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About

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News in Brief

Europe is planning a 25-fold increase in offshore wind capacity by 2050. Shorter term, the plans aim to make offshore wind capacity hit at least 60 GW by 2030.The European Commission estimates that almost 800 billion euros of investment will be required for the goals to be met.

The Advanced Clean Energy Storage project in Utah aims to build the world's largest storage facility for 1,000 megawatts of clean power, partly by putting hydrogen into underground salt caverns. An $11 trillion global hydrogen energy boom is coming. Storing fuel in salt caverns isn't new, but hydrogen's growing role in decarbonization has revitalized interest in the concept. The concept is quickly gaining momentum in Europe.

NASA and the U.S. Department of Energy will seek proposals from industry to build nuclear power plants on the moon and Mars to support its long-term exploration plans.The goal is to have a flight system, lander and reactor ready to launch by 2026. The facility will be fully manufactured and assembled on Earth, and tested for safety. The nuclear power plants will provide enough electrical power to establish an outpost on the moon or Mars.

While countries like the USA retrofit their current electricity grid with decentralized energy storage and generation, Africa is on the brink of moving straight to the grid of the future: an interwoven mesh of generation and distribution providing smart, flexible, and reliable power. Africa is positioned to build the grid of the future, today, by providing power through an interwoven mesh of main grid connections, mini-grids, and solar home systems.

The European Union has taken a big step toward solidifying plans to become the first climate-neutral continent with the European Commission's announcement that it is adopting a methane strategy as a part of the European Green Deal. This strategy is a leading effort for more accurate measurement and reporting, as well as effective mitigation measures for methane emissions, which are critical to meeting global climate targets. Given this, the European Commission has placed focus on the energy sector as a critical path to reducing methane emissions in the near term, as it can be done quickly and at least cost.

An 'underwater super-highway' could soon funnel electricity from Scotland to England. Authorities in Scotland want offshore wind capacity to hit 11 gigawatts by 2030. Scottish Power, SSE and National Grid are leading the scheme.

Amazon this week announced three new renewable energy projects in the U.S. and Spain that support the company's commitment to reaching 80% renewable energy by 2024 and 100% renewable energy target by 2030 on its path to net zero carbon by 2040. In Europe, the company is announcing a large-scale project in Spain, located southeast of Sevilla. Once complete, the new solar farm will provide 149 megawatts (MW) of new renewable capacity.

On November 15th the world's largest trade agreement was signed in a virtual meeting room, bringing an end to eight years of negotiations. The Regional Comprehensive Economic Partnership (RCEP) links 15 Asia-Pacific economies, including the 10 members of the Association of Southeast Asian Nations (ASEAN), plus Australia, China, Japan, New Zealand and South Korea. This is a historic step – and a major trade blow to the United States. Trade between the signatories was worth $2.3 trillion in 2019, making the RCEP the world's largest trading bloc, eclipsing USFTR and the European Union. The member countries account for nearly one third of the world's population and 29% of global GDP. Commodities – in particular fossil fuels likes oil, coal, and natural gas – will play a central role in this unprecedented trade organization.

During China's 13th Five-Year Plan period, the development of new energy has entered the "fast track". Inner Mongolia takes new energy as the main direction to adjust its energy structure. At present, wind power and photovoltaic power generation generate more than 80 billion kilowatt-hours of new energy, ranking first in China. New energy sources account for nearly a third of the region's electricity generation and a fifth of its electricity consumption.

To build Belt Road in recent years, green technology and green industry cooperation projects continue to come. China and the relevant countries strengthen the cooperation in the ecological environment, biodiversity protection and climate change, in order to promote green infrastructure construction, green investment, green financial development, jointly create green "area" all the way. In the first half of this year, renewable energy accounted for a larger share of Belt Road investment than fossil energy.

European Union's Offshore Renewable Energy Strategy, published on 19 November and targeting as much as 300 GW of installed offshore wind capacity by 2050, also outlines the goal of supporting green hydrogen production. In anticipation of the launch of the new Renewable Hydrogen Coalition, it is ever so evident that EU's (offshore) wind and hydrogen are to merge onto the same highway leading to 2050, given that one of the key members of the new Renewable Hydrogen Coalition is WindEurope.

India added 438 megawatts (MW) of solar capacity in Q3 2020, a 114% increase compared to 205 MW installed in Q2 2020, according to Mercom India Research's newly released Q3 2020 India Solar Market Update. Solar installations were down by 80% year-over-year (YoY) compared to 2,177 MW added in Q3 2019. Mercom India Research is forecasting approximately 3.3 GW of solar installations in 2020 as most of the projects scheduled for commissioning in the second half of 2020 were moved to the first half of 2021.

Adapting

Remote Working: Implications for the Electricity Network and Emissions

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Introduction

The Covid-19 pandemic has resulted in drastic and abrupt changes to daily life. One area where this change has been particularly stark is energy consumption. Lockdowns across the globe resulted in a reduction of overall energy consumption, carbon emissions and air pollution. It is estimated that during April 2020 there was up to 25% reduction in global CO2 emissions and significant reduction in other greenhouse gases and air pollutants [1]. These estimates are primarily based on the changes observed in peoples' mobility as shops and offices closed and those who could do so, started to work from home. While remote working for most is a temporary interlude necessitated by public health measures, it has been a growing trend prior to the pandemic and now some companies, such as Twitter, have announced that employees will be allowed to work from home indefinitely. This raises the question about the possibilities and the implications of remote working in a longer-term perspective for the energy sector and emissions post pandemic.

Sustainable Reductions?

The common assumption has been that remote working can reduce overall energy demand and the resulting emissions by replacing commuting and office demand with less intensive home-based energy consumption. However a recent paper reviewing 39 research studies in the area reveals a more complex and inconclusive landscape [2]. Estimates of the emissions impact of remote working vary considerably, with 26 suggesting it would reduce emissions (one suggesting a 77% reduction), 8 indicating no change or even an increase in emissions, and the remaining studies were unclear in their conclusions [3]. In particular, once the wider impacts outside of simply the reduction in commuting, are considered the benefits become less clear. Three key considerations upon which the emissions reduction potential depends have been identified:

1. **Full- or part-time remote working.**
   A sizeable portion of the UK workforce could do their jobs remotely (up to 44% [4]), however the emissions reductions potential are highly dependent on uptake and the remote working policy put in place. Surveys suggest that following the lockdown in Spring 2020, many people would like to change their work routines to divide their time between home and the office [5]. This hybrid model where people work from home for some portion of the week may not lead to significant emissions reductions since for many firms this would not warrant downsizing or doing away with office space. In addition, remote working during the pandemic has led many people to move further away from their places of work [6], which could ironically lead to higher overall emissions if they continue to go to the office even once or twice a week [7].

2. **Changing routines and filling the commuting time void**
   Key benefits of remote working, for employees, are the elimination of commutes and the flexibility to perform other activities during working hours. During lockdown this has resulted in many taking up new hobbies, baking being the most prominent [8], which could result in increased energy consumption. Although these may not be long term phenomena, people will change their daily routines and do things with this newfound time, the energy and emissions implications of which are interesting yet highly unpredictable.

3. **Manufacturing information and communications technology (ICT) equipment**
   The lockdown saw a surge in interest for webcams and computer monitors [7]. In order to facilitate large-scale remote working significant amounts of additional ICT equipment will be required resulting in emissions associated with

manufacture, shipping and disposal.

An Opportunity: Domestic Demand Flexibility

The extent to which remote working will reduce overall consumption and emissions remains unclear. However, its effect on electricity demand and in particular the daily variation of demand is more apparent. The first few weeks of lockdown in the UK resulted in a decrease in electricity demand and importantly a change in the shape of the demand curve across the day (see Figure 1) [9]. With offices closed and reduced service on the rail network, the usual distinction between weekdays and weekends was blurred.

Historically, electricity demand in the UK has two distinct peaks: one in the morning at around 08:00 when people are getting ready and going to work, and one in the evening between 17:00 and 19:00 when people are returning home and preparing dinner. The Oxford METER project, which collects activity and electricity consumption data, has shown that during lockdown there was a significant change in people's daily routines (see Figure 2 right) [11]. The morning activities shifted by an hour to 09:00 as people slept till later and the evening activities reduced dramatically. Being at home meant that people spread their activities more evenly across the day.

The emissions intensity of the electricity network and effect of a reduction in demand is highly dependent on when those reductions occur. For example, in 2019 the average emissions intensity (i.e. the amount of CO_2 emitted per kWh of electricity produced) in the UK during the evening peak (17:00-19:00) was 243g/kWh, during the middle of the day (10:00-13:00) the emissions intensity was 212g/kWh or 12% lower and at night (00:00-04:00) the emissions intensity was even lower at 186g/kWh [13]. With increasing amounts of intermittent renewables on the electricity network overall emissions could reduce. However the emissions intensity of the electricity grid will vary significantly across the day as expensive and polluting, gas turbines (known as peaking plants) would be needed to match supply and demand. Additionally, given the electrification of the heating and transportation sectors, it is expected that the peaks and troughs in demand will become more pronounced [14].

Domestic demand-side response (i.e. shifting or

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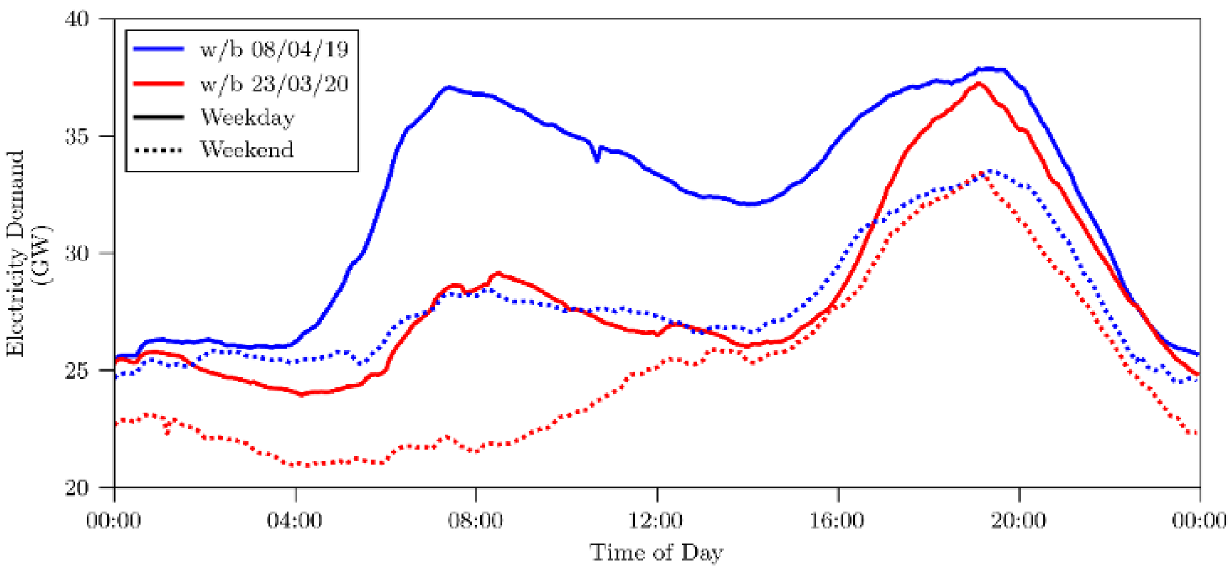

Figure 1 - Effect of lockdown on electricity demand in the UK [10].

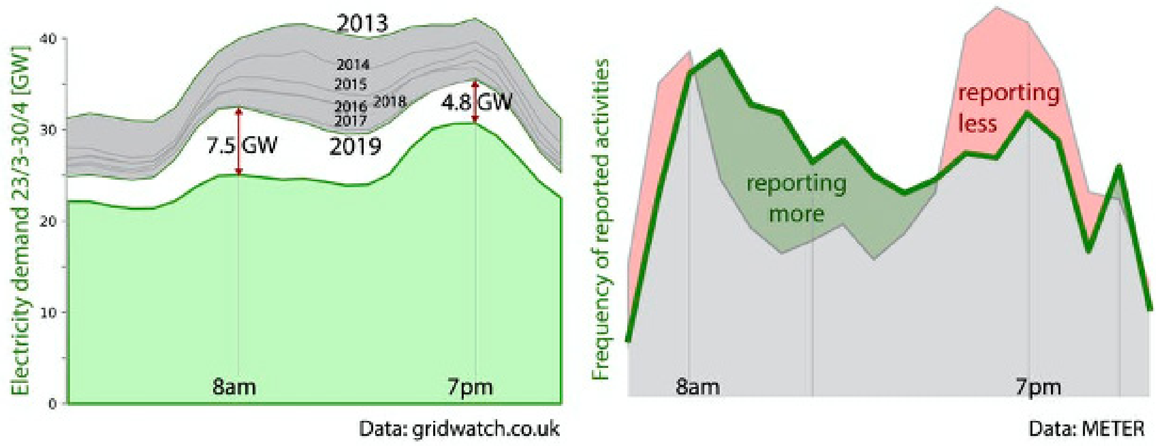

Figure 2 - Changes in UK electricity demand [12].

reducing demand in response to price signals) could provide an alternative source of the much-needed flexibility in a cost-effective way while also reducing emissions. However previous trials, performed under normal conditions, have shown mixed results [15]. The engagement, responsiveness and persistence of demand-side response have varied significantly across trials and commercial uptake is currently limited. One of the major hurdles has been that people's demand flexibility is inextricably linked to when people are at home [16]. Although automation can overcome this to a certain extent, the trials mentioned above show limited use of such technologies even when they are provided. The interesting finding is that the lockdown and remote working has shown that even without price signals demand has been spread more evenly across the day reducing the morning and evening peaks (see Figure 2 left) and this, among other things (e.g. more wind power on the network), has led to an overall reduction in electricity related emissions in the UK in 2020. Price signals or information on the time-varying nature of emissions could further enhance responsiveness of people given their greater flexibility when working from home.

Conclusions

The Covid-19 pandemic and the resulting lockdown has inadvertently created a global social experiment in remote working. It has given us a glimpse into what widespread adoption of remote working policies may entail and what their implications might be on the energy sector. However, determining the persistent trends and impacts remote working may have on overall emissions remains unclear. Indeed, a lot depends on the behavioural responses people will have in terms of changes to their routines, where they live and what they do with the time they gain from not commuting. Remote working does offer opportunities beyond reduced transport emissions, specifically into the electricity network. The flexibility of being able to spread activities across the day, may not lead to reductions in demand but could increase the potential for domestic consumers to shift their electricity consumption to times when emissions are lower, for example when the sun is shining, or the wind is blowing. This maybe where the true benefit of remote working could be realised for emissions reductions.

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In the Shadow of AC: The Growing Demand for Cooling Energy

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Air conditioning (AC) has long been considered a luxury in many parts of the world. In the EU, for example, less than five percent of households had an AC unit as of 2019 [1]. However, as the planet continues warming as a result of climate change and with population growth and urbanization rates soaring higher than ever, effective methods of keeping ourselves and our living spaces cool are becoming more and more necessary for health and survival. Cooling, however, does not come cheap in any sense of the word. The environmental effects of modern AC paired with its enormous energy consumption are growing at a pace that will soon become impossible to support. The world needs to take initiative.

It is widely known that extreme heat strongly affects the elderly and immuno-compromised population, but healthy, young people are not invulnerable. A study in 2018 by Harvard's T.H. Chan School of Public Health [2] demonstrated that there is a significant difference in cognitive performance between university students living in air-conditioned dorms as opposed to those in non-air-conditioned ones. This is serious enough without examining the many illnesses linked with exposure to extreme temperatures for prolonged periods of time, such as heat stroke and heat exhaustion. Maintaining an acceptable surrounding temperature is crucial to human function, which has, in recent decades, rendered AC not a luxury at all, but a necessity.

The increasing use of AC worldwide is a huge factor in the overall growing energy demand. The International Energy Agency's 2018 Future of Cooling report [3] found that global energy use for cooling has tripled between 1990 and 2016. Today, cooling accounts for roughly 2020 terawatt-hours (TWh) of energy usage around the globe, corresponding to about 10 percent of the world's total energy use. This is unsurprising, given that temperatures on the planet are climbing steadily. The irony of the fact, however, is that AC is a major contributing factor to those rising temperatures.

Fundamentally, air conditioning has undergone very little design change since its invention in 1902, a time when the climate situation was much less dire, the planet was 1.2 degrees Celsius cooler [4], and the global population barely exceeded 1.6 billion [5]. Standard household air conditioning units release a mixture of greenhouse gases, exacerbating global warming potential and indirectly increasing global AC use. It is, simply put, a vicious cycle.

Most earlier air conditioning units used chloro-flouro-carbons (CFCs) as a refrigerant. In 1987, this class of molecules was identified as largely contributing to the decay of the ozone layer. In response, the Montreal Protocol, an international agreement to combat this deterioration, committed to ban the use of CFCs by the year 2010. Today, they are outlawed in 197 countries [6]. Although AC units no longer use CFCs, many are still reliant on hydro-flouro-carbons (HFCs), a related class of pollutant which is nearly 1500 times more damaging to the climate than CO2 and has an atmospheric lifetime of up to 29 years [7].

Most modern units function the same way their predecessors did, drawing heat out of the air by means of evaporation of a refrigerant. In urban environments, where most AC units are situated on windows, the heat drawn out of buildings is redistributed into the very well insulated concrete jungle, causing city temperatures to rise, and contributing to what is known as the "urban heat island effect", a phenomenon in which the average temperature of a city tends to be 1-3 degrees Celsius higher than its surroundings [8]. A research team at the University of Arizona found that simply running ACs at night increased the mean air temperature of some cities by 1˚C [9]. Further research by the Rocky Mountain Institute (RMI) projected that, at the current rate, the use of room air conditioners (RACs) alone would contribute a 0.5 degree Celsius increase to global temperatures by the year 2100 [10].

The effects of air conditioning on the climate are

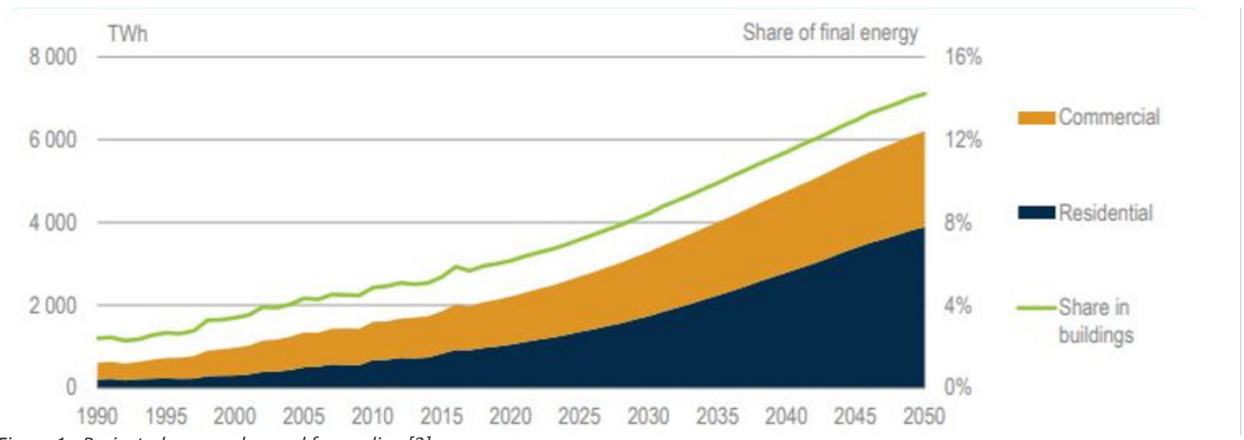

Figure 1 - Projected energy demand for cooling [3].

not the only worrisome ones, though. The energy demand of air conditioning is astronomical now and will only continue to grow, straining a grid that may not be prepared to handle it. In temperate climates, AC is only needed at its full capacity for a few weeks a year, in the summer. The power grid, however, must either be overdesigned to accommodate these times when cooling accounts for almost 50 percent of total electricity usage [9] or be severely overstrained.

To illustrate the projected growth of cooling energy demand, several assumptions must be made. The IEA describes the "Baseline Scenario" in their Future of Cooling report [3]. In essence, the Baseline Scenario assumes that people who need and are able to afford AC units will buy and use them, eliminating the possibility of moral choice. Under this scenario, global energy usage for cooling specifically is forecasted to grow from today's 2020 TWh to 6200 TWh in 2050. This increase in energy usage is even more staggering when put into context of total global energy consumption. The 6200 TWh figure is expected to make up 16 percent of total energy usage in 2050, a large increase from today's 10 percent, as shown in Figure 1 [3].

Many people, scientists and politicians alike, have recognized that this kind of growth is unsustainable and that if we don't act now, in a century, we may not be able to support humanity's cooling demands. This realization has inspired many different efforts to innovate and promote more energy-friendly cooling systems. Prominent among these efforts is the Global Cooling Prize, an initiative by the RMI and the Indian government "to develop a climate-friendly residential cooling solution that can provide access to cooling to people around the world without warming the planet" [11]. Among the many participants competing for a 3-million-dollar prize, eight were shortlisted as finalists.

One of these was Transaera, a Massachusetts based start-up that humidity levels in the air were a severe obstacle to more efficient AC operation. They developed a porous sponge, which draws moisture out of the air before sending it onward to a regular AC unit. It is intended as a supplement to existing AC systems, and while simple in premise, has been shown to improve their efficiency by as much as 25 percent [12].

A different start-up, unaffiliated with the Global Cooling Prize, sought to harness the power of "radiative cooling" to help alleviate the energy burden on air conditioning. SkyCool Systems created an exceptionally thin material that acts as a mirror to sunlight. It reflects light in the infrared range, allowing it to bypass the atmosphere into outer space. In a 2018 TED Talk, Aaswath Raman, the chief science officer at SkyCool, revealed that, in practice, the material was able to stay almost 5˚C cooler than the surroundings, despite being in direct sunlight, as shown in Figure 2 [13]. The idea behind the material is to integrate it with standard air conditioning in order to improve efficiency. The improvement is estimated to be roughly 500 kWh/m2 annually [13].

Many people, scientists and politicians alike, have recognized that this kind of growth is unsustainable.

Few of these innovative systems are full replacements for the century-old AC unit. Mainly, they seek to work in tandem and improve the efficiency of energy use.

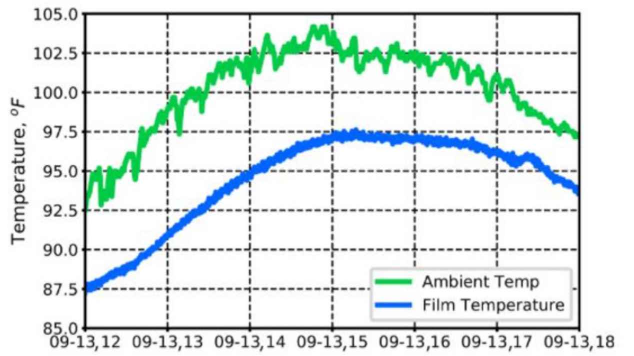

Figure 2 - Temperature of SkyCool reflecting film versus ambient temperature [13]. Data measured from rooftop in Mountain View, CA on 13.9.2019.

However, technology is not the only way that cooling efficiency can be improved. Infrastructure design is a huge factor in humanity's need for air conditioning. Trees, for example, provide excellent natural shade and cooling at absolutely no cost, financial or environmental. Unfortunately, natural elements are difficult to integrate into urban infrastructure and even many suburban neighbourhoods have all but eliminated them as a design element.

The journey to reducing humanity's growing dependence on energy-hungry AC units will be a long and undoubtedly complicated one. For many years, in temperate climates, that sector of the energy industry was largely ignored and underfunded. If AC works, why fix it? This attitude, however, is no longer an option. Air conditioning needs a revolution and fast. It must involve innovation, policy, and collaboration. With many companies and governments starting to take notice of the looming cooling energy crisis, and initiatives like the Global Cooling Prize becoming widespread and effective, perhaps mankind might finally be on the right path to a sustainably cooler planet.

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Lampposts: A Brilliant Way of Increasing Charging Infrastructure

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EV[1], BEV[2], PHEV[3], HEV[4]… So many acronyms that have been gradually introduced into our daily lives and that are becoming commonplace. They all refer to a megatrend taking place in transportation: electrification. The promotion and development of such vehicles have become the focus point of many countries as they embark in their energy transition journeys towards low-carbon or carbon-neutral economies. Policies, regulations, targets, frameworks have been implemented, paving the way towards the increase of such vehicles. For example, the United Kingdom wishes to ban the sale of Internal Combustion Engine (ICE) vehicles by 2035 and considers bringing this date forward to 2030 [1]. The share of EVs in the country has been on an upward slope over the past years reaching 7.4% in 2019 and is expected to attain over 10% in 2020 [2]. Nevertheless, the path towards electrification is paved with obstacles amongst which the issue of charging facilities.

The infrastructure for this new type of refuelling can be of two natures: public or private. When it comes to public infrastructures, and more specifically fast charging, the installed capacity in the United Kingdom is said to only cover 40% of the UK's needs in 2025 and 20% in 2030 [3]. On the other hand, for private charging infrastructure the main issue is that one must have a private parking space to be able to use such devices. Nevertheless, if we take the example of London, the majority of car owners have no off-street parking options: only 48% of London car owners have access to off-street parking [4]. Yet, it's in urban areas that short-term benefits of the increase in electric vehicles will be felt the fastest: reduced noise and air pollution. How can the electric refuelling needs of city dwellers be met in such context?

One of the most interesting things about electricity compared to other refuelling sources is that it is everywhere; no need to go far to find an electrical power outlet. Therefore, the idea would be to use the existing infrastructure in which electricity flows. This is exactly the vision that ubitricity, in collaboration with Siemens, developed, and to do so they focused on the untapped potential of lampposts. Lampposts

The road towards a green, low-carbon and sustainable transportation future is not far out of reach.

can be found on every street in every European country and city. These electricity source points represent a great opportunity to make up for the impossibility of home charging for some urban citizens. Siemens and ubitricity began, in 2018, to transform the London streets' lampposts into charge points, backed by London's Go Ultra Low City funding scheme which aimed at supporting the uptake of low-emission vehicles in the city. The overall installation process is quite simple: a SimpleSocket, developed by ubitricity, is incorporated in the compatible street infrastructures and then the customer just needs to plug in his or her Type 2 charger. Today, up to 1,300 can be counted

[1] Electric Vehicles
[2] Battery Electric Vehicles
[3] Plug-in Hybrid Electric Vehicles
[4] Hybrid Electric Vehicle

across the different boroughs. The City of Westminster is leading the race in terms of number of converted lampposts, with approximately 300 of them, including an entire street which saw its 24 lampposts turned into on-street charge points, becoming the first “Electric Avenue”. The benefit of using of such infrastructure for charging purposes is that it uses low power charging: the maximum electric output is 5.8kW. Therefore, to recharge a Nissan Leaf equipped with a 40kWh battery it would take approximately 6 hours which might sound like a very long time just to “refuel” a vehicle as we are used to the couple of minutes needed at traditional gas stations. Nonetheless, something that often goes unnoticed is that vehicles are actually in use for only 4% of the time, meaning that for the remaining time, they are parked at home or elsewhere [5]. Why not use this period of idleness to recharge them? When leaving an EV to charge for longer periods of time it enables the recharging process to sync with renewable energy generated electricity. Ubitricity has understood that to really go towards low-carbon economies, EVs will not suffice. It’s necessary to charge them using green, renewable energies in order to get closer to being CO2-neutral and to participate in the general CO2 emissions reductions.

Furthermore, these new charging infrastructures are accessible to all through the use of traditional charging cables and the scan of a QR to initiate a pay-as-you-go option or by using a SmartCable. This new technology, also developed by ubitricity, incorporates an electricity meter and a SIM card which enables it to record the electricity consumption to the kWh. The client also has the possibility to conclude a power contract just for the cable to pay for the exact amount of electricity used in charging. Starting from the authorization, to the transfer of consumption data for billing, passing by consumption metering, everything is done thanks to the SmartCable.

Ubitricity and Siemens have been able to find a solution to one of the biggest barriers hindering EV adoption: charging facilities in urban areas. Such innovative solutions that use existing infrastructure like the retrofitting of lampposts can truly help make the numbers add up: Firstly, by providing sufficient charging points to meet the needs of the increasing numbers of EVs and further pushing their adoption. Indeed, in 2019, Westminster observed a 40% increase in the number of plug-in vehicles and ranks now at the top of the London boroughs in terms of registered EVs [6]. Secondly, such solutions help countries meet their CO2 emission targets by providing renewable energy charging possibilities to EV drivers. The road towards a green, low-carbon and sustainable transportation future is not far out of reach: it just requires looking at the world with another eye and thinking outside of the box to find the right solutions.

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Decarbonising

Renewable Energies and Crowdfunding: Could Local Authorities be the Missing Link in the Energy Transition?

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Introduction

Nowadays we are witnessing an important surge in the development of renewable energies throughout the world, as a "cleaner alternative to fossil fuels and supplier to a growing electricity demand". However, these projects still encounter many challenges, from the intermittency of solar and wind power to population defiance [1].

In spite of the geopolitical, environmental and demographic stakes of these sources of energy, smaller projects start to appear around the world, and especially thanks to a new source of financing, "crowdfunding". This tool could be a great way for local authorities such as regions, counties or city councils to take an integral part in the energy

What is Crowdfunding?

Simply put, crowdfunding is a way of raising finance by asking a large number of people each for a small amount of money [2]. There are 3 main types of crowdfunding:

1. Donation: most widely used (85,3% of projects in 2018), can exist with or without financial reward [3];
2. Loan: regroups most of the amounts collected (67,9% of funds, €273M in 2018 in France); and,
3. Share in the project.

One main advantage of crowdfunding is the alternative it represents to traditional business loans through banks. Moreover, if well executed, the fundraising can be particularly fast.

There already exists crowdfunding platforms specialized in the funding of renewable projects, such as Enerfip or Lumo in France. These only propose loans and equities systems, as donations are more appropriate for charity events or NGOs campaigns.

Table 1 - Pros and cons of loans and shares from the investor's point of view.

	Pros	Cons
Loans	High interest rates (4-8%)	No tax advantage
	Participate to economy of scale	Risk of failure
	Possibility to exit early with short loan maturity	Low liquidity (though better than shares)
Shares	Tax advantages...	...but need to keep capital for 5 years first
	Participation in an entrepreneurial project	Very low liquidity
	Portfolio diversification	Risk of failure

It is important to stress the fact that a renewable energy crowdfunding project has very little chances to fail, especially with the tax incentives provided by the State (or also the electricity purchase agreements over long periods of time).

Population's Perception Towards Energy Transition

In January 2019, a "Grand National Debate" was launched by President Emmanuel Macron over the energy issues in France. This was a great way to gauge the population's back up of renewables, their expectations and how they perceive the role of each one in these issues. Today, 81% of French people back the development of solar energy, and 77% the development of wind energy. The study showed that 9 out of 10 people declare themselves ready to "engage individual actions to contribute to the energy transition" and also how they perceive the role of the State. 93% of the people interviewed declared that it was first and foremost the role of public players to engage long term and durable projects [4].

Despite this apparent support of the population towards renewables, an important challenge faced by these is a latent defiance from a non negligible part of the population, towards projects conducted by big corporations, especially those whose territory might welcome such projects. The “Not In My Backyard” opposition often encountered by renewable projects, especially wind power, can greatly hinder their development [5].

Renewable energy projects will have little chance of success if the population isn’t backing it.

Additionally, people want to have their say in these projects. As explained by Mr Stockmann, municipal councilor of the village of Sainte-Lizaigne, which welcomed several wind projects on its territory (including one in partnership with Enerfip), “people get informed more and more, and wish to profit from the economic benefits, which is obviously a normal and sane reaction”.

Defiance towards wind projects, for example, comes from the fear of the destruction of the landscape, biodiversity issues, but also from the lack of information that can arise.

This can also be linked to the need of the rural populations to get back to a local solidarity, increasing their willingness to take an active part in the economic development of their territories.

Why Local Authorities?

In this context, a vital aspect must therefore always be considered when launching a renewable project: the involvement of local citizens. This implies informing them, gaining their trust and, if possible, engaging them durably and tangibly in the development of such projects.

From this acknowledgement arisea a necessary “tripartite” management of the projects: first, the companies taking care of the development of the projects, bringing their expertise and resources to build the plants and exploit them, such as EDF Renouvelables or Engie in France.

Then, the crowdfunding platforms, mentioned above, taking care of the fundraising, the communication of the project (before, during and after the development) and the financial reward of the people involved.

Finally, the local authorities such as region boards or city councils: these institutions know their territories, the population and its expectations, therefore their expertise and proximity to the citizens must not be underestimated. On the contrary, these are precious bodies for the developing companies to get acquainted with the population, inform them on the projects and gain their trust.

Crowdfunding and Renewables: Instruction Manual

How can a local authority engage a crowdfunding campaign towards its citizens to develop renewables? What are the vehicles to use to operate an efficient fund raising? Which pedagogy?

Not long ago, local authorities still essentially had a role of observer and juridical processes facilitator (planning and development permits), but a growing involvement of these bodies can be witnessed in the last few years.

A primary (and vital) process that must be engaged by local authorities are the preliminary studies about the population: this allows companies, crowdfunding platforms and local authorities to detect potential oppositions and skepticism.

To remedy any such defiance, the logical next step is a thorough groundwork with the population, operated jointly by the 3 players mentioned in the tripartite governance before:

1. Information sessions with elected officials;
2. Popular gatherings;
3. Presence at the local marketplace, where engaging conversations with citizens is a great way to give more information about the projects and get additional information from them;
4. Public reunions where citizens can express their fears and ask questions to the players involved;
5. Regional press;
6. Leaflets posted in mailbox (for retirees for example); and,
7. Finally, durable partnerships with associations taking care of the local environmental, biodiversity and cultural heritage issues.

It is important to take into consideration the fact that parts of the population may not be comfortable with the now-traditional ways to promote projects via the internet. Moreover, from the point of view of companies,

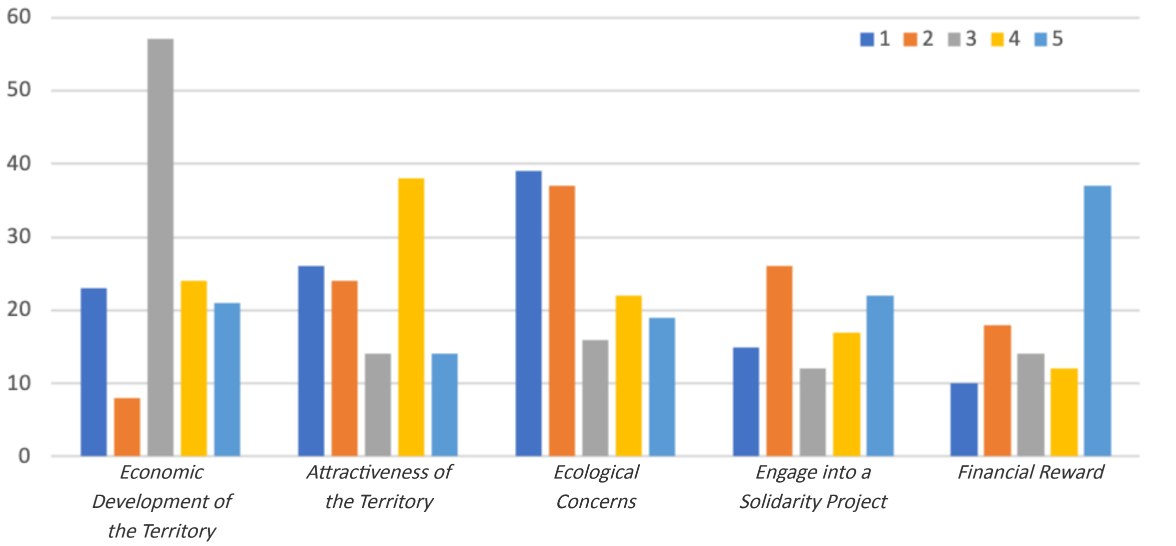

Figure 1 - What would be your main motivation to invest in a renewable project? (1 = Strongest, 5 = Weakest)

it is extremely important to "humanize" these projects, show willingness to engage the population and their adaptability and flexibility to their expectations.

Ms Vanderkam, Development manager of renewable energies at the Compagnie Nationale du Rhône (CNR, first provider of renewable electricity in France), explained in another interview that renewable energy projects will have little chances of success if the population isn't backing it.

For these companies, crowdfunding is essentially an "acceptation tool" (the funds will represent at most 10% of the total amounts needed), but an excellent mean to introduce the project and make it closer and more accessible to the population.

Which Motivations?

The local authorities must use different levers to gain the population support. The most important one is the transparency of the project. An impact assessment study conducted by the company at the very beginning of any project must be presented to the citizens: they allow them to observe how all environmental, cultural and landscape stakes are taken into consideration. Any renewable project will have downsides, but it will be necessary to present them to the population.

The quantitative study conducted along with the interviews also showed the main motivations for the citizens to invest in the projects (Figure 1).

We can witness here that the ecological concern is the primary reason a citizen would invest in a renewable project. Solidarity is an important aspect too.

For now, the primary way a local authority can make its citizens invest in a renewables projects thanks to crowdfunding is through loans, with maturities varying between 6 months and 5 years, and interests rates between 4% and 8%, making them particularly attractive to citizens.

More Integration: Semi-Public Companies

An interesting alternative can be proposed to the citizens: the authorities can decide to open the capital of a semi-public company, or simply create the latter and make citizens shareholders. This induces an even stronger need for pedagogy from authorities and the private company (taking care of the construction of the plant), as now citizens are taking part of the governance of the company. Here, the collectivity must remain the majority shareholder to keep decision power.

The interest here resides in an even greater degree of integration of the population, which holds a strong influence over decisions: the collectivity remains the decision maker and truly engages its citizens , while benefiting from the expertise of the private company.

Mistakes to Avoid

First, a company trying to use crowdfunding as a means to buy social peace, or "silence oppositions" will often create the opposite effects. Citizens have the capacity to understand the various stakes of these projects, and informing them will always be more beneficial than just trying to "buy" them.

Then, it is also very important to operate an early communication of the project, to let citizens have time to prepare themselves to invest, and understand the stakes of the project.

After Fundraising

A continuous communication about the construction of the plant, its electricity production, financial data on the shares or loans, maintenance of the plant etc is primordial. The survey conducted showed that a monthly email newsletter, coupled with regular information sessions, are the simplest and most effective ways to inform the investors. But traditional means such as physical letters mustn't be ignored.

Moreover, several means of valuing the lands used, such as vegetable growing, apiculture or cattle breeding also exist: these allow for a "multipurpose" project, further improving the acceptance of the project by the population [6].

Conclusions

A true collaboration between the local authorities, crowdfunding platforms and energy companies is vital. Indeed, this "tripartite governance" rests on each's expertise: The companies have the financial means and expertise to construct the plants, while the crowdfunding platforms master the fundraising methods and the pedagogy to be brought to the population.

The local authorities benefit from a profound understanding of its territory, and especially from its proximity to its citizens.

Many tools exist for authorities to integrate their citizens into these projects, but one supersedes the others: groundwork. This will truly complement the integration momentum started by the crowdfunding campaign, by adding an aspect of proximity to the population.

Crowdfunding alone cannot make citizens adhere to the project, and the local authorities must use its strong bond with them to ensure the intermediation with the other players involved on one hand, but also raise the voice of the population.

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Liquid Air Energy Storage and its Contribution to Energy Decarbonisation

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"The Earth has a deadline" were the words looming over the passers-by in Manhattan this September [1]. The warning appeared next to the famous Metronome clock, as it displayed the time left until the effects of global warming become irreversible [1]. The urgency of combating climate change is widely accepted around the globe and is certainly not underestimated by the scientific community. The list of innovative technologies that have been proposed to achieve the vision of a carbon-free future is long and constantly expanding.

As we are nearing the deadline, it is worth focusing on the pursuit of solutions that can have an impact here and now. According to studies, electricity generation sector has the greatest potential for decarbonisation in the coming years, and thus deserves significant attention [2]. This potential stems from the prevalence of renewable energy technologies, such as solar or wind, in the sector. Among other decarbonisation solutions, renewable technologies stand out as boasting both technological feasibility and economic viability, which clearly explains their popularity. Since the road to technological feasibility can be long and arduous, the probability of developing more innovative technologies in time to meet the impending deadline is not in our favour. Therefore, in the short term, it is worth considering how to make the implementation of renewable energy faster and easier.

Liquid Air Energy Storage (LAES) is an example of a technology that can greatly contribute towards that goal. The concept behind it is to store the renewable energy available from wind or solar power plants in liquefied air so that it can be released and utilized at any chosen time (Figure 1). To achieve this, the air is first compressed and expanded in stages. As a result, a very low temperature is reached, at which air can exist in the liquid phase, and thus this series of steps is usually referred to as 'Liquefaction' [3].

The liquid air is then stored in tanks, specially designed to be able to sustain this extremely low temperature [4]. When energy is required, the air is retrieved from the tank and evaporated using an external heater [5]. The resultant gas is sent to a turbine, where the energy contained in the highly pressurized air is converted to electricity. The operation of that unit is based on simple laws of physics: as air is expanded, it releases its internal energy, inducing the movement of the turbine, which is used to generate electricity. The retrieval of

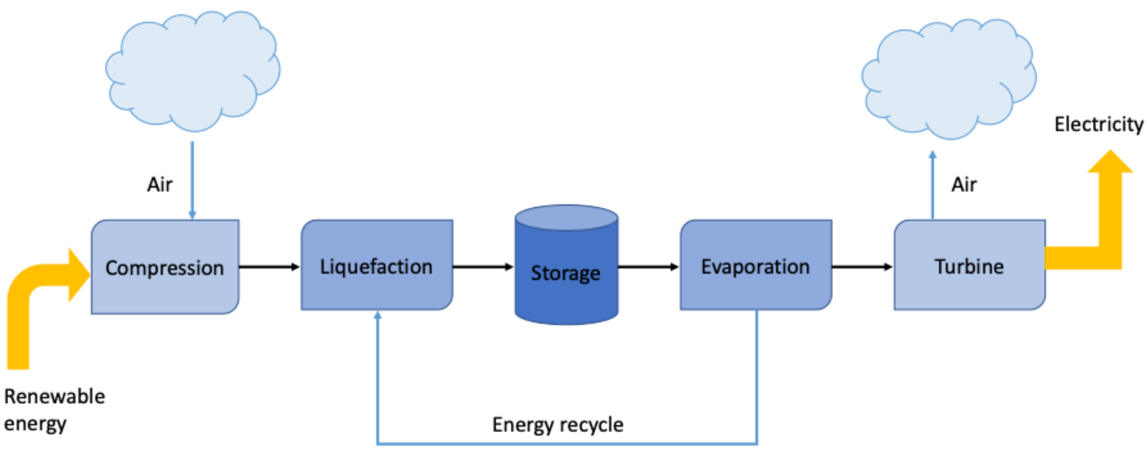

Figure 1 - Liquid air energy storage process.

As we are nearing the deadline, it is worth focusing on the pursuit of solutions that can have an impact here and now.

energy causes the air to return to its original condition, including atmospheric pressure so that it can then be released safely into the atmosphere.

Employing energy storage mitigates the most important challenge associated with increasing electricity generation from renewable energy sources – their unpredictability and inflexibility. Renewable energy supply varies based on time and weather conditions, experiencing peaks and troughs, which will not necessarily align with the variations in electricity demand, leading to a grid imbalance. Therefore, energy storage plays an important role in grid balancing, as it allows surplus energy from renewable resources to be stored and released with great flexibility. Thus, energy storage helps to both reduce the waste of potential energy at the time of low demand and to satisfy the additional energy load needed at the time of high demand.

Additionally, LAES has certain advantages over traditional large-scale energy storage methods, such as pumped hydro-electricity storage (PHS) and compressed air energy storage (CAES)[4]. The former does not have significant potential, as it involves pumping water from a lower to a higher reservoir and thus is heavily limited by the geography, has a considerable impact on the natural environment, and is associated with large capital costs [4]. Therefore, it is unlikely to play an important role in grid balancing and decarbonisation of the electricity generation sector, as it cannot be implemented on the necessary scale. On the other hand, LAES has no special location requirements, and thus offers greater flexibility. The process is also non-polluting, therefore having minimal impact on the environment, and can be easily implemented into existing plants, offering a potential reduction in capital cost [5].

The other alternative, CAES, is largely similar to LAES. The main difference between the two processes is the absence of the liquefaction step, following air compression, in CAES. Since this step increases the efficiency of the energy storage, it makes LAES a much more promising alternative. More precisely, the efficiency in LAES is improved by recycling of air between the liquefaction and evaporation sections. The cold thermal energy available in the evaporation section, in form of air at cryogenic temperatures, can be used to enhance liquefaction earlier in the process [4]. Although this energy cannot be recycled completely, this small alteration still significantly improves the performance of the process.

The potential of Liquid Energy Storage has not gone unnoticed. To meet the government's pledge to achieve net-zero emissions by 2050 [6], industries in the UK are actively implementing solutions to aid the transition to carbon-free electricity. One example is a LAES plant near Manchester, equipped with the world's largest liquid air battery, which is being developed by Highview Power [7]. The construction of this plant commenced this year and according to predictions, the operation will begin in 2022 [7]. This bold undertaking coincides with the growing share of renewable energy in the UK and the problems with grid balancing that arise as a result. Currently, energy used to balance the grid and boost the electricity supply during high demand is produced mainly from fossil fuels [2]. Effective energy storage can eliminate the need for the generation of this supplemental energy, reducing dependence on fossil fuels even further. Moreover, implementing energy storage makes renewable energy more appealing to investors, by adding an economic incentive. According to predictions, the benefit of deploying energy storage will reach approximately £2bn/year by 2030 and £11bn/year by 2050 [8]. These savings come from the reduction of renewable energy waste, which can be halved if energy storage is implemented [8].

Will the plant in Manchester, and others that might follow, help the world successfully meet the impending deadline? That is not something we can know for certain. What we do know is that in only 2 years this technology will be employed, and from that day it will have a tangible impact on the way energy generation evolves to combat climate change.

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One Step Forward for Renewable Energy: Energy Storage

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What is Energy Storage?

Energy storage means to keep energy in order to use it in the short, medium or long term. To begin with, maybe we are not aware, but we use energy almost for everything, whether for transportation, heat or electricity. Moreover, the energy-supply process is quite complex since energy should be available when is required and at the lowest possible price. For this reason, consumers and companies have consistently stored energy in its classical forms throughout history, such as thermal energy (e.g. heat), chemical energy (e.g. oil), electrical energy, etc. For example, storing coal or oil are traditional methods of energy storage; while batteries, dams or hydrogen are "modern" alternatives to keep energy.

Renewable Energy and Energy Storage

Since energy storage has always been practiced, what has changed so that energy storage has become a trending topic? The answer is the eruption of renewable energy in recent years.Over the last centuries, fossil fuels such as carbon, natural gas and oil, have been the main sources of energy. Even now, the main source for transportation around the world comes from oil. However, fossil fuels bring two relevant problems to society:

1. An economical problem, in terms of the total expenses in energy and its lack of predictability. Oil and natural gas (specifically, Liquefied Natural Gas - LNG) are commodities and their prices depend on specific regional markets, such as WTI in America or Brend in Europe, both of them for oil. For instance, the WTI barrel of oil exceeded 150 US$ in 2004, but it was negative (-37 US$) during last June because of the Covid pandemic. Some experts say that the era of high oil prices has finished with the emergence of shale oil [1]. We cannot say for sure however, how oil prices will behave in the coming years. A similar scenario is expected for the natural gas, which is projected to become one of the main energy sources in the coming decades [2], especially in South and East Asia.

2. An environmental problem, since the burning of fossil fuels releases immense amounts of greenhouse gases, such as CO2, causing pollution and accelerating climate change, which is considered a worldwide catastrophe. For sure, this problem does not need more explanation, since we are experiencing all of the consequences of climate change, such as the lack of consistency in the weather systems. Thus, in order to stem the problems associated with fossil fuels in recent years, renewable energy is one of the main logical substitutions.

Renewable energy has better prices and less environmental impact than fossil fuels. For instance, solar energy has had a sharp cost reduction in past years and is currently the cheapest source of electricity, even in comparison natural gas power plants [2]. While all human activities have an impact in the environment, some are more harmful, such as the burning of coal. Renewable energy also affects the environment, but if we use renewable energy as a substitution for fossil fuels, we will be improving the system by reducing net pollution.

Renewable energy can provide different types of benefits to the energy systems, such as a robust energy matrix. One of the benefits of employing renewable energy is the variety of generation technologies available. When talking about renewable energy, we refer to technologies such as solar, wind, geothermal, hydro, and tidal energy. Their diversity allows them to complement each other. For instance, one cannot control solar energy output as it depends on available sunshine, and even during the summer we can have days of short supply when it is cloudy. Decades ago, the homogeneous answer for dealing with these short periods of energy deficits, as well as for peak demand

Table 1 - Storage to meet the need of the system. Adapted from [3].

Services Needed	Description	Storage Type	Timeframe
Seasonal Heat Demand	Seasonal demand for heat. Reduced PV generation in winter.	Medium – Long	Weeks – Months
Meeting Daily Peak Demand	Provide energy to meet peak demand - heat or electricity	Short – Medium	Minutes – Hours
System Resilience	Provide security of energy supply for unexpected loss of generation or extreme weather conditions.	Short – Medium	Minutes – Hours
Renewables Integration	Large-scale variability in output from wind and solar due to weather patterns	Medium	Minutes – Days
	Short, hourly variations in weather - sunlight (PV generation) and wind	Short – Medium	Minutes – Hours
	Reduce curtailment of wind & solar - capture 'surplus' energy when generation is higher than demand	Short – Long	Minutes – Hours
Electricity System Services	Stabilize electricity networks - manage very short-term variations in supply and demand. Synthetic inertia: smooth very-short changes in supply - a service that was inherent in conventional power generation, but not in renewables.	Very Short	Milliseconds – Seconds

hours, was through the development of oil-fired power plants. However, new methods and technologies have been developed which allow the energy systems solve this problem using different means. Excess of energy, which could come from any renewable source can be used to pump water into a dam, allowing electricity to be generated when it is required. Alternatively, it is possible to keep the energy in batteries, with the same purpose. The result is not only less cost, but also less pollution.

Nevertheless, one of the main problems of renewable energy is its intermittency. Demand wants energy when it is needed, but the renewable energy only supplies when it is windy or sunny for example. This is the reason why an energy system should be complex enough to have different sources of energy (a diversified energy matrix) and a margin of reserve (excess of capacity). Additionally, this lack of flexibility implies the necessity to develop storage systems. The more renewable energy an energy system has, the more facilities for energy storage it will need. Some primary situations in which energy storage would be needed in order to ensure security of supply in an energy system are summarised in Table 1.

Energy Storage Challenges

Energy storage systems need more government support to overcome their actual challenges. Decades ago, it was assumed that electricity couldn't be stored efficiently, and so electricity systems were designed so that there should be a permanent equilibrium between supply and demand in order to avoid losses. This means that the electricity systems were built mainly unidirectional, taking the energy from the generation hubs (supply) to the distribution systems (demand) through transmission systems as shown in Figure 1. However, the principle that energy cannot be stored efficiently is not valid anymore, meaning that it is possible for distribution systems to be suppliers (prosumers), especially when energy demand is low. This means that electricity systems need to be bidirectional (Figure 2). However, most electricity systems are not prepared for these changes and several modifications need to be made, not only in

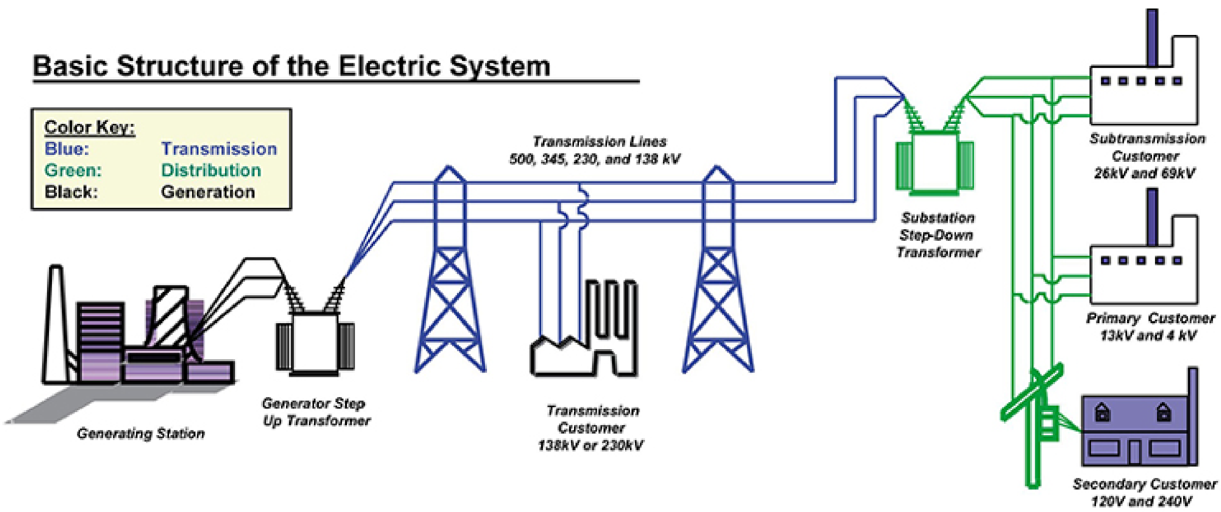

Figure 1 - Structure and targets of the energy concept. Source: IEA.

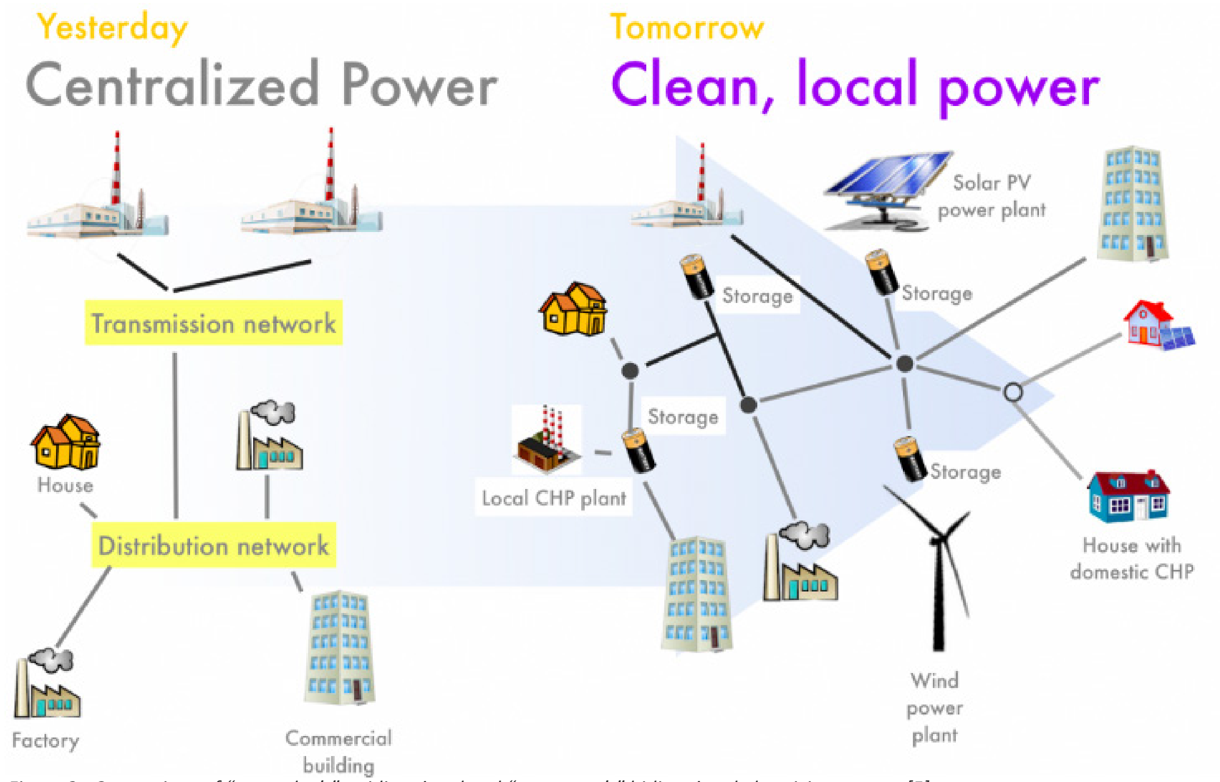

Figure 2 - Comparison of "yesterday's" unidirectional and "tomorrow's" bidirectional electricity systems [5].

terms of infrastructure but also in terms of regulation.

This is happening in electricity grids, but the context is the same in all the different fields where renewable energy and energy storage have arrived, such as transportation. For example, nowadays the prevalence of electric cars, buses and trucks means that there are many electricity storage devices driving around on our streets. However, a real change from fossil fuels cars to electric cars implies the development of new infrastructure, such as electric vehicle charging stations. In addition, some important regulation decisions are required, for example, in terms of standardization, unidirectional or bidirectional supply, ownership, etc. [6].

Probably, the most complex question to answer is about the nature of energy storage. Technically, energy storage has two categories, as it is energy user and energy producer at the same time. The storage system buys energy from the system (user phase), stores it (e.g., pumped hydroelectric energy as shown in Figure 3), and then injects the electricity back into the system when there is demand (producer phase). This lack of a well-defined producer/consumer category is a situation of great importance in conventional unidirectional electricity systems, since the payment of the tolls and tariffs depends on which category an entity belongs to. Should energy storage systems pay the tolls and tariffs corresponding to consumers, producers, or both? In some countries where the legal framework is complex, energy storage has had to pay both consumer and generator tariffs, which clearly constitutes an unfair and anticompetitive rule for this technology.

Nevertheless, the good news is that the worldwide authorities are conscious that energy storage significantly matters. In the United States, in 2018 the Federal Energy Regulatory Commission (FERC), responsible for the regulation of the interstate transmission of electricity, natural gas and oil, issued the Order 841 approving "Electric Storage Participation in Markets Operated by Regional Transmission Organizations and Independent System Operators". The FERC explains that energy storage faces important barriers, since they use existing participation models

> Energy storage falls under two system categories, as it is both a consumer and a producer at the same time.

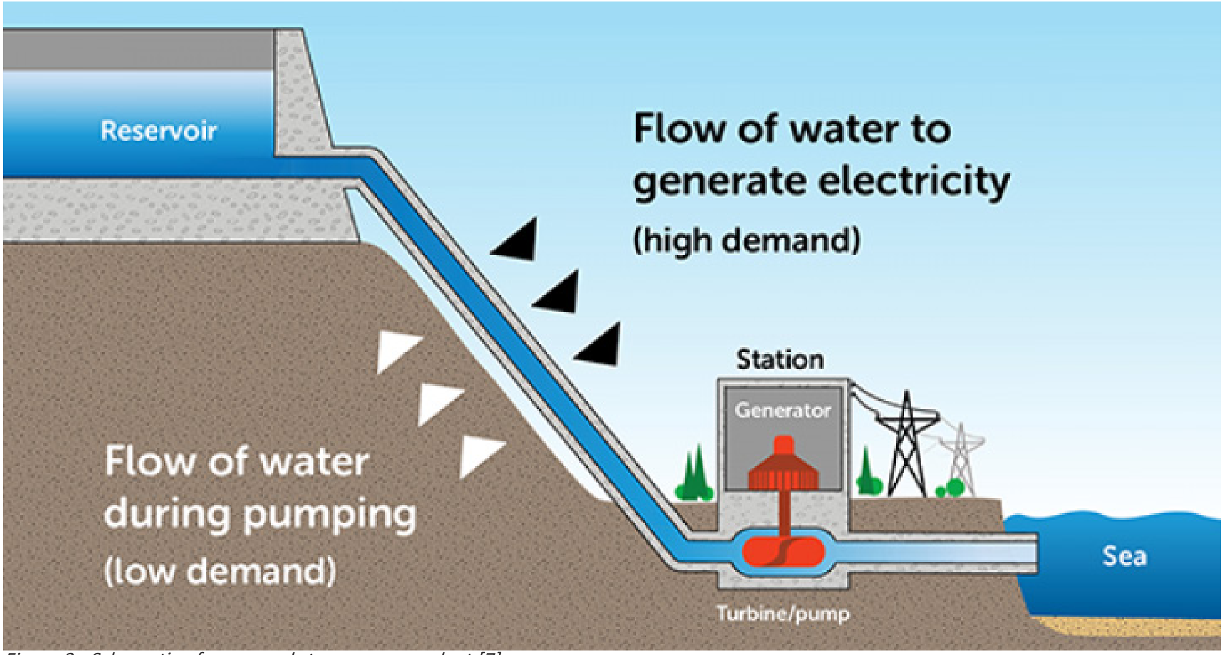

Figure 3 - Schematic of a pumped storage power plant [7].

designed for traditional generation or load resources, which do not recognize electric storage resources' unique physical and operational characteristics and their capability to provide capacity, energy, and ancillary services. Consequently, the electricity resources are not efficiently dispatched, affecting competition in the market. For this reason, the FERC requires changes in order to allow energy storage to participate in the provision of capacity, energy, and ancillary services. In addition, the FERC establishes that the minimum size requirement for participation in the markets must not exceed 100 kW; and, that the sales of electric energy for energy storage must be at the wholesale marginal price.

Similarly, in 2019 the European Union issued the Regulation on the electric internal market (EU) 2019/943, Directive on common rules for the internal market for electricity (EU) 2019/944, and an amending Directive 2012/27/EU. These regulations "establish rules to ensure the functioning of the internal market in electricity and include certain requirements related to the development of renewable energy and environmental policy, in particular specific rules for certain types of installations for the production of renewable electricity, as well as a threshold for CO2 emissions for the new generation capacity" [8]. The key to these regulations meeting their objectives consist is to make use of all available sources of flexibility, particularly demand side solutions and energy storage, and make use of digitalization through the integration of innovative technologies with the electricity system.

Finally, in the case of the UK, Ofgem, the gas and electricity market regulator, has recently (October 2020) made the decision to classify energy storage as a subset of generation. This change will enable energy storage to be treated as generation in terms of rules and regulations; and, as a result, energy storage will avoid the unfair double payments that it is currently facing as a generator and a consumer.

Final Conclusions

This is only the beginning for energy storage, the future appears promising. We know that energy systems are moving towards renewable energy. The economic and environmental problems related to fossil fuels make it mandatory to undertake this transition. In the development of these new markets, the participation of energy storage is also a must. Renewable energy and energy storage make the perfect match, complementing and supporting each other (see Table 1). However, not only infrastructure but also rules and regulations are not prepared for renewable energy and energy storage. Nevertheless, recent regulatory decisions allow us to believe that the governmental authorities are aware about the regulatory challenges that energy storage is facing, and how we should solve them. Even though in the war against climate change and pollution there is a long way to go, major regulatory reforms regarding renewable energy and energy story must be accelerated.

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Security of Supply

From Nuclear Phase-out to Renewable Energy in Germany: Can Natural Gas Operate as a Bridging Fuel?

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Abstract

This article develops a factual analysis of the renewable energy transition in Germany. Starting from the German decision to phase-out from nuclear power, an economic discussion is conducted on the specificities of this energy shift and its associated economic and environmental constraints. In this dynamic, natural gas is thought to play a crucial role. Less carbon intensive than other fossil resources, gas-fired plants require a relatively lower capital cost than renewable energy sources, dealing for their part with important technological and time constraints. Analysing the current public and political debate on hydrogen, it is shown that the issue of natural gas presents itself as a controversial issue, but in a concealed way. All in all, this article is thought to represent a fruitful energy communication able to bring inclusive knowledge to the reader.

Introduction

When it comes to their electricity mix, Germans are quite vocal on what they don't want. Nuclear power? "Nein Danke"! Coal? "Climate killer"! Those were not only the slogans of the environmental movement, but also became the foundation for the phase-out from both technologies until 2022 (nuclear) and 2038 (coal). While the goal for 2050 is a carbon-neutral energy system [1], the question arises which technology can bridge the remaining time until a fully-renewable-based energy system is established. Among others, the International Energy Agency (IEA) therefore underlines the role of Natural Gas [2]. This article contextualises the economic and political developments concerning natural gas in Germany and its role in the upcoming years.

Natural Gas as a Bridging Fuel: Economic Insights and Environmental Constraints

The crucial role of national gas in the transition towards low-carbon technologies is far from being a coincidence and can be explained with several arguments. Above all, the German economy has been showing an early interest in natural gas for these past decades, becoming thus the world's 8th largest natural gas consumer in 2018 [3]. Covering more than 25% of its total primary energy use in 2019, natural gas is more efficient, can be easily stored and provides a strong operational flexibility and safety [4,5]. In addition, gas-fired plants lower the requirement in time and capital costs when compared with renewable energy facilities, which eases investment decisions for many firms [5,6]. Overall, a range of econometric assessments have highlighted the existence of crucial linkages operating between natural gas consumption and economic growth in various economies [7-13]. Providing far-reaching policy implications, a unidirectional causal relationship running from natural gas consumption to economic growth may emerge if the economy is considered as an energy dependent one. In line with the "growth hypothesis", any policy limiting the deployment of natural gas may adversely affect the economic indicators. Therefore, natural gas seems to be an attractive and relevant option of energy substitute among other fossil energy sources (notably coal-burning power plants) [14]. Although it remains non-carbon neutral, generating power based on natural gas is less environmentally harmful than other non-renewable resources as it releases less CO_2 emissions into the atmosphere. In this quest, it has emerged as a cheaper, cleaner, and non-negligible alternative source of power, especially under a context of energy transition [6,11].

Resulting from numerous controversies and early protests movements, the German decision to phase-out from nuclear power by 2022 and from coal until 2038 will have drastic consequences [15-17]. Naturally, a critical gap will emerge in the power supply. And one should not omit that still in 2011, coal and nuclear have made up more than 85% of the German power supply [18]. Thus, it calls for comprehensive energy

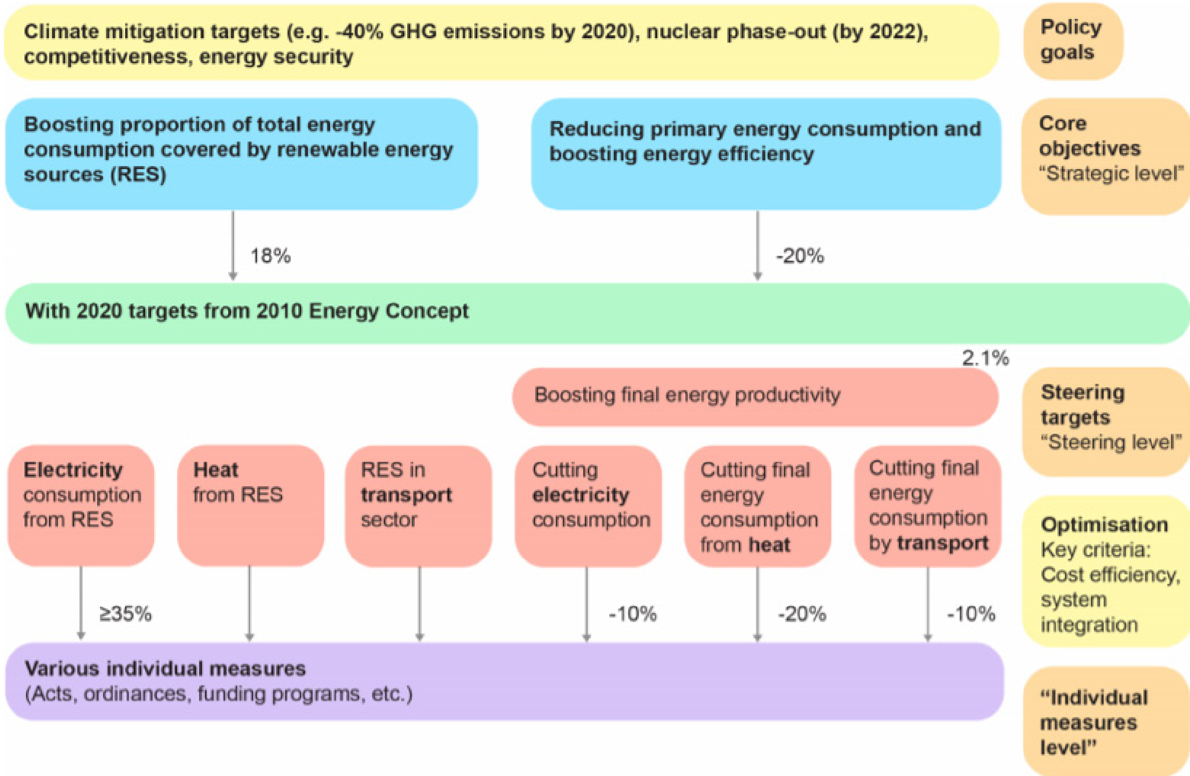

Figure 1 - Structure and targets of the energy concept. Source: IEA.

measures aiming at filling this differential. While low-carbon resources are heavily promoted to take an important share in the near future, electricity remains substantially generated from non-renewable energy sources and nuclear power. Thus, pressure is high for the Energiwende. Although several policy measures have been implemented to support the research and the deployment of low-carbon energies, research papers and policy reports identified several key barriers to the adoption of renewable energy technologies [2]. Consequently, in line with the IEA's recommendations (i.e., Germany should "clearly convey the role of natural gas" in the future), natural gas is seen as a bridging fuel able to ensure a feasible energy transition towards a long-run sustainable path.

But five unavoidable obstacles should be addressed. First, due to insignificant domestic fuel resources, Germany must rely on massive imports, covering about 94% of the gas consumed annually [19,3]. As over a third of all imports comes from Russia, with an increasing tendency [20], Germany's reliance on natural gas thereby causes tensions with its neighbours and partners, most notably over the almost completed North Stream 2 pipeline, which is considered as geopolitical threat by the United States and Poland [21-24].

Second, with a length of about 35,000 km, the German high-pressure gas transport infrastructure faces important challenges [25]. Deploying transport-related infrastructure for natural gas can be correlated with pipe leakages, harmful for the environment, and whose quantification is at the centre of ongoing research [26]. Third, another barrier for gas stands in its lack of cost-effectiveness (known as the "missing money" problem in the literature). Indeed, when electricity generation from renewables increases, prices for power may fall lower than the costs of necessary investments [27,28]. Fourth, one cannot avoid the fact that the global benefits from the shift towards power-based natural

When electricity generation from renewables increases, prices for power may fall lower than the costs of necessary investments.

gas remain conditional to adequate environmental regulation decisions [14]. To avoid a serious rise in environmental pollution, proper policies need to target all "fugitive emissions" by enhancing the deployment of new highly efficient and flexible gas power plants, but also on the possible capture and storage of carbon residuals efficiency along the whole power generation process [29].

Fifth, when looking at the structure and targets set by the Energy Concept (Fig. 1), one finds that reducing the consumption of primary energy through efficiency is at the forefront of the Greenhouse Gases (GHG) reduction strategy. By boosting the fuel productivity, the government projects to achieve significant emissions cuts in terms of electricity and heat consumption, while the transport sector is thought to contribute substantially to this dynamic.

This objective is laudable but comes up against a critical obstacle: the level of total energy consumption of the German economy. Fig. 2 presents the time plots of total final energy consumption by sector in Germany from 1990 to 2019. Data are collected from the IEA [3]. One striking observation is that, although the global energy consumption has almost stagnated over time, industry, transport, and residential sectors remain highly energy-intensive [3]. This indicates that the deployment of a low-carbon electricity capacity should not only cover the gap created by the abandonment of nuclear power, but also meet the heavy energy needs required by domestic and industrial operations. Finally, one should not avoid the progressive electrification of the transport sector in future power and environmental planning. While expecting short-run benefits from the current energy efficiency measures is limited, it would undoubtedly facilitate the development of a green power sector by lowering the energy demand in the long-run. In-between, natural gas may ensure a tailored supply of electricity to those sectors.

For the above-mentioned reasons, natural gas imports emerge as a relevant strategy to address the German challenge and reconcile its short- and long-run policy constraints. Thus, beyond allowing the development and the market penetration of renewables on the long-run (i.e., the "bridging" purpose), natural gas could also act as a "backup generator" able to meet the remaining loads depending on the well-known volatility of power-based renewables across time and seasons. Naturally, in a 100% renewable-based energy system, hydrogen and methane, produced with renewable energy (power-to-gas), would play this role. But reaching the substantial demand requires time and the further development of the necessary technology, so in the medium-term, most prognoses see an increasing share of natural gas in electricity production until 2030 [30,31]. While it was mostly coal and the rising share of renewables that initially replaced the nuclear power plants that have been taken off the grid after 2011 [32], the share of natural gas in power generation is now on the rise again due to an increase in the CO2-price and the legally decided coal phase-out. Up to now, besides its utilization for power

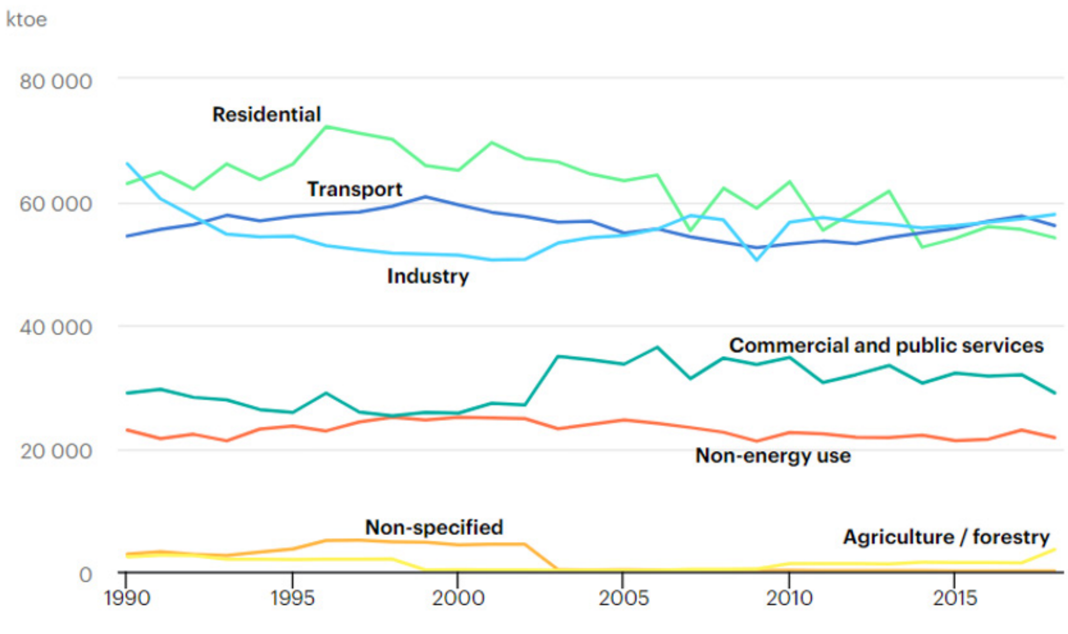

Figure 2 - Total final energy consumption by sector in Germany from 1990-2019. Source: IEA [3]. NB: Non-energy use covers use of other petroleum products such as white spirit, paraffin waxes, lubricants, bitumen and other products. It also includes the non-energy use of coal (excluding peat). These products are shown separately in final consumption under the heading non-energy use. It is assumed that the use of these products is exclusively non-energy use [3].

and coupled power-and-heating generation purposes, a substantial share of gas imports is rather used for industrial, private consumption and trade purposes. While its consumption by households will decline as efficiency rises [24,31], Germany is not sheltered from a significant natural gas surge in the near future [33].

A Colourful Picture: The Concealed Political Conflict on Natural Gas in Germany

Besides the intense public debate on the time horizon of the coal phase-out [17], Germany's energy policy debates in 2020 revolved primarily around the Federal Government's hydrogen strategy, which was adopted in the summer [34]. In contrast, natural gas often seems to be overlooked in the public debate. But while it may not be visible at first sight, the debate about the orientation of the hydrogen strategy was indeed decisive for the future role of natural gas. The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, led by the social democrat Svenja Schulze (SPD), insisted that only "green" hydrogen would be promoted. Her conservative colleague in the Ministry for Economic Affairs (BMWi), Peter Altmaier (CDU), however, also considered "blue" and "grey" hydrogen as indispensable for the transition process [35]. While this play of colours initially may look like a question of detail, it actually conceals the future role of natural gas. While "green" hydrogen is produced by electrolysis from water with the use of renewably produced electricity, "blue" and "grey" hydrogen is extracted from natural gas [36]. The hydrogen is thereby considered blue instead of grey, if the CO2 released during this process is stored using Carbon Capture and Storage (CCS) and is not released into the atmosphere.

The debate on the priority setting of the hydrogen strategy was closely followed and commented by the lobbying associations of both the gas industry and renewable energies [37,38] thus forming a decisive arena in 2020 in which the future of natural gas in Germany was negotiated. With promoting "CO2-neutral" hydrogen (including the blue one) and "technology openness" (e. g. regarding hydrogen cars instead of focussing on more efficient battery electric vehicles), proponents of natural gas present it as an important component of the future's energy system, instead of a fossil technology which has to be overcome [24,39]. The Christian Democratic governing parties CDU and CSU are open to this view. They regard CCS as an important step towards climate neutrality [40], even though concrete experimental projects often meet with resistance from the population [41] and plants adopting CCS are predicted to still have significantly higher overall life-cycle carbon emission than renewable technologies [42].

Concluding Remarks and Policy Suggestions

Drawing on insights from an economic and a political perspective, our analysis has shown that natural gas will clearly play a role as "bridging fuel" in the road towards a renewable-based energy system in Germany. The extent to which natural gas will be needed in this transformation process, however, will depend first and foremost on the success of the German government's energy efficiency efforts. If it succeeds in significantly reducing the energy demand in the coming years, it can thus reduce its dependence on natural gas, including the associated difficulties outlined in the analysis. The planning of future gas infrastructure should be based on realistic assumptions about the future needs of the electricity, mobility, heat and industrial sectors.

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Demand Response: Small Changes by Consumers, Giant Flexibility in the System

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Since electricity supply and demand should be balanced dynamically to avoid voltage and frequency collapse, the power system is experiencing rapid upgrades in energy generation globally as the electricity consumption continuously increases. In a traditional power system, the electricity is mainly supplied by large thermal power plants. The thermal power plants burn substantial fossil fuel every year, resulting in the high emission of carbon dioxide. Such excessive emission of greenhouse gases (e.g. carbon dioxide) leads to global warming and climate change. To fight against global warming, it becomes a worldwide agreement that greenhouse gases emission must be reduced. One of the promising approaches to cut back carbon emission is to have renewable energy resources to replace traditional combustion generators in electricity supply [1,2]. In modern power systems, the increasing penetration of the renewables includes both the centralised form (e.g. off-shore wind farms) and the distributed form (e.g. photovoltaic panels installed in residential buildings).

Although the renewable energy resource has advantages for carbon emissions, the inherent uncertainty and volatility of power output have brought great challenges to the security and stability of the power system. The power fluctuation of RES can be addressed in different parts of the power system. One widely implemented solution is to have spinning or standing reserves to ensure the power supply. The changes in renewable power output can be compensated for by part-load gas turbines, known as close cycle gas turbines (CCGTs), or fast response generators (standing), for example, open cycle gas turbines (OCGTs). Such reserves can respond to the unbalanced electricity demand in a relatively short time, but the generation efficiency is lower and fossil fuel usage is higher than the conventional combustion turbines, mitigating the emission reduction brought by the renewable energy [3]. Another possible way to tackle the uncertainty of renewable energy resources is to interconnect the power systems in different regions, therefore flatten the fluctuation of the output of renewables by exchanging power with neighbouring power grids. However, the interconnection between the power systems might potentially lead to a larger scale of blackout during fault, which limits the application of this method. The idea of changing the demand corresponding to supply to meet the provided energy, known as demand response (DR) or demand management (DM), is widely explored by researchers. In the context of reliable power supply, DR and DM are regarded as efficient ways to make use of the generation capacity (both central and distributed) and network capacity.

DR is not a new concept. In 1988, price signals were proposed to regulate electricity consumption to implement DR [4], which was regarded as an indirect load control method. Instead of changing the load by estimating an appropriate price, some researchers proposed direct load control methods [5]. Under direct load control, the system operators have entire access to control the responsive demands, which means that they can utilise the most of the potential of those demands. However, comparing with indirect load control, the requirement of communication and computation of direct load control is much higher [6,7].

Generally, customers can participate in DR by reducing electricity consumption in peak hours through load curtailment or shifting the demand to off-peak hours. Such load curtailing or shifting usually has trivial or limited impact on customer comfort. For example, considering the heating or air conditioning, the occupiers can accept it when the temperature is within a predetermined range. This is allowing these loads potential to be regulated, as long as the temperature constraints are meet. Although it may not be sensible to the customer, the flexibility introduced by a large number of responsive loads makes a difference on a system level, since it provides system operators with a new option to mitigate the fluctuation of the RES power output.

Although there are varying criteria [8], DR programmes can be classified as below:

1. Rate-based DR programmes: the electricity price changes with time to regulate the electricity consumption of the customers. Customers would need to pay a higher price for electricity during peak hours, therefore they are encouraged to shift their load to off-peak hours, flattening the load curve. The electricity price is usually published hours or days ahead.

2. Event-based DR programmes: customers are rewarded by responding to the request of demand reduction, which is triggered by grid congestion or power supply outage. DR service provider (or aggregator) usually have an agreement on hours limits (both for individual event and throughout the year) with the customers in such DR programmes.

3. Demand reduction bids: large industrial or commercial customers can participate in the price market, offering flexible capacity and their price.

DR programmes can also be divided into different groups according to the pricing options, including time of use rates (TOU), critical peak pricing (CPP), and real-time pricing (RTP) [9].

The implementation of DR can bring multiple advantages to the whole electricity sector. Considering system security and the uncertainty of renewable energy sources, the traditional power system tends to have more spinning power reserve (e.g. CCGTs) and standing reserve (e.g. OCGTs) as the penetration level of renewables increases, leading to an increase in the investment and operation costs [10]. As mentioned before, the efficiency of such reserve is relatively low while the carbon emission is higher than conventional power plants. Such devices can be replaced by DR, which is considered as a more environmental-friendly and cost-efficient approach. The system service is also improved since DR is utilising the flexibility of a large number of geographical-distributed loads, whose reliability is higher than the reserve provided by several combustion generators [5,11]. Other than system security, the response rate to the RES fluctuation can also be improved by DR. Usually, it takes around 30 minutes for thermal power plants to go from 0 output to rated output [12]. Although CCGTs and OCGTs are specially designed to provide capacity reserves, the response rates are much higher than conventional ones but still limited by the accelerating process of the rotor. The change in electricity demand can be nearly instantaneous under ideal conditions, providing a significant improvement in response rate.

Another benefit brought by DR is the cost decrease in system planning. One of the prior concerns of the system operators is to ensure reliable power supply, so that the remaining capacity during fault or maintenance should be able to meet the demand. When the electricity demand increases, in the context of maintaining system safety margin, DR utilises flexibility from the demand side, significantly reducing the reserved capacity needed, thus reducing the reliance on CCGTs or OCGTs. Furthermore, DR allows the existing power plants to operate at rated output, where the efficiency is optimal and the greenhouse gas emission is controlled at a lower level [3]. In addition to the reduction in reserved capacity, DR can also ease the congestion of power consumption in the system, hence investment in upgrading and reinforcing the network can be delayed or lessened. Real-time price DR was proposed by researchers reduce the coincident peak, which determined the reserve level of the power system [13].

> DR utilises flexibility from the demand side, significantly reducing the reserved capacity needed.

Other than system reliability and planning, DR shows superiority in economic efficiency. By implementing DR, the cross-regional electricity exchange will reduce, indicating a decreased dependency on electricity import and export. This is economically efficient since if the output of the renewable energy resources is scarce or excessive, a similar situation is likely to happen in the neighbour regions, thus the electricity price in those regions would be high or low.

Although DR has been proved to have multiple advantages to the power system, there are some barriers to the application and development of DR in the grid. Under most of the current electricity market frameworks around the world, which are designed for centralised power generation, the level of participation of responsive demand is very limited [14]. The existing markets usually require day-ahead bid, which indeed wastes the high response rate of DR. In other words, the effective response time of DR becomes several hours, if the bid must be made hours ahead, which makes DR less competitive with the combustion turbine reserves [14]. To better utilise the potential benefits of DR, the market framework needs to be modified to suit the distributed and diverse nature of demand. Another challenge in applying DR is the pricing structure. Fig. 1 shows electricity price components in the UK and Denmark. The cost of energy, which is the main incentive in DR, is not taking an extremely large share of the electricity charge, resulting in lower enthusiasm in participating in DR, especially for residential customers. However, the redesign of the pricing mechanism should be very carefully considered when shifting the

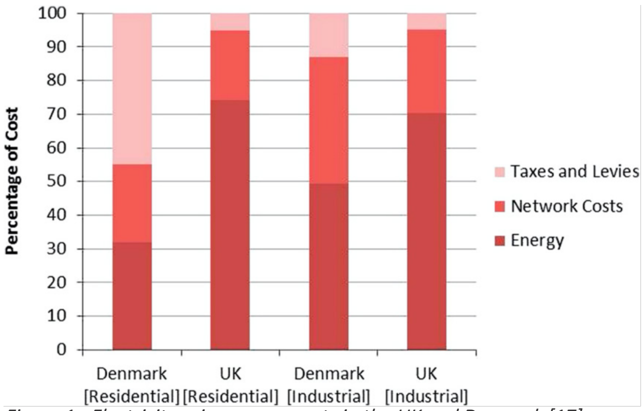

Figure 1 - Electricity price components in the UK and Denmark [17].

original pricing structure to a more incentive one, since the fact that by participating in DR, the customers are taking more responsibility on system stability and reliability without noticing it. To ensure the safety of the system, researchers state that limitations should be introduced into the DR programme [15,16].

It is widely acknowledged that DR is a cost-efficient approach in power system upgrade and planning, it presents a challenge for numerical evaluation. Strbac [3] highlighted the difficulty in establishing a business model to justify the investment in developing DR infrastructure. Moreover, as the unbalanced power can be well compensated by flexible generators in existing power systems, the extra cost of DR implementation might make DR less attractive to the system operator. As noted by Stcbac [3], DR may only be appealing to systems with a large share of inflexible baseload and high penetration level of the renewables. Another challenge in DR is that customer behaviour cannot be predicted using conventional economic models [18]. Unlike power plants run by commercial companies, domestic loads are less economically rational. Maximising the profit is not always the highest priority for the users, and the willingness to participate in DR might be influenced by multiple factors.

In conclusion, with the increasing penetration of renewable energy generation, DR appears to be an optimal approach to ensure system security and reliability. It has been widely acknowledged that DR can bring multiple benefits to the power system operators, aggregators and the customers, both operationally and economically. However, as the demand is naturally distributed and uncertain, further challenges need to be addressed, including a better understanding of the nature of the demand and appropriate upgrades made on the existing power system and the market mechanism.

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Threats to the Electric Vehicle Revolution: Supply Bottlenecks of Lithium and Cobalt

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The demand for electric vehicles (EVs) is not just growing, but also accelerating. Through a combination of generous government incentives schemes, cost competitiveness, and simply the status they confer, sales of EVs are set to comprise 10% of global car sales in 2024 and 20% in 2030, up from just over 1% in 2015 [1]. This acceleration is cheered on not just by firms who want to ride the EV wave, but also by policy makers and analysts who are tracking the decarbonisation of the transport sector, which contributed 25% of total CO2 emissions in 2018 [2]. Despite a small downturn in EV sales in the US last year [3], the direction of future demand is beyond any doubt. The same cannot be said about the direction of future supply. There are a set of very important questions surrounding two commodities that are currently essential to the production of battery electric vehicles, namely lithium and cobalt.

Since their commercial introduction in 1991 [4], the lithium-ion battery has gradually come to be favoured by EV manufacturers due to their relatively small size and weight compared to their predecessor, the nickel-metal hydride battery [5]. Types of lithium-ion batteries mainly differ in their cathode chemistries, with lithium cobalt oxide being a very common variation. We have lithium cobalt oxide to thank for the excellent energy density (i.e. the energy able to be stored relative to the space that is taken up) of modern batteries, which enables the manufacture of ultra-thin laptops and phones today [6]. However, there is still room for improvement in the performance of lithium-ion batteries in EVs, as evidenced by the current average driving range of 181 miles [7]; weak compared to that of the average internal combustion engine, which is 400 miles [5]. In a survey by Deloitte, driving range was listed as the top concern customers had regarding the feasibility of EVs against internal combustion engines [1]. When EVs do manage to match the driving range of their gasoline-fuelled counterparts, the questions will then be regarding supply – will we have enough lithium and cobalt? Where will it come from? What are the threats to a reliable supply base?

In a 'Stated Policy Scenario' (i.e. a scenario where all current and stated EV-related policies have already had their effect) the IEA estimates that 185kt of lithium will be demanded for EV production per year, which is significant compared to the 17kt which was used for EVs in 2019 [8]. Thankfully, the total supply of lithium does not look to be an issue. Vikström et al. (2013) tally the total lithium resources in all the world's known mineral deposits and estimates a maximum figure of roughly 31Mt [9], enough for 167 years of EV production in the IEA 'stated policy scenario'. Grosjean et al. (2012) put their estimate at 37.1-43.6Mt, enough to produce 12.3-14.5 billion EVs [10].

This is important because lithium is the only metal common to all five battery chemistries that have the potential to become the commercially viable for EVs, meaning future market supply needs to be strong and certain. Forecasting by the consultancy McKinsey shown in Figure 1 gives reason to be confident, with total demand in 2025 for lithium in all end-uses estimated at 893kt, and total supply capacity in 2025 (i.e. current capacity plus capacity of announced projects) reaching 1206kt [11].

However, a large supply capacity does not automatically entail a future awash with lithium. The 'lithium triangle', composed of land belonging to Argentina, Bolivia, and Chile, comprises 43.6% of the world's lithium resources [11]. Having such a large concentration of the metal in these three countries does not come without risk, not least because of the lukewarm enthusiasm investors have held towards the region in recent decades. The dust is yet to settle in Bolivia from last year's political unrest. In these early days of Luis Arce's Presidency, relationships with foreign investors must be re-kindled following ex-leader Evo Morales' withdrawal from a joint lithium extraction venture with German firm ACI Systems just a week prior to his resignation last year [12]. In Chile, lithium is classed as 'strategic' because of its usefulness in nuclear fusion reactors, a yet unproven process of energy generation with nonetheless monumental potential, meaning extraction is limited by the government [13]. Currently, lithium production does not look well placed to match the rapid expansion of the EV industry. Industrialising lithium looks to be a problem of politics as well as economics given the less-than-ideal conditions of current South American institutions.

Cobalt, the second metal needed to produce lithium-ion batteries, could present a greater challenge with regards to future supply. As is the case with lithium, the world is not short of cobalt. Mudd et al. (2013) estimate the world having 26.8Mt of known resources [14], which is reassuring if we refer back to the IEA stated policy scenario of EV uptake, which would require 180kt of cobalt to meet demand in 2030 [9].

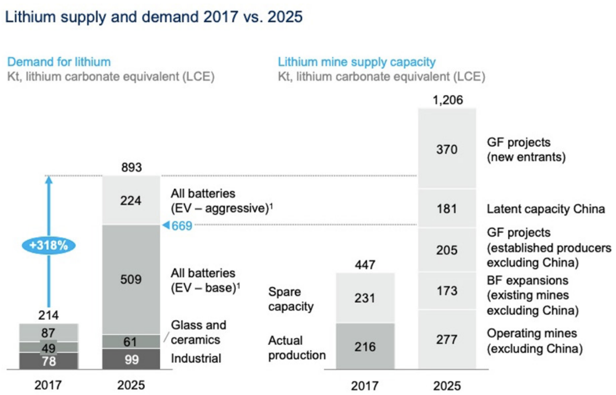

Figure 1 - Comparison of Lithium supply vs demand in 2017 with forecasts for 2025 [3].

However, another feature that cobalt shares with lithium is its geographical concentration. Over 65% of cobalt production occurs in the Democratic Republic of Congo (DRC), where instances of political unrest (in 1978 and then in the mid-1990s) have led to supply constrictions and subsequent price spikes [15]. The DRC also attracts strong criticism for the working conditions in so-called 'artisanal mines', which are unregulated, lack formal oversight, and subsequently see high rates of child labour, injury, and death [16]. EV producers are obviously deterred from such abuse of human rights, and therefore this represents the first of the two substantial material risks to future cobalt supply.

The second arises from the fact that over 90% of cobalt is not extracted as a primary product, but rather as a by-product from copper and nickel mining [11], meaning that the economic viability of cobalt extraction is subject to that of copper and nickel. In fact, a European Commission Report puts an 11% drop in cobalt production between 2015 and 2016 down to a simultaneous drop in nickel production, from which 39% of extracted cobalt is a by-product [17]. The risk of supply constrictions is heightened, as Campbell (2020) points out, since the demand for cobalt is becoming increasingly tied to the demand for EVs, and less so to its other uses in alloys and chemicals. This means that those vying for a rapid EV revolution find themselves increasingly exposed to the price dynamics of copper and nickel, and to the possibility of price spikes in the event that copper and nickel production cannot ramp up quickly enough [15].

Efforts are being made to develop commercially viable, cobalt-free lithium-ion batteries. Earlier this year it was reported that Tesla were in "advanced stages of talks" with CATL, a Chinese company who manufacture lithium iron phosphate batteries [18]. The high price of cobalt means that Tesla's decision to move away from it is primarily a cost-related one, but it is also thought that such decisions may accelerate the wider EV revolution, given the relative attraction of "equally feasible, cost competitive" [11] battery chemistries that do not carry the risk associated with

If the EV era is to be ushered in quickly and ag-gressively, can lithium and cobalt production keep pace?

linked markets of co-produced compounds.

The worries surrounding lithium and cobalt supply in the future are not related to geological abundance – we have plenty of both. Concerns are mainly centred around supply bottlenecks. If the EV era is to be ushered in quickly and aggressively, can lithium and cobalt production keep pace? There are a handful of reasons to believe that it may not be so easy. The importance of lithium necessitates strong supply chains and even stronger institutions in those regions it is plentiful. South America is slowly welcoming the world to its lithium-rich salt pans, but it is still early days of their ascendency as the world's supplier of the metal. The historical volatility of cobalt gives more reason for concern. EV producers cannot be dependent on the economic viability of copper and nickel, the primary products of cobalt production. Nor can they be seen turning a blind eye to the obvious human rights abuses in the DRC. Both factors may invite more research and development into cobalt-free battery chemistries, but those options are still not commercially viable to produce EVs that can match the driving range and cost competitiveness of the gasoline-fuelled alternative [19]. The road to an EV future is certainly not a straight one.

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