Ambition to Action

Co-benefits on the interface between energy security and ambitious climate policy

Working paper

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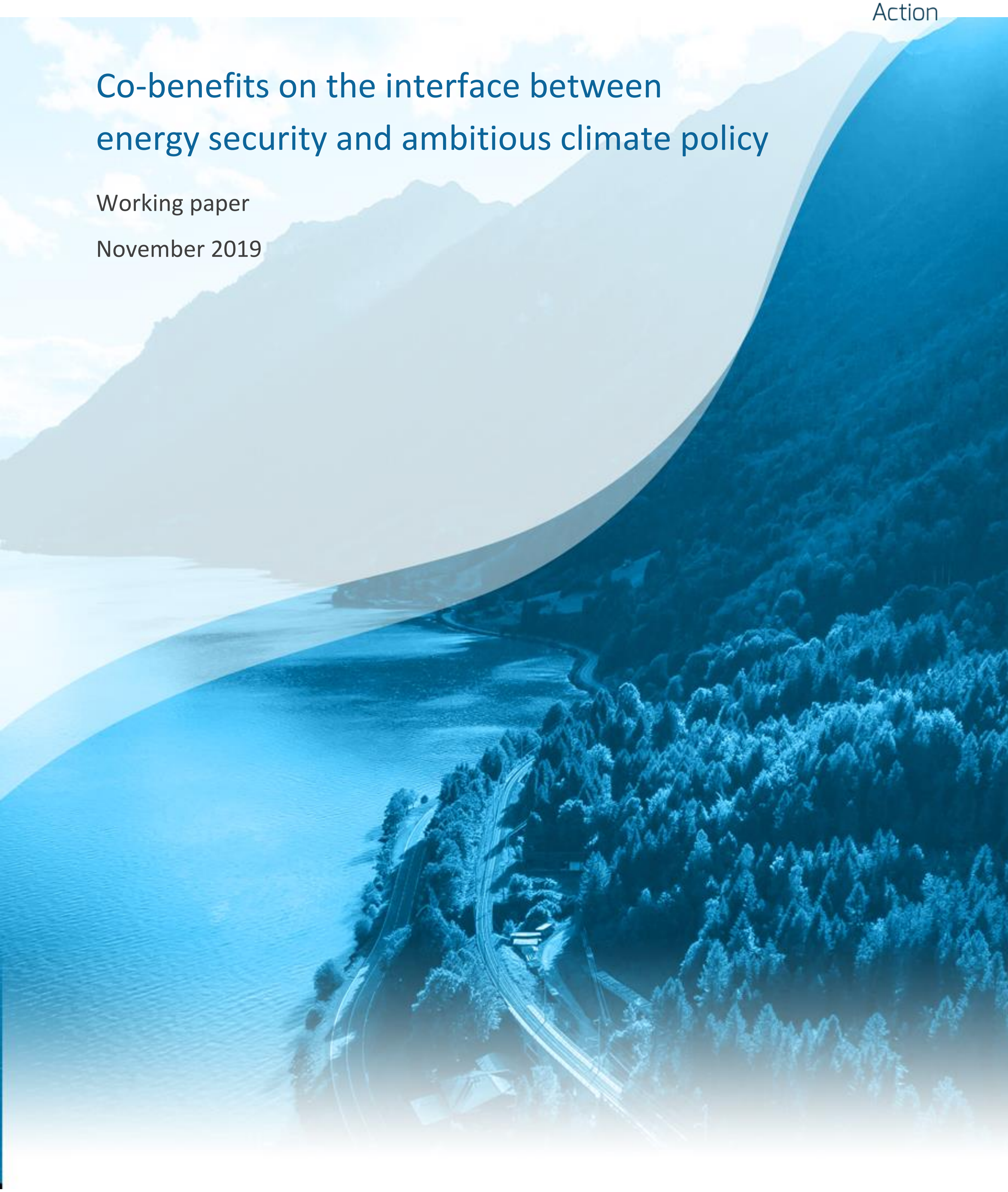

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Cover Summary

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Taking a closer look at *energy security* reveals that it is used as an umbrella term that covers a broad range of topics and indicators, and that summarising energy security in a few metrics is not all that useful. To structure energy security topics for those involved in NDC planning and implementation, we present 10 themes on the interface between energy security and ambitious climate policy, as a starting point for identifying co-benefits, NDC support, and choosing the 'highest possible ambition' for NDC updates.

Authors: Xander van Tilburg, Jasper Donker, and Sam Lamboo

Contact: xander.vantilburg@tno.nl

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Contents

Executive summary

Energy security is a broad term to describe a condition of uninterrupted energy supply, and it is so directly linked to economic progress and development, that disturbances can quickly lead to social discontent and economic stagnation. This paper takes a closer look at energy security and how it relates to ambitious climate policy. It aims to help the reader think more clearly about energy security as a co-benefit in the context of increasing climate ambition. Optimising these co-benefits involves finding the right balance between different aspects of energy security, and between energy security and other development priorities.

In addition to prevailing energy-related challenges individual governments face, the world as a whole is experiencing a serious climate crisis. Under the Paris Agreement, all countries have signed up to submitting updated Nationally Determined Contributions (NDCs) every five years starting in 2020; these updates should 'represent[s] a progression' and 'reflect[s] the highest possible ambition'. There is a direct and obvious link between climate policy and energy security: more ambitious NDC targets require a faster transition away from fossil fuels and thus stricter climate and energy policies. Under pressure of ambitious climate targets, the focus is shifting from securing oil imports to managing large power grids.

What the energy systems of the future will look like is uncertain and local circumstances play an important role. Nevertheless, some contours are emerging: electrification and clean power production will dominate most countries' energy transitions, demand is expected to increase significantly, and 'net-zero' emissions most likely require full decarbonisation of the power sector. For all countries involved, clean energy transitions present strategic energy security-related development opportunities, but new technologies come with their own challenges that governments need to address in order to avoid slowing down progress such as stabilising the power grid and making sure vulnerable business and private consumers are protected.

	THEME	RELEVANCE FOR NDC AMBITION RAISING	AVAILABLE	ACCESSIBLE	AFFORDABLE	ACCEPTABLE
1	Mapping RE potential	Basic evidence for robust energy strategy	●			
2	Trade and business opportunities	Industry policy creates enabling environment		●	•	
3	Infrastructure investments	Mobilise (very) large amounts of capital		●	•	
4	Balancing the grid	Prepare for intermittent supply		●	•	
5	Poverty and access	Scalable clean energy solutions		●	•	
6	Energy subsidy reform	Protect people and businesses		•	●	•
7	Analysis of cost-drivers	Design policies that target cost reduction		•	●	
8	Competition over resources	Avoid conflicts over land, water, etc.		•	•	●
9	Local and societal impacts	Identify vulnerable groups and assets		•	•	●
10	Demand side acceptance	Confront norms and behavioural patterns		•	•	●

Taking a closer look at energy security reveals that it is used as an umbrella term that covers a broad range of topics and indicators, and summarising energy security in one or a few metrics is not so useful. To structure the topics for those involved in NDC planning and implementation, we consider a traditional framework for energy security (available, accessible, affordable, and acceptable), and present 10 themes on the interface between energy security and ambitious climate policy, as a starting point for identifying co-benefits, NDC support, and choosing the 'highest possible ambition' for NDC updates.

Energy security co-benefits can be a powerful tool to promote ambitious climate policy. Maximising energy security benefits is principally about finding synergies and dealing with trade-offs; energy security has an unusually high linkage with other topics and sectors but there is so much variety in local conditions and interactions between aspects of energy security, that generalisations should be treated with caution.

Energy security co-benefits can be a driver for ambitious climate policy, but more importantly, ambitious climate policy needs to come with energy security guarantees in order to be politically feasible.

To maintain buy-in for the transition, governments will need to consider energy security concerns of all stakeholders and find a balance that is politically acceptable. Understanding the energy security impacts of the transition, and where they can be influenced, is therefore crucial to a smooth transition. Without an agreed approach to energy security, ambitious climate policy runs the risk of losing support and becoming ineffective.

1. Introduction

Energy security is a broad term to describe a condition of uninterrupted energy supply, and it applies to electricity, transport fuel, as well as heating and cooling. When energy security is compromised, this is often disruptive for people and businesses: unexpected failures of power supply; shortages and queues at gas stations; price jumps; and when problems persist there could be scarcity. Energy security is so directly linked to economic progress and development, that disturbances can quickly lead to social discontent and economic stagnation. Ongoing digitalisation and electrification make modern societies ever more vulnerable to the consequences of energy systems failure.

In addition to prevailing energy-related challenges individual governments face, the world as a whole is experiencing a serious climate crisis. As a response, 186 countries have signed the 2015 Paris Agreement in which they commit to reducing emissions to the point of avoiding dangerous climate change and keep the global temperature 'well below two degrees' (UNFCCC, 2015). As a bottom-up framework, the Paris Agreement depends on the 'ratcheting mechanism' or 'ambition mechanism' to reach this goal. It requires countries to submit updated Nationally Determined Contributions (NDCs) that reflect their 'highest possible ambition' every five years starting in 2020. This ambition needs to increase over time and no backsliding is allowed. Looking at the current emission reduction pledges, in the first round of NDCs, these fall way short of the cuts needed to keep global warming within agreed limits (CAT, 2019; UNEP, 2019). The 2020 climate summit COP26, in Glasgow, will need to show the ambition raising mechanism works; at the time of writing the outcome of which is all but sure[1].

There is a direct and obvious link between climate policy and energy security: more ambitious NDC targets require a faster transition away from fossil fuels and need to thus stricter climate and energy policies. Under pressure to raise climate ambition and implement stringent policies, there is growing interest in 'co-benefits' of climate policy[2]. An established body of evidence points to significant positive impacts from climate mitigation in areas such as energy security, air pollution, health, employment, and economic growth (IPCC, 2014; von Stechow *et al.*, 2015). Energy security is definitely among the most politically relevant co-benefits, perhaps even the most crucial one. Unlike some other co-benefits though, energy security is an umbrella-term that is not easily captured in one or even a few indicators.

This paper takes a closer look at energy security and how it relates to ambitious climate policy. It aims to help the reader think more clearly about energy security as co-benefit in the context of increasing climate ambition and deal with the fact that energy security has many aspects to it. This paper is organised as follows. Chapter 2 looks at how energy security is affected by the clean energy transition, and what type of strategic opportunities and challenges this brings. Chapter 3 breaks down energy security into dimensions and metrics and presents ten themes on the interface between energy security and ambitious climate policy that warrant investigation and dialogue. Chapter 4 discusses how energy security co-benefits could feature in making the case for ambitious climate policy and what governments can do to prepare.

[1] *A survey conducted prior to COP25 in 2019 among 100 respondents showed that over half the respondents cannot (yet) provide clarity on whether their government intends to raise ambition in the NDC update that is due the next year (A2A, 2019).*

[2] *Terminology: we use 'co-benefits' for positive impacts of climate mitigation; these co-benefits arise as a result of 'synergies' between climate mitigation and another policy priority; if the impact of climate mitigation is negative this leads to a 'trade-off'. We use 'climate policy' to include national and sector policies for which emissions reduction is a motivation.*

2. Energy security in transition

- The focus of energy security shifts from securing oil imports to managing large power grids.
- Electrification and clean power production will dominate most countries' energy transitions, complemented by biofuels and hydrogen (and possibly CCS) where the local conditions are right; 'net-zero' emissions most likely requires full decarbonisation of the power sector.
- Clean energy transition presents strategic energy security-related development opportunities, but comes with its own challenges that need to be addressed in order to avoid stagnation.

2.1. Shifting focus from oil to power

The International Energy Agency (IEA) defines energy security as "the uninterrupted availability of energy sources at an affordable price" and goes on to say that "energy security has many aspects: 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." (IEA, 2019a)

Historically energy security was all about oil

For most countries, the term 'energy security' has been synonymous with securing access to coal, gas, and in particular to oil. The notion of energy security emerged in the early 20th century, originating in logistics problems of oil supply for armies during war time. In the late 1960s and 1970s, the focus shifted to securing oil imports to keep peace-time economies running. The vulnerability of modern economies became very clear in 1973 and 1979, when oil crises caused price hikes, shortages, and even rationing in most of the developed world. Both crises were caused by the Organisation of Petroleum Exporting Countries (OPEC) lowering supply as a response to international political events. After the shock and seeing responses by countries individually, the International Energy Agency (IEA) was established in 1974 to coordinate member states' collective response to disruptions and to increase their resilience to shocks. During a period of stable, low oil prices in the 1980s and 1990s, the policy (research) interest in energy security waned but then re-emerged in the 2000's under influence of rising energy demand in Asia and growing awareness of the environmental impact of existing energy systems (Cherp and Jewell, 2014). Notwithstanding environmental concerns, natural gas has become the centre of attention in recent decades: in Europe predominantly because of a history of conflict with the Russian Federation threatening gas supply, and in the United States interest is driven by the shale-gas revolution and changing trade balances (i.e. more export, less import)[3].

Climate policy forces technology transitions

Under pressure from the impacts of climate change, but more importantly of ambitious climate targets, the focus of energy security is shifting. Concerns about securing international supply chains for oil and gas become less important with time, since fossil fuels will need to be replaced by alternatives with no emissions, such as renewables or nuclear energy. This 'clean energy transition' will need to happen fast and across all countries: the Intergovernmental Panel on Climate Change (IPCC) finds that, based on the best available science, we can still achieve the Paris Agreement goals, but time is short: emissions need to fall by around half in 2030 and then reach net zero in 2050 or shortly after (IPCC, 2018). This presents countries with the

[3] *This continues to this day: "The United States is in the middle of an unparalleled expansion in oil and gas production that continues to shake up the established order." (IEA, 2018)*

draconian task to decarbonise all sectors of the economy in the next three decades. Not only will most of the remaining coal, oil, and gas resources need to stay in the ground, existing energy infrastructure such as power plants, refineries, and distribution networks will need to be replaced or – and this is not always possible - adapted for use with clean sources of supply.

Some sectors will be easier to decarbonise than others. In many sectors and across a significant number of economic activities, existing fossil technologies can be replaced with competitive clean alternatives (e.g. electric vehicles, wind turbines, solar panels, heat pumps). There are some sectors in which reducing emissions is more difficult and more costly, such as heavy industry (cement, steel, and plastic) and heavy transport (ships, planes, and trucks), but analysis by the Energy Transition Commission shows that even for harder-to-abate technologies, industry deems it possible to reach net-zero by mid-century (ETC, 2018).

Under pressure of climate change concerns, all sectors of the economy will need to decarbonise in the next three decades, and for the energy sector this will require nothing short of a radical transformation.

What could a clean energy system look like?

It is not entirely clear how the clean energy transition will unfold. One reason is, that to date only a handful of countries have been able to make significant progress towards fully decarbonising their economy. There are no 'leading examples' to take guidance from and it is not at all clear which technologies will dominate in three decades from now – the uptake and use of technologies could change drastically as innovations find their way to becoming mainstream (e.g. cheap battery storage, intelligent demand management, affordable electric transport). Several countries have high shares of renewable power and integrated significant amounts of variable (wind, solar) power supply, including, Denmark, Spain, Ireland, Uruguay and Germany. In recent years, a few countries have been able to gather experience with running the grid on 100% renewable power supply for extended periods of time (e.g. Costa Rica, Portugal) or switching off coal as baseload production (e.g. parts of the US and Germany). Progress on decarbonisation in the heat sector is markedly slower, despite technology availability; 50% of global energy demand comes from heat, but only 10% is renewable. Similarly, electric vehicles are starting to gain traction, but with 'only' 5 million electric cars in use worldwide in 2018 (up from 2 mln in 2017), the overall penetration is small compared to around one billion vehicles with internal combustion engines in use around the world (IEA, 2019b).

Another reason for the unpredictable nature of the clean energy transition, is that the overall (academic) understanding of how systems transformations work is limited: "There is no established transformation theory, but there are various lines of work that can provide useful insights on how transformations occur… The most fundamental point is that there is no single line of causation: transformation results from a concurrence of multiple changes." (Schmitz, 2014).

With this in mind, some general contours of what clean energy systems could look like are emerging.

First, think larger. Many countries expect that economic growth will drive energy demand to a much higher level in 2050 than it is today. Global projections show that energy demand can be up to 50% higher, with the bulk of the demand resulting from strong economic growth in non-OECD countries combined with continued urbanisation, increasing demand for mobility, and an expected population growth of 2 billion people. Energy demand in individual countries, especially those who experience fast growth, may well exceed the global average, for example in India where energy consumption is expected to triple until 2050 (IEA, 2019b).

Second, think electrification. Across all sectors very promising decarbonisation options involve switching from fossil fuels to electricity generated by renewable sources. Electrification will be a major mitigation measure in transportation, manufacturing, agroprocessing, and heating and cooling homes and businesses. Efficiency improvements will continue to reduce the energy intensity of activities, but on balance most countries will face a significant net increase in electricity demand. In addition to expansion, it is safe to assume that electricity generation will be more decentralised, that the distinction between producers and consumers becomes less clear, and that automation and intelligent demand-side management will have a profound effect on the way energy systems operate.

Alternatives to electrification, such as biofuels, hydrogen, and geothermal heat, can be the technology of choice if the local circumstances are right. Use of biomass is attractive in situations where a surplus or waste stream is available and/or the conditions are right to grow crops for fuel at (internationally) competitive prices. The use of hydrogen is interesting in situations where excess clean power is not met by local demand and instead converted into hydrogen onsite, for example in setups with large offshore wind parks, or where specific industry demand for hydrogen exists, for example for use in high-temperature industry processes. Overall though, from an economic perspective it currently looks like electrification and clean power production will dominate most countries' energy transitions.

Third, when talking about 'net-zero', this most probably means full decarbonisation of the power sector. Emissions from fossil fuels can be eliminated by switching to zero-carbon alternatives (renewables or nuclear) or by capturing and storing the emissions, so in theory carbon capture and storage (CCS) or usage (CCU) technologies could take the pressure off the climate crisis and prolong the viability of conventional fossil infrastructure. However, CCS has been under development for decades and in the power sector it is hardly being realised at scale, mainly because the incremental costs of capture, and the development of transport and storage infrastructures are not sufficiently compensated by market or government incentives (IPCC, 2018). In addition, CCU potentials are (very) limited and dependent on local demand for CO_2. If and when CCS becomes more widely available, the high costs per avoided tonne of CO_2 makes CCS most suitable for hard-to-abate actions (such as heavy transport and industry), since fossil power generation with CCS will have difficulties competing with renewables. With uncertainty surrounding the role of CCS, reducing emissions from energy use in line with the Paris Agreement will therefore probably require (near) complete elimination of fossil fuels in the power sector.

Energy security is in flux constantly

At this point, it is worth noting that energy security is always in flux, even without climate change and without clean energy transitions. In the short and medium term, security is influenced by, for example, the state of transmission and distribution grids, new discoveries of gas and oil, change the relative attractiveness of technologies through ongoing cost reductions and innovation, and changing geopolitical relations. In the medium to long term, larger societal and technology trends also play a role: increased connectedness and collaboration (e.g. social media, gig- and sharing economy), urbanisation, and population demographics, smart appliances and advances in industrial automation such as the internet of things (Schwab, 2015).

Decarbonisation will be a major determinant of energy security in the coming decades, but it is certainly not the only one.

2.2. Opportunities and challenges

Beyond the general contours outlined above, energy transitions differ across countries and regions and governments face their own specific strategic policy decisions. With ambitious policies they can – to a certain extent – guide the direction, speed, and timing of the different transitions. It is widely recognised that energy transitions can bring development opportunities, and that governments play an important strategic role in enabling such transitions. To illustrate, consider the following sample of recent large-scale policy-driven reorientations: the 'Energiewende' and nuclear power phase out (Germany), phase-out of (residential) gas infrastructure and halt of major gas production (Netherlands), restrictions on the use of diesel cars in cities (Germany and Netherlands), realisation of large-scale offshore wind parks (North Sea) and solar parks (Morocco, China), and fossil fuel subsidy reforms (various countries).

To provide a context for where strategic opportunities and challenges could arise, a useful starting point is to consider how differences between renewable and fossil energy carriers play out in specific country contexts. Coal, oil, and gas resources are concentrated in a limited number of countries, while renewable energy is available to every country in one form or another. Most renewable energy sources are flows while fossil sources are stocks, which makes renewable energy easier to protect but less suitable for trade or storage. Some renewable technologies have variable output according to time and weather (e.g. wind, solar) while others are constantly accessible (e.g. geothermal, large hydro). There are also differences in investment properties: renewable energy capacity typically requires a high up-front investment, often higher per kilowatt (kW) than fossil capacity, but has lower operational costs. Lastly, many renewable energy technologies are scalable in size, allowing for more flexible, decentralised applications and for smaller investments.

Strategic opportunities in energy transitions

A number of themes reoccur in discussions about the strategic direction of the clean energy transition: the prospect of national energy independence, opportunities for trade and business, and better access to energy to reduce poverty.

The current geopolitical landscape is shaped by access to oil and gas, which are produced and exported by only a handful of countries. The other (vast majority of) countries are dependent on import to keep their economies running. Protecting and securing access to supply chains has been the source of many international conflicts and awkward geopolitical alliances over the years, and for numerous countries the need to protect supply chains abroad has dictated their foreign policy and restricted (perceived) national sovereignty. Moving from fossil to renewable energy allows for a higher degree of independence from these asymmetrical trade relations. Using domestic renewable resources allows countries and regions to be energy self-sufficient and largely eliminate energy-related geopolitical risks. This is a strong political argument that can count on support across the political spectrum and resonates well with nationalist narratives.

Although energy independence is a politically attractive proposition, it does not necessarily require energy autarky (without trade) to regain independence. From an economic perspective it might still be beneficial to engage in trade of energy for countries with a comparative advantage, businesses which are internationally competitive, and to balance power grids against intermittency. Other business opportunities arise in the construction and operation of the energy systems, and it is expected that areas with access to stable low-cost (renewable) energy will attract businesses that depend on that to stay competitive (see section 3.4 trade and business opportunities).

Clean energy transitions require new technology but will also allow existing actors to assume new roles: decentralisation and scalability of renewable energy systems, and the advent of intelligent demand management, will make it possible for passive consumers to become active ‘prosumers’. There are already many examples of cities (e.g. the C40 initiative), corporations, and individuals who are developing new business cases as producers and sellers of excess power or heat (see section 3.5 system services).

On the far end of the energy consumer spectrum are those without access to modern energy services: there are still around 3 billion people without access to clean cooking and just under 1 billion without electricity. Some renewable energy technologies, it is hoped, offer unique opportunities to help eliminate poverty and reduce energy insecurity for vulnerable parts of society (see section 3.4 poverty and access).

Clean energy transitions come with energy security challenges of their own

Alongside strategic arguments for *accelerating* energy transitions, clean energy systems also come with challenges of their own that could slow down the transition or deliver sub-optimal outcomes. For ambitious climate policy to be feasible, there needs to be sufficient capital to keep the growing power system functioning, and there need to be safeguards to keep policy outcomes socially and environmentally acceptable.

Power system focus

Electrification is expected to play a dominant role in reducing emissions, and this will lead to increased electricity demand from transport, industry, buildings, and agriculture. Combined with population increase and economic growth, and despite an overall improvement of energy efficiency, most countries face a steep increase in electricity demand in the coming decades and this calls for serious investments in the power grid. In addition, power systems will need to be able to accommodate high shares of variable renewable energy sources such as wind and solar. Building and operating a strong and stable grid is not only challenging from technical and financing points of view, it could also introduce governance challenges. The overall picture of consumers and producers is likely to change and cause a decentralisation of energy supply, but also of economic power, away from the large energy corporations. This decentralisation of power might necessitate a different type of policy approach for the energy sector: governments and regulators need to be alert to make sure specific commercial interests and vulnerable parts of society remain protected.

Impacts across sectors and stakeholders

First, renewable energy technologies can impact their surroundings in ways that people might find unacceptable. This can range from mild annoyances about the visual impact of wind turbines, to more serious concerns about food security and biodiversity in case of unscrupulous expansion of biofuel production, or water shortage as a result of hydropower operations. Section 0 below presents acceptance of renewable energy in some more detail. Second, at the very least, the spoils of the clean energy transition may not be shared equally, and there will be winners and losers. In the early stages of the transition the emphasis will be on showcasing pilots and motivational stories about winners. As targets get stricter, there will need to be more attention given to those who are adversely affected and whose energy security ends up being worse than before.

While the poorest share of the world's population has been largely ignored access to energy in energy systems dominated by fossil fuels, there is the hope that the clean energy transitions will provide opportunity to the underprivileged to gain and improve access to modern energy services.

Threats to energy security can shift to parts of society where such concerns were not an issue. To avoid social and economic disruption, governments anticipate and plan for those stakeholders that will not be able to stay competitive and go out of business. The first to be affected are the coal industry, oil and gas operations, and car makers and utilities who are slow to adapt. In addition to the workers, the transition will also affect the (often powerful) elites who are invested in production and distribution or extract rents from fossil resources, such as export licenses or land leases.

3. Breaking down energy security

- Energy security is an umbrella term that covers a broad range of topics and indicators and cannot be summarised in one or few metrics; analyses involve using a model to generate and compare scenarios.
- Energy security concerns performance under normal conditions and resilience to shocks and stresses; the 4A-framework identifies four useful categorises: available, accessible, affordable, and acceptable.
- On the interface between energy security and ambitious climate policy, 10 themes offer a starting point for identifying co-benefits, NDC support, and choosing the 'highest possible ambition' for NDC updates.

3.1. Indicators, many of them

The IEA definition of energy security presented in the previous chapter is commonly used, but far from the only one; and although many definitions are proposed and criticised, there is no meaningful convergence. Energy security is used as an umbrella term covering a broad range of topics dealing with energy availability, infrastructure, energy prices, energy efficiency, societal effects, environment and governance. Hundreds of metrics and indicators have been documented and used, but it turns out to be difficult, if not impossible, to sensibly capture energy security concisely. In a review of energy security literature, Ang *et al.* (2014) note that the use of indicators to measure energy security for a country has gained in popularity, but meaningfully capturing the energy security situation in a single indicator is hardly useful. There may not be a definitive way to assess energy security and it is the responsibility of the analyst to be explicit about the perspective, timing, and assumptions of the analysis (Valentine, 2011). This is not to play down the importance of energy security metrics and indicators. On the contrary, a robust evidence base is essential, especially where it is used to describe the mechanisms behind the numbers. Instead of relying on a few metrics, for energy security analysis it would be more appropriate to think in terms of a dashboard of indicators.

Energy security indicators come in three types. *Simple indicators* measure one metric or ratio, such as the energy intensity (Total Primary Energy Supply (TPES)/Gross Domestic Product (GDP)), reserve-to-production ratio, energy price, share of renewables in generation mix, etc. Simple indicators are easy to understand and follow. A second category comprises *diversification* indicators, which measure the spread of energy type, geographical source, or suppliers, in order to get a sense of risk diversification. Commonly used indicators to measure diversification are the Shannon-Wiener index and the Herfindahl-Hirshmann index. These diversification indicators are more difficult to interpret and may become less important as the focus of energy security shifts from oil and gas import to maintaining national power system stability. As a third type, *composite indicators* use subjective expert weights to combine simple indicators into a summary metric, for example the Supply/demand (SD) index which covers a large part of the energy system (Scheepers *et al.*, 2007). Composite indicators have a strong communicative value (comparing progress over time or between countries) but have the drawback that they hide the story behind the values. In addition, challenges with composite indicators include choosing the number of indicators, their weighting, type of aggregation, and a number of methodological issues (Ang *et al.*, 2014; Sovacool, 2012).

The World Energy Council (WEC) has long used their 'energy trilemma' to show how energy security is balanced against economic competitiveness and environmental sustainability. This trilemma is especially useful to put energy security in a broader perspective and many countries use the three dimensions as pillars under their energy strategy (clean, reliable, and affordable); however it does not break energy security down into its components (see 3.2 below for a framework that does).

Where does energy security co-benefits evidence (data) come from?

The data used for analysing energy security comes from direct observation (past and current conditions) or is constructed using a model (future projection). Historical datasets for energy are available through energy ministries and statistics bureaus in most countries, as well as through public reporting of producers and grid operators. Energy planning usually involves some form of forward-looking pathways analysis, in which one or more possible scenarios for energy demand and supply are simulated. Projections made with energy models are often national in scale and differentiate between fuel types and technologies, and different categories of supply and demand.

LEAP is a popular and accessible tool for modelling an energy system (even with limited data) and evaluating different scenarios. More advanced models, such as TIAM-ECN and other MARKAL- or GAMS-based systems, can optimise within the scenarios. These optimisation models typically find the policy parameters or technology/fuel shares, within specified constraints, that lead to a minimal emissions or minimal costs, or the optimal value for some other indicator. Energy scenarios are vulnerable to assumptions and it is good practice to perform a sensitivity analysis in order to gain a fuller understanding of the model outcomes.

In a distinct category, oil and gas, and power sector models are also used for energy planning and analysis; these models are different in structure and can be much more detailed, often with specific information for individual installations and the connections between them; examples of power sector models for simulation and stress-testing include PLEXOS and models from engineering firms such as General Electric and ABB. In practice, policy makers and analysts have access to a suite of models to analyse policy decisions; a toolkit[4] with sub-models for topics such as investment decision making, power market dynamics, congestion analysis, etc. Sometimes these toolkits are integrated (e.g. the TNO OPERA model for the Dutch energy system) but more often than not the analysts themselves are responsible for consistency across assumptions and outcomes.

Not all energy security dimensions are easily captured in quantitative models, and subjective factors may play a role; often the numbers that come out of models are the starting point for further analysis (such as multiple attribute analysis or qualitative assessments). Pathways analysis can be an integral part of the stakeholder engagement process, if appropriate and resources allow, and it can be especially useful to clarify how short-term decisions can be informed by a longer-term perspective[5].

Building on the idea of looking beyond the energy system to analyse the transition, the World Economic Forum (WEF) proposes an energy transition framework "to provide a structure to the interdependencies of energy transition with elements of the economy and the society beyond the technological boundaries of the energy system." The framework includes an Energy Transition Index (ETI) which consists of performance indicators (energy trilemma), as well as measures for transition readiness across 6 dimensions. It "provides metrics by which countries can track their progress over time, as well as benchmark against peer economies." (Singh *et al.,*2019).

3.2. Performance and resilience

A dashboard makes it easier to keep an overview of a large interconnected collection of metrics, and thus identify where synergies and trade-offs can occur. A first step in organising the diagnostics, is to make a

[4] *Ringkjøb* et al *(2018) review 75 state-of-the art modelling tools for energy and electricity systems (with large shares of variable renewables)*

[5] *See for example the experiences in the Long Term Mitigation Scenarios (LTMS) process in South Africa and the MAPS programme in Latin American countries*

distinction between indicators that show how the system performs under 'normal operation' and indicators that reveal how the system responds to shocks and stresses.

Performance: Introducing the 4 A-Framework

First, consider the energy system under normal operation conditions. A widely used framework for analysing energy security revolves around the '4 As': availability, accessibility, affordability, and acceptability (Cherp and Jewell, 2011; APERC, 2007). Availability deals with the physical presence of energy resources such as oil, gas, wind, or solar irradiation. Accessibility then considers whether there are barriers to explore and develop these resources. Affordability deals with the relative costs of energy sources and services. In early uses of the framework, acceptability focused on the environmental impact of the energy system. Over time, acceptability has come to include other social norms and values.

The 4A framework is popular and easy to use for communication. It offers four dimensions that are more or less independent and jointly span a large area of topics. But the framework has limitations. First, it is focuses on security of *supply* and less on security of the energy *services* that users demand, which could be meaningfully different (Jansen and Seebregts, 2010). Second, the 4A framework is less suitable for analysing basic security-related questions such as 'security for whom? Against what threats? By what means?'. Cherp and Jewell (2014) argue that zooming in on what they call 'the vulnerability of vital energy systems' will encourage policy makers to identify which part of the supply system is so vital that it needs protection and hence prompt a healthy policy discussion.

Despite the limitations of the 4A framework, it is simple and flexible enough to use on multiple levels, from national to sectoral and interest group-specific. The framework offers a reasonably good match with the topics covered in the text of the Paris Agreement. For example, availability is relevant to mitigation (article 4) and possibly for cooperative approaches (article 6); accessibility is relevant for climate support to developing countries on finance, technology development and transfer, and capacity building (articles 9-11); affordability and acceptability are key determinants of climate ambition and there is a strong link with ambition raising in the NDCs (article 3).

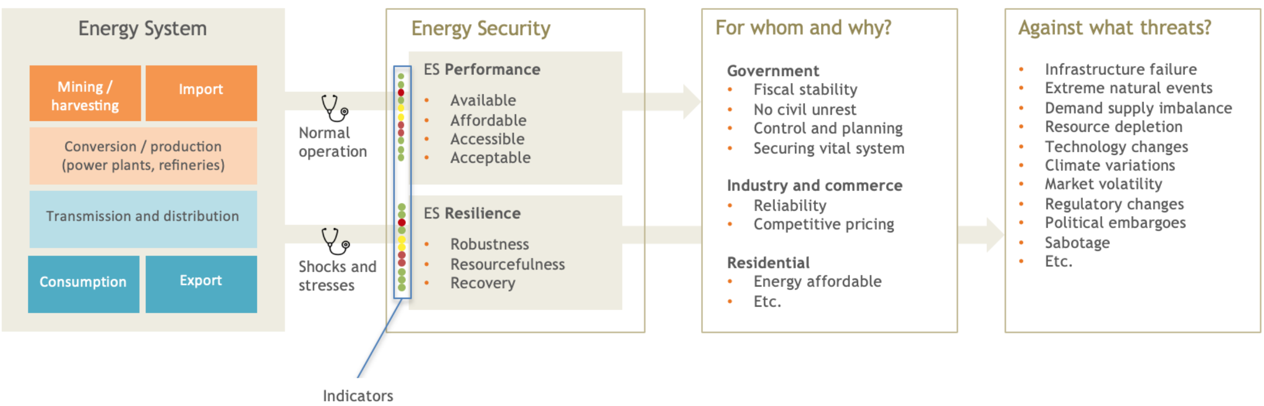

Figure 1: Energy system security – measuring performance and resilience

Figure 1 shows a stylised version of the energy system in the leftmost rectangle, describing the origin of the primary energy, the conversion, transmission and distribution, and its use. This is the object of investigation. The second rectangle from the left in the figure is the diagnostic panel which contains a host of indicators to gauge energy system *performance* under normal operation, and energy system *resilience* under shocks and stresses (i.e. the dashboard). Using this framework can provide a starting point for the more in-depth questions surrounding performance 'for whom and why', and resilience 'against what threats', and to zoom in on how individual stakeholders/groups are affected.

Resilience: a few words on shocks and stresses

How an energy system holds up under stress and shocks is at least as important for energy security as its performance under normal operation, but much more difficult to analyse. Threats to the energy system come in many shapes and intensities and include extreme natural events, infrastructure failure, demand/supply imbalance, climate variations, resource depletion, technology changes, regulatory changes, market volatility, exercises of market power, political embargoes, sabotage, war, attacks to name a few. Some of these put stress on the system, possible for a long time, while others are temporary and could be more intense. Analogous to the four As of performance, infrastructure resilience topics can be organised into three Rs: the *robustness*, or ability to withstand threats and keep operating as shocks occur, the *resourcefulness* to maintain essential functions under extreme events and manage the disruption as it unfolds, and then the ability of a system to *recover* to normal operations as quickly as possible. Variability of wind and solar is largely considered under accessibility (performance) and not thought of as a stress or shock; provided the grid is robust and properly managed, high shares of variable renewables should be achievable without putting a strain on the system.

Are clean energy systems more resilient?

It is safe to assume that clean energy systems can be made as resilient as (or more resilient than) traditional fossil-based systems. Increased decentralisation, as a result of deployment of many small-scale renewable energy units, can make a network more resilient compared to traditional large centralised systems. In contrast, systems with a higher number of connected assets are more vulnerable to disruptions following cyberthreats and terrorism. On the whole, experiences with making traditional fossil-based systems more resilient can be transferred to clean energy systems management as well (e.g. backup power and network redundancy, diversification of sources, strict regulation, and cross-border trade). Resilience does not equal full protection from external influences: electricity blackouts are known to occur as a result of external events, negligent system management and maintenance, or sabotage and this is likely to continue; there are no clear indications whether blackout would occur more or less frequently for clean energy systems.

Does climate change pose additional risk to energy security?

Nowadays, energy systems need to be designed with climate-resilience in mind. IISD (2018) highlights the importance of identifying and assessing climate-related risks when appraising new energy projects or managing infrastructure portfolios. Planners and developers will need to take *adaptation* considerations into account in order to deal with those impacts of climate change that cannot be avoided.

There are several direct and indirect ways in which energy systems can be affected. Global warming results in slowly rising temperatures and sea levels, changing weather patterns, and increased incidence of extreme events such as droughts and floods. Changing temperatures will initially lead to higher energy demand for heating or cooling, depending on geographic location, at least until the built environment is adapted to the changing conditions. Energy supply is affected too, in several ways: warmer weather reduces the efficiency of thermal plants that depend on water from lakes or rivers for cooling; changing precipitation leads to hydropower reservoirs running dry (or having to cope with excess water) and biomass yields to decline; increasing incidence of extreme weather events such as storms can damage power lines and other (offshore) energy infrastructure; and changes in cloud cover and wind speed affect solar and wind power respectively. For coastal and low-lying areas, sea level rise can be a slow but serious threat to energy infrastructure.

In more general terms, climate change is increasingly recognised as a 'threat multiplier' or conflict accelerant, by governments and businesses, as well as the UN Security Council. Especially in fragile states or unstable regions, conflicts can be detrimental to energy security because of infrastructure destruction, but also changing population sizes (as result of migration) and demographics can put serious pressure on the security of energy supply.

What is the relevance of energy security resilience to NDC ambition raising?

Resilience is an important consideration in the design of any energy system, whether it is highly centralised and based on fossil fuels, or clean and decentralised. In both cases a comparably high level of resilience is achievable, albeit with different strategies and means. In early stages of the transition, resilience needs to be a topic of discussion and clarification with technical people[6] and system planners and operators; they are best positioned to assess what is required technically to integrate renewables and decentralise production, and their concerns need to be addressed. In the longer-term perspective, resilience needs to be part of the energy transition strategy; high levels of resilience are possible, but there is a logical trade-off with affordability, particularly when costs of redundancy and management are recovered through energy pricing.

Themes relevant to NDC ambition raising and energy security co-benefits

Energy security co-benefits are best viewed by comparing contrasting alternatives. There are two sides to consider: the challenges no longer faced from the old system and the features of the new system that offer opportunities to increase energy security.

The rest of this chapter will discuss the 4As of energy security and present 10 themes on the interface of energy security and ambitious climate policy (see Table 1), as a starting point for identifying co-benefits, NDC support, and choosing the 'highest possible ambition' for NDC updates.

	THEME	RELEVANCE FOR NDC AMBITION RAISING	AVAILABLE	ACCESSIBLE	AFFORDABLE	ACCEPTABLE
1	Mapping RE potential	Basic evidence for robust energy strategy	●			
2	Trade and business opportunities	Industry policy creates enabling environment		●	•	
3	Infrastructure investments	Mobilise (very) large amounts of capital		●	•	
4	Balancing the grid	Prepare for intermittent supply		●	•	
5	Poverty and access	Scalable clean energy solutions		●	•	
6	Energy subsidy reform	Protect people and businesses		•	●	•
7	Analysis of cost-drivers	Design policies that target cost reduction		•	●	
8	Competition over resources	Avoid conflicts over land, water, etc.		•	•	●
9	Local and societal impacts	Identify vulnerable groups and assets		•	•	●
10	Demand side acceptance	Confront norms and behavioural patterns		•	•	●

Table 1: 10 Themes across 4 dimensions covering areas where NDC support can help harness energy security co-benefits

As Table 1 shows, there is a match between the 4 dimensions and the 10 themes, but most themes touch on more than one dimension. We have indicated this with larger dots for the main topic, and smaller dots for

[6] In case technical people are afraid that the system can't handle it, this needs to be heard and taketaken seriously. All other stakeholders will base their decision on technical experts' advice.

the. A wide range of programmes and projects to support of energy planning and implementation exist today, across all of these themes. National and international development banks, for example, actively support energy infrastructure development and there are established programmes to support sector and market reform (e.g. International Institute for Sustainable Development (IISD) Global Subsidies Programme; World Bank technical and governance support). However, in light of the Paris Agreement and the latest IPCC findings on the closing timeframe for the transition, a critical evaluation of Paris-compatibility of all public finances will need to happen (Germanwatch and NewClimate Institute, 2018).

3.3. Available

The dimension *availability* refers to the physical availability of stocks of fossil fuels and/or flows of renewable energy resources. Fossil fuel resources are not uniformly distributed around the globe and only a limited number of countries dominate production and export. Most of the oil is in the Middle East and parts of Latin America; and the Russian Federation dominates the gas reserves. Coal is more evenly distributed with China, Indonesia, Canada, and Australia as main producers. This leaves the vast majority of countries without fossil resources dependent on import from those who have – either directly or through international commodity markets.

Phasing out fossil exploration

The search for new fossil fuel resources is ongoing and new scanning and mapping technologies make it possible to explore areas not previously within reach. New geological and engineering techniques, notably hydraulic fracturing (fracking) of shale sediments containing oil and gas, have shifted interest to so-called tight oil and shale gas formations. The United States has recently 'discovered' the world's third largest tight oil reserves and the fourth largest shale gas reserves in the world: in the past 20 years their total reserves have doubled and it is on its way to become a net oil exporter for the first time in decades.

From the perspective of climate policy, further exploration[7] of fossil resources makes limited sense: the remaining carbon budget consistent with a two-degree pathway is around 800 $GtCO_2eq$ while use of existing reserves will result in 1000 $GtCO_2eq$ emissions. Despite this observation that 'remaining fossil fuels need to stay in the ground' in order to reach the Paris Agreement goal, one could argue that exploration might reveal lower cost resources and that it does not necessarily mean that all the new discoveries will have to be consumed. There are also those who argue that CCS will allow for a larger carbon budget once the technologies mature. However, such optimism is not without danger when continued exploration generates financial incentives to maximise fossil production revenues and slow down the clean energy transition.

Countries that depend heavily on fossil fuel export, such as Venezuela, Nigeria, Russian Federation, and several Middle Eastern countries, will have to reform and diversify their economies. There will certainly be energy security aspects for these countries to consider in their economic transition but reforming the economy to escape dependency on a single commodity as such is not an energy security topic[8].

Theme 1: **Mapping RE potentials**

[7] *IEA (2019): Total investments 1.8 trln: around 50% goes to Paris incompatible investments such as 127 bln in fossil power, 477 bln upstream + 249 bln downstream in the oil and gas, and 80 bln coal supply. Less than 3% is invested in power grids (47 bln)*

[8] *IEA (2018)* Outlook for producer economies *describes the current state of energy export dependency per country and strategies for a smooth transition; UNCTAD (2019)* State of Commodity Dependency 2019 *provies a detailed description of export dependency for all countries and a range of products including energy, minerals and ores, agricutlural products, and non-commodities.*

Renewable energy potentials are much more uniformly distributed around the globe and unlike fossil resources every country has some renewable potential - many countries have plenty. There can still be a mismatch between supply in demand, for example urban areas with high energy demand, will need to be supplied from other locations further away (in that sense not different from the existing centralised fossil power grids). The reverse, where supply is larger than local demand, is also common with solar plants in remote deserts (e.g. Sahara, Atacama, Gobi) and large wind potential in offshore locations (e.g. the North West Europe, North Eastern Asia).

Resource potential maps show what to expect in terms of energy flows, for specific coordinates in a more or less dense grid[9]. Wind potential, for example, is usually measured between 50-200 meters above terrain in meters per second (m/s_; Solar potential can be expressed in solar irradiance in Joules per surface area (J/m2), but also in the expected output of a single kiloWatt installation (the ratio kWh/kWp). Determining geothermal potential requires similar geological techniques to those used in oil and gas exploration; maps include the contours of reservoirs with additional information. Determining biomass potential can be more involved; the size of some of the biomass streams depends on human activity, such as agricultural and other organic waste and deliberate biomass-for-energy production.

Governments have always based their energy strategy on robust evidence of resource availability, and this is not different for renewable resources. In the process of setting ambitious climate targets, accurate knowledge of resource potentials is a necessary starting point. For most countries potential studies are available, but the data is often outdated and coarse. If an NDC is to reflect the 'highest possible ambition', which it should according to the text of the agreement, it must be informed by a thorough study of the available resources.

3.4. Accessible

The *accessible* dimension of energy security deals with the possible barriers to develop and use available resources, such as access to trade, access to infrastructure investments, access to technology and human capital, and many other preconditions that need to be in place before the 'available' potential becomes 'accessible' and ready for use. In the age of oil and gas, most countries are dependent on import from a handful of producers. Fossil fuel import dependency needs to be constantly managed and is so vital that it can threaten autonomy and hence be worth waging war over. Securing access to oil and gas trade has been the driver behind many international conflicts and continues to be an essential part of international relations and diplomacy.

A recent analysis by the IRENA-hosted 'Global Commission on Geopolitics of Energy Transformation' looks at the geopolitics of a global transformation towards renewables and finds that for the majority of countries, energy independence is within reach making their development paths more secure; that the uptake of renewables is likely to coincide with decentralisation of diffusion and influence of actors; new clean energy leaders will emerge, but are unable to dominate trade relations in the way fossil leaders were; and that fossil producing countries should adapt or lose influence. It is not surprising that the future of international relations is difficult to predict, but according to their analysis it will be different and can be safer (GCG, 2018).

In a future that relies heavily on power grid stability, some warn that neighbouring countries will be able to use electricity disruption as geopolitical weapon; much like the global oil supply disruptions in the 1970s or the Russia-Ukraine gas supply disruptions of 2005-2009. This may seem a serious risk, but the historical

[9] IRENA maintains a repository of potential maps, available at https://www.irena.org/globalatlas

evidence shows that this has not happened often. Power grids of the future are likely connected to balance against intermittency, but the bulk of production will be domestic and neighbouring countries will be mutually dependent (Overland, 2019).

Theme 2: **Trade and business opportunities**

As discussed in section 2.2, ambitious climate policy can present various trade and business opportunities related to energy security. First, there is trade in power and fuels. Power trade is likely to be regional, because of the need for physical interconnectedness and also because electricity transport is costly (long distances lead to losses). Hydrogen and biomass can be sold like common commodities and shipped internationally as per usual, much like LNG or coal nowadays. Second, there is trade in raw materials needed for energy infrastructure (e.g. steel, optic fibre, cement, but also lithium). Some of the materials are 'rare earth elements' and scarce, but their geographical spread is wide. Countries with raw materials can trade these like any other commodity and analysts expect this is not a market that likely leads to geopolitical tensions (GCG, 2019; Overland, 2019). Third, there is trade in clean energy technology: anything from wafers for solar cells to magnets for wind turbines and licenses for patented battery chargers. Markets across all three categories (fuel, materials, technology) are constantly developing and (re)consolidating, as the uptake of renewables progresses, and several countries including China, Germany, Denmark, and the United States have already been able to capture significant shares of the international markets. Despite this, the Global Commission on Geopolitics expects that "RE leaders are unlikely to gain the degree of market dominance that fossil leaders have enjoyed" (GCG, 2009). In summary, there may be opportunities for trade without having to compromise energy independence.

In addition to business related to trade, opportunities are expected to arise in the construction and operation of the future energy systems. Literature on green employment in the energy sector finds that overall clean energy systems offer more and better quality jobs than fossil energy systems, and that clean energy transitions will stimulate the emergence of new business models around energy service provision.

The third type of business opportunity concerns the prospect of long-term energy price stability. Various renewable energy sources can offer 'price security' due to its low and predictable operational costs. This can be especially attractive for energy intensive industries, who are expected to move to places with abundance of cheap renewable energy (e.g. datacentres, metallurgy, etc).

Theme 3: **Investment in power infrastructure**

As mentioned in Chapter 2, electrification and clean power production will dominate most countries' energy transitions, demand is expected to increase significantly, and 'net-zero' emissions most likely require full decarbonisation of the power sector. This will require serious investments across four themes: clean generation capacity, grids and flexibility, end-use efficiency, and end-use electrification [10].

Renewable energy is typically characterised by high capital expenses (CapEx) and moderate to low operating expenses (OpEx). Although often not more costly than fossil alternatives on a per unit basis, renewable energy capacity requires higher upfront investments. Intermittent technologies have a lower load factor and are on average only available part of the time. As a result, the installed capacity needs to be larger. For example, if a coal power plant runs 1 GW at a 90% load factor, this requires 4.5 GW of wind power at 20% load factor for the same output. The average costs in this example may be comparable, but the upfront investment is significantly higher for wind power.

[10] *IRENA (2019a) expect over 80 tln in investments in electricity until 2050 (capacity 26%; grids 15%; efficiency 44%; electrification 15%). Another 25 tln goes to direct use of renewables and nuclear.*

Investments in coal have decreased, but the global fleet is still growing. “In most regions, low-carbon sources were the largest part of generation spending while fossil fuel power investment played a bigger role in the MENA region, and Southeast Asia” (IEA, 2019b; Global Trends in Renewable Energy Investment). The current pipeline of new coal is over 300 GW and over 200 GW is under construction (Boom and Bust, 2019).

Investments in cleaner sources and power grids need to increase rapidly, over and beyond the volume redirected from planned fossil investments (IEA, 2019b; IRENA, 2019). Mobilising the necessary capital for the clean energy transition will be a challenge for many countries and companies, and particularly those who are confronted with ‘shallow’ domestic capital markets and limited access to international finance. Development finance institutions (domestic and international) have a long track record of working with governments to mobilise infrastructure investments and are well positioned to provide support mobilising investments (pursuant to article 9 of the Paris Agreement).

Theme 4: **Balancing the grid**

Power grids always need to be in balance, and if demand changes then supply needs to follow. In fossil-based power systems this adjustment is done by turning ‘dispatchable capacity’ on and off; gas-powered stations are especially suitable for quickly responding, coal-powered stations less so. Clean energy systems can face the additional challenge of variations in supply, in cases where wind and solar take up a large share.

While some sources (geothermal, biomass, hydropower) do not require a very different approach than fossil sources (coal, oil, gas), other renewable sources are less controllable and fluctuate due to natural variability (solar and wind). Hydropower can be variable under special circumstances such as droughts or floods but is normally not counted as Variable Renewable Energy (VRE). On the demand side, digitalisation, automation and electrification of sectors like mobility (electric vehicles) and heat (heat pumps) impact electricity demand profiles.

To make sure that electricity supply and demand are in balance at all times and everywhere, adjustment is necessary to increase flexibility of the system. *Flexibility* has become the core concept of the future power system, which is defined as the ability of the power system (actors, technologies, processes, measures and markets) to respond reliably and rapidly to large fluctuation in the supply and demand balance (IEA, 2018b).

Solutions of providing flexibility are available and cover the whole chain of operation of the power system: supply, demand, markets, and grids[11]. The solutions are often a mix of procedural, technical, and policy interventions. Flexibility has always been an important feature of power systems and grid operators typically must respond to highly variable demand patterns on a daily basis. However, future low carbon power systems, especially with high VRE penetration levels, will have to deal with more, irregular and more extreme patterns at different levels and geographical locations of the grid.

Theme 5: **Poverty and access**

While we talk about oil and gas being the engine of modern life, it is easy to forget that a large share of the world’s population (840 million people) has *no* access to electricity or to clean cooking (2.9 billion people) and depend on traditional biomass for their energy needs (IEA *et al*., 2019). This lack of access is related to the prevalence of poverty and low levels of economic development. Renewable energy technologies, due to

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[11] *See DeVivero et al (2019) for a framework to analyse power system transformations. This study was conducted under the Ambition to Action project and developed a qualitative assessment framework that allows policy makers to understand the complexity of power sector transformation and to analyse their country’s position in the transformation process, including key challenges impacting the integration of vRES and examples for technically feasible solutions.*

their scalability and decentralised nature, offer opportunities to improve energy availability in remote and isolated regions which have so far been difficult to connect to larger energy networks (IRENA, 2019).

Addressing this severe energy insecurity is recognised in the preamble of the Paris Agreement ("*Emphasizing* the intrinsic relationship that climate change actions, responses and impacts have with equitable access to sustainable development and eradication of poverty") and covered by the UN Agenda 2030 framework under sustainable development goal (SDG) target 7.1 which calls to ensure "universal access to affordable, reliable, and modern energy services).".

Poverty reduction policies tend to be somewhat separate from more mainstream economic policies, and there is a tendency to downplay the energy demand that will result if today's poor are moving up the development ladder. Bazillian and Pielke (2013) warn against trivialising energy demand increase through poverty reduction: "to raise the entire region of sub-Saharan Africa to the average per capita electricity access available in South Africa (which in 2010 was about 4,800 kWh, similar to the level of Bulgaria) would require 1,000 Gigawatts (GW) … increase its installed capacity by 33 times to reach the level of energy use enjoyed by South Africans — and 100 times to reach that of Americans." The World Bank Energy Sector Management Assistance Program (ESMAP) program has developed a framework to distinguish between different levels (or tiers) of energy access, showing that access goes beyond connectedness and is different for households, productive use, and community use.

Energy poverty is not restricted to 'poor countries' and 'poor people' only – it can have broader geographical or social dimensions. People in certain segments of society could experience deterioration of access or affordability as a result of the clean energy transition. Vulnerable groups, for whom access to basic services such as electricity is non-existent or fragile, exist in societies across the world: populations in remote areas, those on a low (subsistence) income, but also groups such as separated families, elderly people living on a minimum income, or people with mental or health problems. Against the background of the clean energy transition, there is renewed interest in *relative* energy poverty in developed countries and emerging economies, where vulnerable groups can find themselves exposed to high energy costs restricting access[12].

3.5. Affordable

Energy security definitions often include an aspect of affordability of energy (e.g. the IEA definition of energy security is "the uninterrupted availability of energy sources at affordable prices"), but it is not always clear what affordable actually means without considering who will be the consumer: households and individuals may compare their energy bill to their disposable income, for business and industries energy costs are compared to those of competitors, national governments need to keep foreign exchange and public budgets in mind, and energy companies and investors need to ensure profitability (Cherp and Jewell, 2014).

Global oil and gas prices have always been determined by supply and demand, and to a large extent producing countries have been able to manipulate prices by adjusting supply. Prices fluctuate based on what countries are willing to pay, recently 60-100 US dollars per barrel, and economic growth projections are a good indicator for future oil and gas demand. For many producing countries, market prices bear no relation to extraction costs and profits from export are considerable. Not only have fossil energy prices been

[12] *If an electric vehicle is more expensive to purchase but on the whole cheaper to drive than a diesel car, this could suggest an improvement of affordability. However, the large upfront expense involved could make electric vehicle less accessible for people without the means to make large purchases (i.e. unaffordable).*

disconnected from their true production costs, they don't reflect the full costs of their use. For example, the costs of externalities such as GHG emissions or air pollution are rarely included in the price of power or fuel.

Theme 6: **Energy subsidy reform**

Governments of energy importing countries have gone to great lengths to smoothen retail oil prices in order to mitigate the social, economic, and political impact of frequent price changes. Perceived failures of government to ensure affordable energy services leaves businesses threatening to move to locations with lower energy prices, and it leaves citizens dissatisfied and less secure. There are many examples of grievances over energy affordability triggering large scale civil society protests. For example, the emergence of the 'yellow vests' protest movement in France in 2018 was triggered, at least in part, by fuel price hikes, and in late 2019 both Ecuador and Chile had to backtrack on price increases under pressure of large-scale street protests.

Across the world, the public has come to expect their governments to secure access to cheap energy. Particularly in resource-rich developing countries, this has led to long-term subsidy schemes that are hard to adjust even when they become unaffordable or ineffective. Energy subsidies, a commonly used instrument, can put a real burden on the public budget for importing countries; a rise in oil prices leads to higher energy spending and this drains budget for other public causes (e.g. education, poverty reduction, or food security). Moreover, fossil imports can affect the trade balance and value of the currency. As box 1 shows, Indonesia is among several countries that are taking steps, albeit hesitatingly, to phase out energy subsidies and reduce exposure of state finances to international markets (in 2013, energy subsidies comprised a record 27% of the total fiscal budget).

Box 1: Fossil subsidies and energy security in Indonesia

Indonesia has a long history of subsidising domestic energy consumption by setting retail prices below market rates or even below cost recovery levels. The prices for fuel and electricity are set by the Ministry of Energy and Mineral Resources (ESDM) and require approval from government. Many Indonesians consider the availability of cheap energy a constitutional right and it has brought positive developments such as economic growth, social mobility, and access to energy. However, overt time fuel and electricity subsidies had become an increasingly large burden on the national budget (27% in 2013), which has seriously affected funds available for infrastructure, education, and social welfare and even the country's credit rating (van Tilburg et al, 2016).

To illustrate exposure of the domestic public budget to international oil markets consider the following example situation. When the international market price is 100 and the domestic price is set at 80, the implied subsidy is 20. If the market price changes to 120 (+20%) this would require twice as much (+100%) subsidy to keep domestic prices at 80.

In 2015, the government started to phase out subsidies by introducing a new pricing system that links the retail prices to the market. The introduction was relatively painless to implement in a time of low international oil prices, which meant that customers did not experience much change in fuel prices. Since then, the system has loosened: President Joko Widodo ordered energy prices to be kept flat in 2018 and 2019 resulting in increasing subsidies on e.g. diesel to compensate for an increase in international oil prices; the government announced in 2019 that subsidies will be 'flexible'

Phasing out of energy subsidies exposes customers to higher and likely more volatile prices for fuel and electricity, where this was previously 'buffered' by the state budget. On an aggregated level energy security has not improved as exposure to fossil fuel prices only shifted from the state budget to individual consumers

Protecting people and businesses is a core task of any government and shaping and regulating the energy system is no exception in that regard – so subsidies and other redistributive policies are on the table. However, over the years academics and policy makers have come a long way in understanding social policy design and targeted support and they no longer have to put the public finances in jeopardy (Victor, 2009;

Lockwood, 2015). The IISD Global Subsidies initiative supports governments with research and advice on how ‘inefficient and wasteful subsidies can be reformed’.

Theme 7: **Analysis of cost-drivers**

Recent developments in renewable energy technologies have seen costs drop to spectacular lows, with a promise of further cost decreases in the (near) future. United Arab Emirates and Saudi Arabia have achieved large solar projects for less than 3 ct/kWh. Yet the cost of renewable energy is highly dependent on context and can even be quite high in some circumstances – for example in regions where renewable resources are limited or where high development and financing costs significantly increase total cost (Couture *et al*, 2019). Selecting the right clean energy technologies, taking into account local context such as resource availability and financing costs, is therefore crucial to ensure continued affordability of energy services.

We highlight two aspects of the costs of renewable energy below, associated with production costs per unit (levelised costs), and with transmission and distribution to end-users.

Levelised costs

The levelised cost of electricity (LCOE), expressed in costs per unit of electricity generated (e.g. €/kWh), represents the predicted average minimum selling price required for a project to break-even over its operational lifetime. The LCOE can be used to compare average lifetime costs of various power supply technologies, but there are differences in the drivers determining the costs for these technologies. Understanding the drivers can provide insights into how the cost of electricity can be influenced by external factors and by (domestic) policies. The main factors of the LCOE are:

- Capital expenditure;
- Operations, maintenance, and fuel expenditure;
- Weighted Average Cost of Capital (WACC);
- Yearly load hours;
- Operational lifetime of the power supply technology.

Many renewable energy technologies have high up-front capital expenditures, low operation and maintenance (O&M) and no fuel costs during operation. In contrast, most costs for fossil fuel-based power generation technologies are from O&M and fuels. Revenues of both renewables and fossil-based power are only generated during the operational phase, which must at least cover capital investment repayments and operational costs.

Because renewable energy projects for power production such as solar PV and wind are characterised by high up-front capital expenditure and no fuel cost during operation, the WACC (commonly used as a measure of financing cost) for these projects has an even more critical impact on the levelised cost of electricity than for their fossil-based counterparts. While technological learning and economies of scale have been key drivers behind steep cost reductions of some renewable technologies in the past decade, large cost reductions through these mechanisms become harder to achieve for more mature technologies. Policy makers and project developers thus need to identify other opportunities for cost savings if they wish to scale up the deployment of renewables. One such domain is financing costs that is impacted by, among others, the stability of local financial markets and banking systems, local regulatory conditions, the robustness and consistency of policy, technological novelty, off-taker reliability and the perceived risks to financiers. Increased understanding of policy makers and project developers about what drives the cost of capital and how (perceived) risks can be mitigated is therefore fundamental (Halstead *et al.*, 2019).

System services

On top of the cost of energy production, there are *system costs* for transport and distribution infrastructure, as well as for flexibility options and power system operation cost to ensure continuous supply of energy. Transport and distribution grid infrastructure cost for gas and electricity are in many countries socialised and passed over to everyone who is connected to these grids. Decarbonising sectors by electrification and the transition to low-carbon energy supply often requires grid reinforcements and extensions. In addition, new types of energy transport and distribution infrastructure are needed such as for hydrogen and heat. Meanwhile, fossil fuel infrastructure might become abundant, for example in parts of the gas infrastructure in the Netherlands or fossil fuel pipelines towards and between large industrial clusters. This transition in infrastructure will impose (temporarily) increased cost that will be distributed towards all consumers connected to these grids, which will impact energy affordability.

In more greenfield situations, such as in countries where energy systems are less developed to date, but where large growth is expected by increased wealth and economic development, increased transport and distribution grid infrastructure cost can also be expected. Accommodating large amounts of new capacity requires major power grid reinforcements and extensions, independent of whether new capacity is based on (variable) renewables or not. However, a leapfrog opportunity presents itself here to directly develop energy grids that support, or are prepared for, a low carbon energy system to prevent additional infrastructure transition cost as described above.

The low-carbon energy system and especially power grids will be smarter, more flexible, but also more complex. To ensure continuous and efficient energy supply, increased investments in energy system operation and services (in planning, smart assets, (ICT) knowledge and expertise, governance, and regulation) is essential. Not investing in this will increase system cost and incidence of black-outs, while excessive investments will increase system cost, putting pressure on affordability. In contrast to expectations, examples have showed us that low carbon power systems do not per se have to be costlier to manage. Between 2009 and 2015, Germany was able to decrease ancillary service procurement costs by 70% for TSO's by making changes to their (balancing) market design, while the system stability increased, and the installed capacity of variable renewable energy sources increased by 200% in the same period (Wang, 2017)

3.6. Acceptable

One of the attractive features of the 4A framework, is that it extends the traditional techno-economic focus on available/accessible and affordable, to also include the more subjective 'acceptable' dimension, which is about social and environmental norms and values.

Powering progress

For most of the 20th century, 'inconveniences' such as pollution seemed a small price to pay for the contribution of the fossil fuel industry to economic growth. The acceptance was high: coal was an improvement over wood, and fossil oil was a step up from whale oil and horsepower in terms of comfort and availability. But with industrialisation came local air pollution and protests. While coal was initially burned close to where the energy was needed (in cities), it gradually moved to locations outside urban areas[13] or was replaced with cleaner fuels. Concerns over air pollution have also forced the development of cleaner personal cars (with mixed success) and more public transport.

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[13] Following a catastrophic pollution event in London (great smog, 1952), the UK started to put regulation on smoke coming from coal burning, which partly involved switching to cleaner burning cokes and (coal)gas, which had to be produced elsewhere, effectively moving the pollution to other parts of the country.

More recently climate change concerns have become a real showstopper for fossil fuel technologies, forcing policymakers to consider low-carbon alternatives. With growing realisation that anthropogenic (i.e. human-made) greenhouse gas emissions cause climate change and need to be phased out, the public acceptance of fossil energy is at an all-time low.

Several civil society movements have emerged with a strong focus on climate change (e.g. School Strikes and Extinction Rebellion) and their main assertion is that in light of current science it is unacceptable to continue using fossil fuels. Furthermore, more and more investors are divesting from fossil fuels, mainly coal. "The divestment movement – where investors allocate capital away from the coal sector – is gaining steam. China's State Development & Investment Corporation, some Japanese trading companies, and QBE, the largest Australian insurer, announced the end of exposure to the sector. Glencore, the world's largest coal exporter, declared a coal production cap, in response to investor pressure." (IEA, 2019b). Despite the positive signal these actions send, divestment is currently (extremely) marginal and not seen by many experts to have a large impact on capital flows. Overall, fossil fuels have had 'quite a run' in terms of acceptance, and economic progress would not have been the same without it; but acceptance is wearing thin and any decisions regarding investments in, and use of, fossil fuel is (and should be) scrutinised.

Nuclear energy has undergone a similar change in acceptance, at least in many parts of the developed world and for a different set of reasons. In the decades following its introduction in the 1950s, nuclear energy enjoyed a high degree of acceptance and was the source of pride (in the technology), and hope that energy would be 'too cheap to meter'. Since the 1970s, there has been a growing social movement against nuclear power, which has included arguments such as there is no permanent solution for the waste, the risk of accidents, and the possibility of proliferation. Following the 1986 Chernobyl disaster and the 2011 Fukushima Daiichi accidents, acceptance of nuclear energy has taken a nose-dive and several countries are accelerating its phase out.

Box 2: Fake news?

There are high stakes involved in the energy transition and it forces us to face uncomfortable truths about our habits and activities. It is perhaps no surprise that this allows misinformation to persist, either as deliberate distraction or deception, or from genuine but questionable beliefs.

Consider the following questions, which are leading but not unreasonable: Is *clean coal* a credible mitigation option or a euphemism for perpetuating a dirty industry? Can we wait for *CCS* to become competitive or will it be too late and too expensive? Should we invest in natural gas infrastructure as *bridging technology* or will such assets need to be retired early (asset stranding)? Can we wait for *carbon markets* to buy offsets or do we need to take action ourselves? Will trade in *green bonds* or *RE certificates of origin* create a conducive investment climate for the transition, or are these mostly distractions? Can we wait for *battery technology* before integrating large shares of renewable, or are there plenty of other ways to address intermittency?

Misinformation can also originate from good intentions, and flourishes when confronted with wishful thinking and confirmation bias. Austin (2019) coins the term *greenwishing* for "the earnest hope that well-intended efforts to make the world more sustainable are much closer to achieving the necessary change than they really are". It is the responsibility of everyone to stay critical of strategies and actions that sustain the use of fossil fuels or defer acceleration of clean alternatives. Since individual decisions are not always clear cut, good practice dictates to always be critical, assess the evidence, and keep an eye on the bigger picture.

Acceptability plays an important role in the clean energy transition. The Paris Agreement calls for low-carbon development to be mindful of social and environmental impacts, which makes the acceptability a very relevant topic for NDC ambition raising. Acceptability also resonates well with the integrated approach to development under Agenda 2030 of the United Nations (i.e. the Sustainable Development Goals) and the concerns of organisations such as the Food and Agriculture Organisation (FAO) and the and the International Labour Organisation (ILO) may have about social impacts.

We can identify three broad categories of concerns around acceptance of clean energy systems: competition for resources, local and societal impacts, and demand side acceptance:

Theme 8: **Competition for resources**

The most prominent discussion around the use of bioenergy is the 'food versus fuel' discussion, which points to direct competition for biomass between use for energy production or as food, and the risk of diverting farmland for biofuels production at the expense of food security. Although the evidence of biofuels affecting food prices in times of scarcity is weak (Filip *et al*, 2019), the 'food versus fuel' discussion has tarnished the reputation of bioenergy.

Second, there are conflicts over competition for water. Large-scale biomass plantations may need to divert water resources away from other crops or use for drinking. Hydropower installations can disrupt the water available downstream, and adversely impact water availability for agriculture. The Chinese government relocated over 1 million people who lived where the flood plains of the Three Gorges dam now exist, and the current conflict over the Ethiopian Grand Renaissance dam and the disruption could cause in Egypt illustrates that conflicts over resource can cross borders. Note that fossil power plants can also impact water availability – hot summers in Europe frequently limit the cooling abilities of power plants due to unavailability of (cold enough) water.

Third, there may be tensions over land-use for technologies with a large footprint such as biomass production or hydropower. As installations get larger, they will need to be included in spatial plans to avoid interference; Solar PV can take up to 14 km^2 per GW, which depending on the conditions can power up to half a million households – an area that is not easily integrated into a city. Similarly, offshore wind parks will need to coordinate with shipping and fishing activities.

Fourth, since the (global) potential of biomass is limited, there are calls to reserve biomass for use in otherwise hard-to-decarbonise activities such as heavy industry and heavy transport, and not for heating or power production (ETC, 2019). This 'cascading' of biomass fits in the larger theme of moving to a bio-based economy; for a recent review of the 'battle for biomass', as the authors call it, see Muscat *et al*. (2019).

Theme 9: **Local and societal impacts**

In addition to competition for resources, installing renewable energy can also incur direct damage to the environment. Clearing land for biomass plantations, hydropower reservoirs, or solar and wind parks could threaten biodiversity (especially when forests are converted) and local livelihoods can be under pressure to the point where they see no choice but relocate (see previous paragraph). Production of Palm oil is one example that has attracted particular scrutiny, because of the fast expansion of the crop replacing forests and peatlands and threatening biodiversity. Less drastic concerns involve impacts on quality of life such as visual interferences in the landscape caused by wind parks.

Society as a whole may find the unmoderated outcomes of the energy transition unacceptable if important businesses or services are at risk (e.g. food supply, hospitals and emergency services, or traffic control), or if the level of control is deemed inadequate to protect vulnerable customers. In this context of societal acceptability, the term 'just transitions' was introduced by the international trade union movement to call attention to the protection of workers' rights and livelihoods.

Theme 10: **Demand side acceptance**

Part of the energy transition will not be all that visible to end-users. After all, electrons are electrons regardless of their source. In other areas, the transition will be very clear: new buildings have very high standards for efficiency and existing buildings will need to be retrofitted. Much of the building's environment will be automated and controlled based on monitoring of activity inside it. Electricity will replace wood and gas for cooking and much of the heating. Transit-oriented mobility will force travellers to use mass transit, cycling, and walking. Long distance travel will be limited.

Analyses consistently point to the important role of demand-side measures in meeting ambitious climate targets. However, cultural norms and human behavioural patterns dictate the way we use energy, and lifestyle changes are hard to establish. There will be obvious improvements in wellbeing for end-users of energy: electric vehicles are not as noisy and polluting as diesel or gasoline cars (and the torque is unparalleled), efficiency improvements in buildings and transport keep lowering energy bills, etc. There are also valid questions that need to be addressed or clarified in order to create public acceptance: Will I be able to cook the same dinner with an electric instead of gas stove? Can I still open windows and control the lights? Can I still enjoy the privacy of a single-passenger car ride, or the luxury of long-distance travel?

Communication plays an important role preparing end-users for the transition, and ultimately in determining the acceptability aspect of energy security. Experiences from green growth point to the importance of messaging to diverse audiences using credible messengers, and the role of the media as gatekeepers of the information flow to the policy makers and the public (GGBP, 2014).

4. Making the case for climate action

- Maximising energy security benefits from the clean transition is about finding synergies and dealing with trade-offs; energy security has an unusually high linkage with other topics and sectors. there is much variety in context, so generalisations should be treated with caution.
- Understanding the energy security impacts of the transition, whom they impact specifically, and where they can be influenced, is crucial to a smooth transition.
- Energy security can be a driver for ambitious climate policy, but more importantly, ambitious climate policy needs to come with energy security guarantees in order to be politically feasible.

4.1. Balancing priorities: security for whom?

As the previous two chapters show, optimising energy security often involves trade-offs between different aspects, and as discussed in section 2.2, there are two sides to consider: getting rid of the challenges of the fossil-based system (e.g. less pressure on the public budget) is as much a co-benefit as the obvious positive impacts of the clean system (e.g. long-term price stability). Real world situations do not often present themselves as clear binary choices, but rather involve complex interactions between stakeholders; in these situations optimising energy security is about finding the right balance between its different aspects and managing the interaction with other priorities.

Energy security and climate policy: synergies and trade-offs

Climate policies and energy security policies can go hand-in-hand: switching from fossil to renewables can improve access to and affordability of energy, and it has the potential to bring social and environmental improvements making the overall system more acceptable. Not surprisingly, there can also be tension between ambitious climate policy and improved energy security: not all clean energy technologies will improve energy security (especially more costly or vulnerable choices), just as not all actions to improve energy security are consistent with ambitious climate policy (use of cheap domestic coal, shale gas, and tight oil) (Froggatt and Levi, 2009) .

Making generalised statements about how energy security and ambitious climate policy are connected is tricky. It would be deceptive to suggest that climate policy and energy security always point to the common solution of moving to a low-carbon economy. Some actors may see an increase in their energy security when the climate changes and from that perspective could be adversely affected by reducing emissions. Depending on the location, it is quite realistic that a warmer climate will reduce demand for heating in cold areas, that melting ice will open new trade routes and possibilities for resource exploitation, and that locally the potential for biomass, solar, and wind can improve (Luft *et al.*, 2011). Climate change advocates who selectively bring up evidence, for example to show that addressing climate change is always (eventually) good for energy security, can be unproductive and inhibit healthy dialogue. The context is important.

Interactions with other development priorities

Trade-offs are not always a result of incompatible objectives, but sometimes it can be as simple as having to choose where to allocate resources. Emission reduction and energy security are only two of the development priorities that need to be taken into account. A recent review of trade-offs and synergies of climate mitigation measures on all relevant SDGs found that “policies targeting energy efficiency, reduction of demand of products and energy services… provide most development co-benefits. In contrast, nuclear and carbon capture and storage were found to be broadly conflicting with SDGs. Although mostly synergistic, renewables have both positive and negative development impacts, with differences across technology types.” (IPCC, 2018; Iacobuta and Höhne, 2017). Using the SCAN-tool[14] to visualise the impacts associated with ‘electricity and heat’ reveals mostly synergies, but also some trade-offs between mitigation and important policy areas such as poverty reduction. To illustrate, consider the increased use of bioenergy on poverty reduction (SDG target 1.2): the potential synergy is “Large-scale bioenergy production could lead to the creation of agricultural jobs, as well as higher farm wages and more diversified income streams for farmers“ while at the same time a possible trade-off exists in that “Biofuels production can lead to land price increase, with impact on food prices which could reduce food access.”. It is important to consider a wide range of co-benefits and trade-offs.

Security for whom?

While energy security is often thought of as a national policy topic – especially when it concerns the geopolitics of securing oil and gas – there is much variation on a more granular level. The transition is likely to affect stakeholders across all sectors, but not everyone in the same way. Analysis on a national level is a good starting point, which can then be extended by differentiating between subsectors and specific actors, and by taking regional differences into account.

Similar to acceptance discussed in section 0, the overall priorities regarding energy are subjective and depend on who you ask. Governments may strive for fiscal stability, secure energy supply to parts of the economy that are identified as vital (e.g. primary healthcare facilities, or certain industries), create an attractive investment climate, and maintain a low risk of social unrest. Industry and commerce on the other hand could be looking for reliability and competitive pricing with less concern for social and environmental concerns. For residential energy users, access and affordability are typically most important and (under certain circumstances) they may be willing to compromise on reliability.

[14] *The SCAN-tool is developed under the Ambition to Action project based on a mapping of IPCC (2018)mitigation actions and their impacts on SDG output indicators (Gonzales-Zuñiga et al, 2018)*

A clean energy transition is not just a techno-economic challenge, but outcomes highly depend on the political economy in the specific country or sector. Stakeholders can have vastly different preferences, incentives, and possibilities to influence climate and energy policy. Political economy analysis does not (yet) feature prominently in NDC planning and implementation, but there is a strong case to be made for more attention to the political dimension to NDC ambition raising (van Tilburg and Minderhout, 2019; van Tilburg and Donker, 2019). Which are the vulnerable groups that need protection? Which stakeholders see their energy security improved and where is additional support useful? Which actors are so powerful that they need to be curtailed by the government to avoid social and environmental risks? Political economy analysis can help identify where rents may need to be redistributed; through industry policy in the case of business and social policy in the case of individuals or groups.

4.2. Energy security driving climate ambition

What is there to choose?

Some governments own and operate large parts of their national energy system, while in other countries ownership of power plants, refineries, and other infrastructure is in the hands of private actors. Governments don’t ‘choose’ a technology mix or ‘determine’ the speed of the transition. More often the government introduces policies that set the conditions for other (public and private) stakeholders to shape and use the energy system. “Governments must develop national transformation strategies, build effective institutions and intervene in markets to create and withdraw rents while avoiding policy capture.” (Bailey and Preston, 2014). However, government capacity to influence the clean (energy) transition differs and the nature of the challenge varies according to the level of development. In poor countries the most pressing challenges originate from lack of government capacity, while in rich countries the barriers are first and foremost political. Emerging economies have the advantage that growth creates economic and political space moving resources and rents around, but fast expansion requires careful navigation to avoid lock-ins. Specific policy control over the energy sector differs across countries too According to Von Hippel *et al.* (2011) three attributes are leading, namely the degree to which: 1) the country is energy resource rich, 2) market forces are allowed to operate as compared with the use of government interventions to set prices, and 3) long-term and short-term planning are used.

Industrial policy plays an important role in guiding transitions, and there is a long history of experience with industry and innovation support (well before emission reduction became an issue). Many renewable energy industry leaders have developed their current businesses in a generous and protective policy environment (e.g. US, Denmark, Germany, China). The question of policy timing is important and though, and with high stakes there will be differing views. Industry policy is about redistributing opportunities for above average rents. Technology optimists, climate sceptics, and those with vested interests may argue *against* early action by either actively blocking change or more passively allowing for non-decisions to preserve the status quo.

When would be a good time?

In reality there is the actual, messy, non-straightforward policy process. While it can be useful to imagine policy as a step-by-step cyclical process in which decisions are made on available evidence, reality is more complex and chaotic, and decision makers are driven by both rational and irrational motivations. A more accurate (and slightly academic) way to describe policy making involves policy entrepreneurs inside and outside government who construct and use agenda-setting opportunities, or policy windows, to bring issues onto the government’s agenda (Kingdon, 1984). So, in addition to acquiring evidence on the energy security impacts of ambitious climate policy, it is important to recognise and/or generate ‘windows of opportunity’ in which this evidence can be a driver for change. It is common to have predictable and routine events, and unpredictable ‘focusing’ events. Such events can put climate policy and energy security in the spotlight and call for policymakers’ attention at short notice. These events create time windows in which change can be initiated. Examples of such events can be the periodic update of the strategic national and sector plans every 5 years, or incidental events such as hosting/attending a G7, UN Security Council, or COP meeting. Unpredictable focusing events could be the aftermath of a natural disaster (earthquake followed by a nuclear meltdown in Japan) or energy crisis (threat of gas supply disruption in Europe).

Which arguments work best?

Rawlins (2019) investigates the influence of the co-benefits narrative on climate policy ambition; how successful has co-benefits evidence been in getting ambitious climate policy accepted. He finds from academic literature that overall the co-benefits evidence base has been well established and continues to grow; notably for pollution and health impacts. Looking at three case studies (United Kingdom, European Union, and China), the evidence on the importance of the different co-benefits is mixed. In the United Kingdom, the motivation for ambitious climate policy seems driven by a desire to avoid climate change while a range of co-benefits are used to support the narrative. In the EU, ambitious climate policy was developed for its own sake, and the prospect of energy security improvements was then used to get a number of reluctant (eastern European) member states on board. In China, the situation appears opposite in the sense that climate-friendly technologies are the logical choice based on other challenges such as extreme air pollution, worsening energy security, and that ambitious climate policy was an almost coincidental co-benefit. Overall the case studies suggest that energy security has been more influential than other co-benefits, possibly because failure to protect energy security has immediate economic and political repercussions.

An assessment of experiences with green growth policies finds that in order to be most effective, communication of benefits should be integrated with context-specific framing and analysis. The evidence needs to be brought to life for the specific audience it targets through “comprehensive and tailored messages that are analytically robust and delivered by credible messengers”. The assessment further finds that “economy-wide transformations have met with opposition from those who have invested in types of infrastructure that risk becoming redundant” … “In practice, the most successful approach to countering challenges by incumbent industries has been to ensure that all analysis is presented in as transparent a manner as possible, with all assumptions clearly stated.” (GGBP, 2014).

4.3. Looking ahead

The aim of this working paper is to help the reader think more clearly about energy security as co-benefit in the context of increasing climate ambition. Energy security arguments can be a real driver for ambitious climate policy, but it is not a magic bullet: It is a multifaceted concept, and rarely will policy changes increase energy security across all dimensions for all stakeholders. Trade-offs are likely to occur between aspects of security (i.e. the 4 A’s), between how stakeholders are impacted (i.e. security for whom?), and also between energy security and development priorities in other sectors. This paper discusses ten themes where co-benefits can be expected; analyses of energy security co-benefits, across all its components, can provide a valuable contribution to the evidence base on which ambitious climate policy needs to be built.

Energy security can be a driver for ambitious climate policy, but more importantly, ambitious climate policy needs to come with energy security guarantees in order to be politically feasible.

To maintain buy-in for the transition, governments will need to consider energy security concerns of all stakeholders and find a balance that is politically acceptable. Understanding the energy security impacts of the transition, and where they can be influenced, is therefore crucial to a smooth transition. Without an agreed approach to energy security, ambitious climate policy runs the risk of being ineffective.

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