fundamentally change the energy companies' business models and strategies as well as cultures. These changes and challenges come along at a time, when the energy sector is already undergoing dramatic changes not least due to increasing deployment of RES, rising energy demand, greater energy efficiency, disinvestment in carbon-intensive industries and the U.S. shale oil and gas revolution (together with the rapidly expanding worldwide LNG trade) with far-reaching impacts on the global oil and gas markets.

The 'energy transition' affects, in particular, the global electricity sector, which is transformed by three reinforcing strategic trends '*3 Ds*': *decarbonisation, digitalisation* and *decentralisation*. This energy transition, based on the integration of renewables and other distributed energy resources, is highly dependent on fundamental reforms of current regulatory frameworks to accommodate the shifting energy supply structure. This happens at a time when daily life and public order will become ever more dependent on the stable functioning of critical (energy) infrastructures, which themselves depend on a stable supply of electricity and internet.

Almost all analyses of the digitalisation of the energy sector have focused on the impacts on energy companies as well as their business models and strategies. This comprehensive study is one of the first which offers a detailed and holistic analysis. It focuses on the wider international impacts and implications for regional and global energy security as well as its inherent systemic geo-economic and geopolitical risks.

The study has analysed five major geostrategic challenges of the fastening digitalisation and automation (including the use of AI) what affecting national, regional and global energy security:

(1) A further increase of global electricity demand;

(2) Advancing technologies for battery storage, which may cause one of the most disruptive changes, are expected to become a major game changer in the power and renewable industries.

(3) The more the energy and particularly the electricity sectors will be interconnected by renewable-based electricity generation, smart meters and smart grids, the electrification of the transport and heating sectors, the internet of things (and applications) and critical (energy) infrastructures (CEIs), the more vulnerable the energy and electricity sectors will become towards sophisticated cyber-attacks and blackmail attempts. They aim at disrupting the stable supply of electricity, and sensitive communication flows to operate and maintain the functioning of CEIs.

(4) Rapid decarbonisation: this might create systemic challenges of the social-economic and political stability of many oil as well as gas producing countries (i.e. fossil fuel exporters) as their economies and economic development strategies are dependent on stable, if not rising exports of oil and gas for their state budgets and economic developments; and

(5) As indigenous energy resources, renewables do not need to be imported from unstable produce countries. This lowers import risks and vulnerabilities, and therefore, enhances energy supply security. But RES, batteries and other 'green technologies' as well as the result of the digitalisation and automation (including by the use of AI systems and robotics) create a rising demand of CRM (i.e. rare earths, lithium, cobalt, platinum and others), whose production is often concentrated in fewer countries (i.e. China has an 85% production and export monopoly of rare earth) and mining companies (compared with the worldwide oil and gas production). This has wide-ranging geo-economic and geopolitical implications. China is currently the only one, which has a highly integrated industry with related supply chains and having an unprecedented combined capability of being one of the future technology and R&D leaders of AI. This enables available and strategic control of the much needed CRMs inside and outside of the country by dominating the production capabilities of the most important CRMs as well as the worldwide demand and value chains of their supply.

These geo-economic and geopolitical strategic trends are already determining the present energy transition towards a long-term carbon free energy system. The further digitalisation will fuel the already the existing global race for the best and most disruptive technologies and competition about access as well as strategic control of CRMs. These strategic developments have wider geo-economic and geopolitical impacts and may transform international energy relations between countries and regions. The heightened competition for the global technology-industrial leadership has already led to a growing technology arms race between the U.S. and China, which is increasingly shaping the present international relations and will determine future geopolitical competition between the two superpowers of the 21st century.

Despite a rising awareness of the EU side about the manifold global implications of the digitalisation and the adoption of disruptive technologies, the EU is being threatened to fall behind the two economic-technological superpowers of China and the U.S. Geo-economic and geopolitical megatrends are also implemented by the global rise of autocratic states with an unprecedented economic power (i.e. China) and the political will to use their economic-financial power (i.e. Russia) to divide and weaken Western democracies. In this regard, the EU needs to define and adopt new holistic energy security concepts that take the five geo-economic and geopolitical trends in global energy security into account.

Any new strategy needs to integrate systematically these five dimensions and challenges rather than to address and conceptualise them in isolation to each other. Supply strategies for CRMs, disruptive technologies and their wide-ranging impacts, new cyber security dimensions, the impact of the decarbonisation on traditional oil and gas producing countries, new geopolitical dependencies as the result of the expansion of RES, and a potential higher increase of global electricity consumption need to be an integral part in order to preserve the EU's future international leverage. The EU has to seek new forms of international cooperation to avoid any new technology arms races with wide-ranging geopolitical impacts at the expense of global stability.

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