ALIGNING STIMULUS WITH ENERGY TRANSFORMATION

A report by Wärtsilä Energy

This report examines the potential to focus governments' energy stimulus explicitly on accelerating transitions towards 100% renewable energy, to spur economic recovery and growth - and put emissions into structural decline. The report synthesises Wärtsilä's Atlas of 100% Renewable Energy modelling, with real-world analysis of over 200 G20 energy stimulus policies, provided by the Energy Policy Tracker. The report illustrates the potential for five key countries (United States, Brazil, United Kingdom, Germany ands Australia) to leverage stimulus to take a giant leap towards decarbonisation.

The report includes:

- A deep dive on two world-leading energy markets - the United States and the United Kingdom, that stand at the brink of a clean energy revolution – and that could provide a blueprint for other economies to follow.
- Qualitative on-the-ground insights from Wärtsilä experts around the globe.

CONTENT

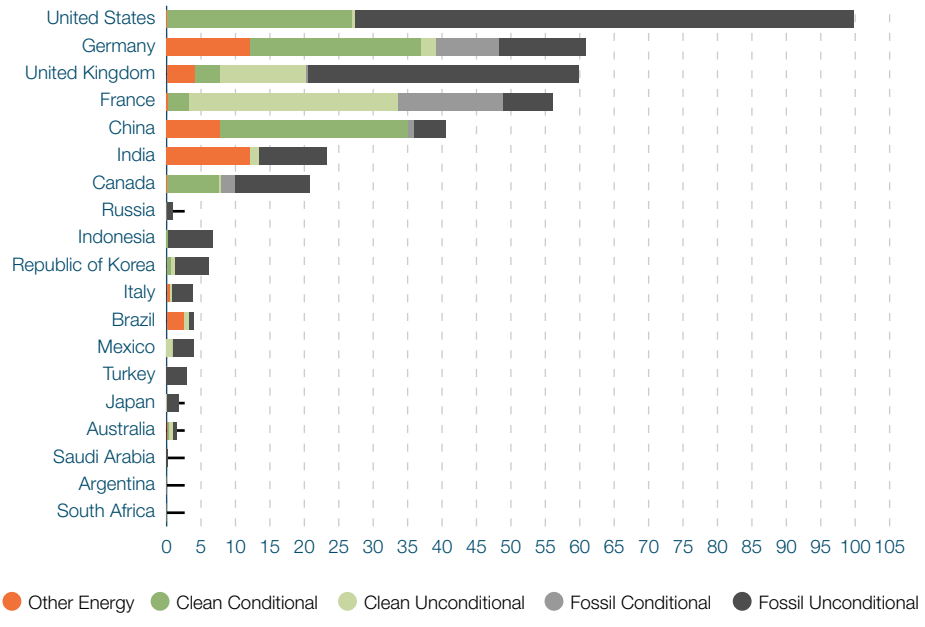
REALIZING A ONCE-IN-A-GENERATION OPPORTUNITY FOR A CLEAN ENERGY REVOLUTION

Since March 2020, policy makers worldwide have made decisions that will shape the energy sector for decades. Enormous recovery stimulus packages have been announced to support industries and communities to get back onto their feet, with hundreds of billions of dollars allocated to the energy sector alone. These investment decisions are designed to counteract the financial shocks of the pandemic, but they will also determine whether the world meets its long-term energy and climate goals.

Leading energy economists from the International Energy Agency (IEA) to the International Monetary Fund (IMF) have reached a consensus that recovery stimulus presents a unique opportunity to boost economic growth, create millions of jobs and put global greenhouse gas emissions into structural decline.

To date, the Energy Policy Tracker, which traces the public finance flows determined by recovery packages, has found that across the G20 nations, $400 billion USD has been pledged to support a range of power types. However, the stimulus 'scales' are strongly weighted in support of legacy fossil fuels, despite the agenda for rapid decarbonisation that's underway worldwide. 54% has been pledged to fossil fuel-based energy against 36% to clean energy[1] .

Sushil Purohit
President
Wärtsilä Energy



PUBLIC MONEY COMMITMENTS TO FOSSIL FUELS, CLEAN AND OTHER ENERGY IN RECOVERY PACKAGES, USD BILLION, AS OF 26 OCTOBER 2020

Graph courtesy of Energy Policy Tracker

The pledges raise a fundamental question for governments, energy leaders and the public alike:

How much stimulus investment should be pledged to kickstart a sustainable recovery, powered by renewable energy, and enabled by system flexibility, to address the climate emergency?

Economic lessons of the recent past

To help answer that question, we can look to the recent past – recovery policy in the wake of the Global Financial Crisis in 2008. A University of Oxford 2020 study[2] assessed 196 fiscal recovery policies in response to the 2008 crisis, finding that 63 were green, 117 were neutral, and 16 brown. The analysis revealed that green stimulus policies were more economically advantageous in both the short and the long run than fossil fuels.

The same multipliers of economic value from renewable energy are in effect today. The potential impact of stimulus boils down to the difference between reviving the economy we already have, compared to building the type of economy we want.

Renewable energy is widely acknowledged to create more jobs than fossil fuels. McKinsey, for example reports that for every $10 million USD of government spending on renewable technologies 75 jobs are typically created[3], compared to 27 jobs in the fossil fuels sector. Additionally, renewable energy generates more labour-intensive jobs in the short run, when jobs are scarce, which boosts spending and increases short-run GDP. In the long run, renewable energy requires less labour for operation and maintenance, which frees up labour as the economy returns to capacity.

The cost revolution is already underway

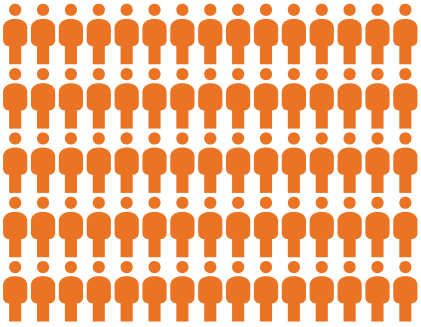
The dramatic fall in once-expensive renewable and flexible capacity costs (such as energy storage) has transformed energy investment over the last decade and the pace of change is accelerating. The cost of offshore wind, for example, has fallen by 63% since 2012. With a renewed focus on future-proofing their business models, utilities have increased renewable energy investments, taking advantage of the certainty that clean energy brings to the balance sheet. In effect, adopting renewable energy, coupled with flexible generation and storage for system balancing, is akin to purchasing 'unlimited' power up-front, as opposed to placing bets on fluctuating oil prices and exposure to narrowing environmental regulation.

This led to profound structural changes in the energy sector well before the pandemic. When the crisis hit, the IEA was quick to recognise that renewable energy such as wind and solar showed 'a degree of immunity to the crisis[4].' As power demand fell in line with slowing economies, the share of renewable energy on national electricity grids significantly increased providing the most affordable power source available. This shows that much higher penetration of renewables is not only desirable, it is viable today.

JOBS CREATED, DIRECTLY AND INDIRECTLY,*

per $10 million USD in spending

Renewable technologies
(wind, solar, bioenergy, geothermal, hydro)



75 jobs

Fossil fuel (oil and gas, coal)

27 jobs

*Excludes induced jobs.

Flexible capacity lies at the heart of a cost-optimal transition

However, the crisis has highlighted the critical need for increased grid balancing technologies to reinforce the energy transition, such as storage and flexible generation. For example, flexibility prices rose by up to 470% year-on-year in Germany this spring, with utilities forced to sell surplus power at -80€ per MWh to neighbouring countries, such as Norway, that have the flexible assets to benefit from negative pricing.

To increase the share of renewables in line with decarbonisation, we need to place flexible capacity at the heart of the energy business case. In modelling countries' energy systems, from Germany to Senegal – regardless of the starting energy mix, a combination of installed capacity, consisting of renewable energy, energy storage, and flexible gas power plants consistently drives the most value in terms of emissions and cost, and thus total cost to society.

Back to the stimulus question

Returning to the stimulus question, the weight of support for the fossil fuel sector from announced stimulus packages shows the persisting institutional bias in favour of preserving a legacy sector. This is very likely to prove myopic, economically-speaking, and misaligned with G20 countries' decarbonisation commitments under the Paris climate agreement.

To test this hypothesis, we set out to shine a light on the impact that stimulus investment could have if pledged to the clean energy transition. This report shows the potential for stimulus to accelerate the energy transition, as a driver of a sustainable economic recovery.

Six months to change the world

As we enter the decade of consequence for the global climate, we must set a clear line of sight to achieve the level of decarbonisation set out by science. 3,000 GW of installed renewable capacity is required by 2030 to achieve the lower Paris target of 2°C[5]. Fatih Birol, Executive Director of the IEA, said in June 2020 that world leaders have six months to put policies in place to prevent a rebound in emissions that could put that target permanently out of reach[6].

Leaders now face a clear choice: either be shaped by the inherent shocks of a worsening climate emergency or take action to shape the energy system around the needs and impact of a net-zero future.

INTRODUCTION

Saara Kujala
General Manager,
Business Development
Wärtsilä Energy

The COVID-19 pandemic has severely impacted populations worldwide, with national and global economies facing the worst economic shock since the 1930s. However, as Albert Einstein said, “In the midst of every crisis, lies great opportunity.”

Governments are investing historic sums of stimulus money into raising industrial output, employment and consumption, to steer economies through the crisis. Energy, as the cornerstone of the global economy, is a key area for governments’ stimulus to drive the recovery. According to the International Energy Agency (IEA), global energy investment is expected to shrink by 20% in 2020 – an unparalleled decline. Since March 2020, G20 governments have announced at least $400 billion USD in stimulus policies to assist the recovery of the energy sector, including power generation, mobility and upstream resources. This presents an unprecedented opportunity to accelerate the global shift to sustainable, renewable energy and tackle the deepening climate emergency.

However, to date, 54% of this energy stimulus has been pledged to support the legacy fossil fuel -based energy sector. Allocating such a high proportion to legacy inflexible energy systems does not reflect the urgent need for a carbon neutral society, or the economic case for renewable energy technologies to deliver it. In the past, a common view was that shifting from traditional, inflexible power generation to a modern, flexible renewable-powered system was inconceivable, impossible and unnecessary. Now, in the current world we find ourselves in, the transition towards 100% renewable energy is - for the first time - conceivable, possible, and necessary.

This report examines the potential for governments' energy stimulus to be focused explicitly on measures to foster an accelerated transition towards 100% renewable energy, simultaneously spurring economic recovery and growth, creating millions of jobs - and putting emissions into structural decline.

The analysis in the report is founded on the Atlas of 100% Renewable Energy[7], where our team of power system experts have modelled 145 countries and regions around the world based on the database from the Lappeenranta-Lahti University of Technology, to define the cost-optimal mix of technologies to produce electricity from 100% renewable energy sources. In essence, the Atlas provides a roadmap for policymakers on the technologies that enable the transition towards 100% renewable energy, and that effective green stimulus will advance.

The Atlas models energy systems from a hypothetical fresh start, or greenfield state, to illustrate the ideal renewable energy scenario: only hydro-power and geothermal are included from today's power systems. The modelling presents the option of allowing all renewable technologies, including solar, wind, battery energy storage, as well as flexible gas plants running on synthetic renewable fuels, produced from renewable electricity with Power-to-X technologies, into the capacity mix. In an alternative scenario only wind, solar and battery energy storage can be added to the system. The modelling therefore demonstrates what kind of power system flexibility, such as energy storage or flexible thermal generation running on synthetic renewable gas, is needed to support renewable energy in each case.

In this report, we have combined the Atlas with the Energy Policy Tracker[8], a detailed, real-world snapshot of over 200 individual public funding commitments related to the production and consumption of energy in the G20 countries since the beginning of the COVID-19 pandemic.

Combining the idealised world of the Atlas with the real-world potential of the Energy Policy Tracker, we have assessed the cost-optimal use of stimulus resources to enable five key countries to transition further towards 100% renewable energy: The United States, Brazil, United Kingdom, Germany and Australia. The countries represent the Americas, Europe and Australia – reflecting a vast range of geographies, political and socioeconomic contexts, incumbent energy mixes and priorities for the energy transition – showing that the shift to renewables is feasible and economic worldwide.

For each of the markets above, our leaders on the ground have provided key insights on the opportunities for those countries to maximise the stimulus to ensure energy systems unlock the value of the energy transition. In two key markets – the United States, as the world's preeminent economic and political power, and the United Kingdom, a leading market for the energy transition – we have undertaken a deep dive analyses on the economic and job creation potential from pledging stimulus to build affordable clean energy systems over the next five to fifteen years.

"Wärtsilä's team of power system modelling experts have systematically invested in building world class knowhow on modelling and analysing the long-term impacts of energy transition, and the need for flexibility in high renewable power systems. We use Plexos, a leading power market simulation software, for the power system modelling results presented in this report and in Wärtsilä Atlas of 100% Renewable Energy."

Antti Alahäivälä
Manager,
Business Development
Wärtsilä Energy

The decisions taken today in these countries will define whether they accelerate a renewable energy revolution.

Wärtsilä supports integration of renewable energy through solutions that provide the required system flexibility, i.e. flexible engine-based power generation, energy storage and in the future, new technologies such as Power-to-X. As a global technology company that has delivered 73 GW of power plant capacity and over 80 energy storage systems in 180 countries and that has modelled the impacts of high renewable energy mixes in over 150 countries and energy company portfolios globally, our experience – and that of our customers – is that the transition towards a decarbonised economy, powered by renewable energy and enabled by power system flexibility, delivers greater energy affordability, reliability and sustainability. Plus, it is deliverable now through a combination of established and emerging technologies.

The analysis and insight in this report make a clear case for world leaders to redress the imbalance of current pledged energy stimulus, in order to tackle the deepening climate emergency by providing affordable, reliable, clean power for all.

ABOUT

Energy Policy Tracker

The Energy Policy Tracker data is provided by 14 organizations: International Institute for Sustainable Development (IISD), Institute for Global Environmental Strategies (IGES), Oil Change International (OCI), Overseas Development Institute (ODI), Stockholm Environment Institute (SEI), Columbia University in New York City, Forum Ökologisch-Soziale Marktwirtschaft (FÖS), Fundación Ambiente y Recursos Naturales (FARN), Instituto de Estudos Socioeconômicos (INESC), Institute for Climate Economics (I4CE), Instituto Tecnológico Autónomo de México.

DEEP DIVE COUNTRY ANALYSES: UK AND US

In this section, Wärtsilä has zeroed in on two global energy leaders whose energy systems are at a crossroads, with governments that face the imminent choice either to invest in reviving their legacy, inflexible energy systems, or accelerate towards a new economy powered by renewable energy. By examining the cost optimal route to delivering a sustainable energy system in each country, we explore how the energy stimulus of the United States and the United Kingdom can act as a platform for a clean energy revolution, providing a blueprint for economies worldwide to follow.

Note: the Energy Policy Tracker data used in the Wärtsilä report is accurate as of 26 October. The data used specifically for the UK and US modelling and analysis is based on data originally compiled as of 22 September, due to the time required to model and analyse the scenarios provided in the report. The underlying data used in the UK and US modelling has been assessed against Energy Policy Tracker data as at 26 October and remains accurate as of 26 October.

UNITED STATES

ON THE BRINK OF AN ENERGY REVOLUTION

The US is a global leader in renewable energy with the second largest installed capacity in the world. Total private sector investment in renewable energy reached a record USD $55.5 billion in 2019, an increase of 28% year on year[9]. Federal government support for clean energy has been significantly reduced in recent years, with federal energy initiatives primarily being focused on the fossil fuel sector. However, given the scale and depth of its energy market, the US has the economic and technological potential to scale-up renewable energy (RE) at an unprecedented rate.

The US has enormous economic capacity to drive towards an optimal renewable energy system. In this report we overlay the currently announced US economic stimulus with the cost-optimal 100% renewable energy mix across 14 regions of the US as shown by the Atlas of 100% Renewable Energy. To build on this, we have modelled scenarios to illustrate how, by maximising stimulus and private sector investment for clean energy, the US could put itself on target to achieve a majority renewable energy system and meet its current national climate change commitments.

Our focus extends also to a key state. Texas is the national leader in the US wind energy industry; with 30 GW of installed wind and fast-growing solar capacity. Given the primacy of Texas as an existing centre for renewable energy, combined with its extremely favourable environmental conditions for renewable generation, we have modelled the potential to supercharge the adoption of RE in Texas, as a state that could go beyond current adoption levels, to spearhead the shift to a net-zero emission power system and economy.

SCENARIO

"$72 billion USD Stimulus Renewable Accelerator"

If all current US fossil fuel stimulus ($72 billion USD) was allocated to renewable energy (RE), it could achieve:

- 6.5% rise in share of RE (from 17.5% to 24%)
- 107 GW of new renewables
- 544,000 jobs in RE, 175% more jobs than if stimulus is focused on fossil fuels

US renewable energy adoption risks missing current climate targets

The US has committed to a 26-28% domestic greenhouse gas (GHG) reduction by 2025 compared to 2005.[10] US renewable energy adoption continues to rise, in 2019, renewable energy sources[11] accounted for 17.5% of total utility-scale electricity generation, with renewable energy generation reaching 720 TWh.

However, allocation of current energy stimulus $100 billion USD, is weighted to the fossil fuel sector, which limits the potential for decarbonisation. A disproportionate amount, over 70%, of US energy stimulus is currently allocated to legacy fossil fuels, compared to less than 30% to clean energy.

The impact of reallocating energy stimulus

So how far could we develop the system by allocating the whole $72 billion USD fossil stimulus towards renewable energy transition? Adopting a very simple methodology where such stimulus was utilised, dollar to dollar, to increase renewable energy output, the United States could achieve:

- 107 GW of new renewable energy capacity
- 6.5 % rise in share of renewable electricity generation (from 17.5% to 24% renewable electricity).
- 544,000 new jobs in renewable energy, 175% more jobs than if the same stimulus was used to revive the legacy energy sector.

While the above key figures provide an overview of the scale of stimulus reach if spent on renewable energy investment, the optimal use for public sector green stimulus is to create an environment that encourages investment by the private sector towards renewable energy, through policies, incentives and enabling market structures. The vital role of flexible capacity, in the form of battery energy storage and flexible gas power generation, in supporting the efficient integration of large quantities of new renewable energy generation would need to be addressed. Therefore, going beyond the stimulus, we have assessed the scale of investment required for a zero emission electricity system by 2035.

A zero emission electricity sector by 2035 could be achieved with $1.7 trillion USD investment

Using our Atlas and the global power system modelling knowhow, we modelled an optimal capacity mix and required investment for a carbon neutral electricity system for the United States by 2035. A cost-optimal, carbon neutral system could be achieved with the following investments into new technologies:

- 1,700 GW of new renewable energy capacity
- 410 GW of new battery energy storage capacity
- 116 GW of new flexible gas-fired power capacity operating on renewable bio- or synthetic fuels
- 151 GW of new electrolyser capacity for Power-to-Gas fuel production to be stored and utilised in flexible gas-fired power plants for system balancing

The system could create 8.7 million jobs in renewable energy alone, and have an expected cost of $1.7 trillion USD.

Flexible capacity has a vital role in achieving an optimal renewable energy system in the United States

To support a cost-optimal renewable energy system, approximately 410 GW of battery energy storage is needed to provide system flexibility, allowing for the shifting of solar generation and for the balancing of daily renewable variations. In addition, the system would also need 116 GW of flexible gas power capacity to balance seasonal renewable energy intermittency. Flexible gas power plants can run initially on natural gas, but when closing in towards a 100% renewable energy target, will switch to utilise bio fuels or synthetic renewable fuels such as hydrogen or synthetic methane, produced by Power-to-X facilities out of renewable electricity and CO2 captured from air. In a 100% renewable energy system, 151 GW of electrolysis capacity and adjacent Power-to-X production facilities would be needed to produce synthetic renewable fuels for flexible gas power plant capacity.

Texas could spearhead the US' clean energy transition

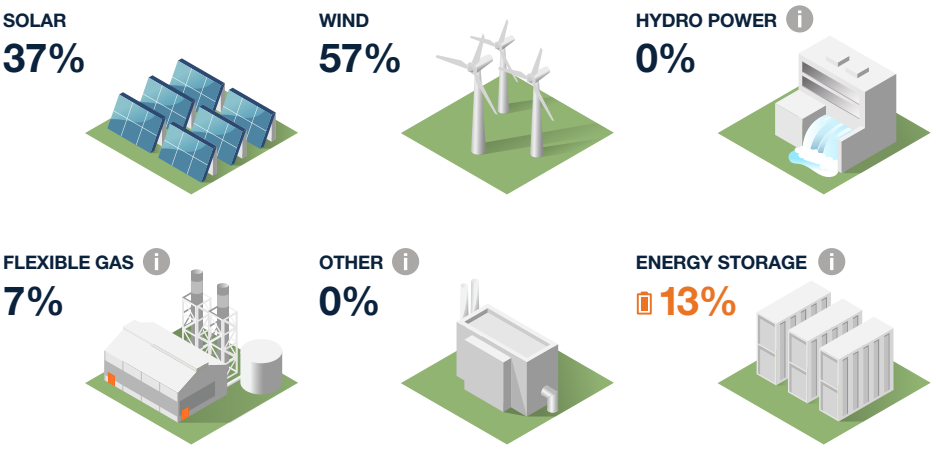
The US state of Texas stands out both as a primary generator and significant user of US energy. Approximately 10% of US electricity demand comes from Texas. Texas is the national leader in the US wind energy industry with 30 GW of installed wind. It ranks first in the country for installed and under construction wind capacity, supporting 25,000 wind-related jobs. We conducted a simple modelling experiment where Texas was allocated a 10% proportion of fossil energy stimulus, $7.2 billion USD in total. The potential for the state to spearhead the US renewable energy transition can be seen as follows:

- 10 GW of new renewable energy generation capacity, including solar and wind by 2025
- 54,000 new clean energy jobs, 175% more than if the same stimulus was used to revive the legacy energy sector[12]
- 15% reduction in power sector CO2 emissions

The use of stimulus money to boost the renewable energy transition would take Texas a long way towards 100% renewable energy system. Based on our Atlas of 100% Renewable Energy, an optimal energy mix for Texas running on 100% renewables, would consist of solar, wind, energy storage, and flexible gas power generation running on synthetic renewable fuels, as shown in picture below.

TEXAS, UNITED STATES RUNNING ON 100 % RENEWABLES

SHARE OF ANNUAL ELECTRICITY GENERATION



See page 26

Flexible gas power generation and energy storage would ensure generation when wind and solar are not available due to weather conditions and would balance intermittency. Considering the huge amount of inflexible base load generation in the current US system, only flexible power generation capacity should be built in addition to new renewable energy capacity and energy storage. As the value of inflexible capacity reduces over time, as the transition to a decarbonized power system progresses, there is a need for it to be gradually closed down, based on a retirement plan. However, adequate back-up capacity must be maintained to ensure system reliability and to provide operational flexibility. Flexible gas power generation needs to be constructed to enable such retirements.

“The economics of renewable power have pushed the US energy system to the brink of transformation, with record levels of private sector investment in clean energy. Its natural geology has also until now provided an abundant availability of affordable, natural gas. As a result, large inflexible coal, nuclear and has power plants have played a key role in balancing the grid to ensure reliability as new technologies come on-line, such as wind and solar, offering lower cost power.

However, given the massive influx of solar in places especially in the states close to the Mexican border, those large-scale plants are now under tremendous strain. They are ramped up and down daily to keep the lights on at night when people come home and solar generation plummets. To be ready for the evening ramp-up, the inflexibility of the power plants forces curtailment of solar and wind, and burning, large volumes of fossil fuel gas are burnt unnecessarily during the high solar intensity period of the day - despite the availability of cheap solar and wind. Such power plants simply cannot be shut down and restarted within a few hours. This adds up to significant fuel costs and carbon emissions, not to mention crippling maintenance cost to keep old plants running - reducing profitability and reliability.

States like Texas are showing how this problem can be solved as the US shifts to renewables. Texas has extremely favourable conditions for wind and solar, with some areas driving world leading capacity factors of 50% from wind and 25% from solar.

Instead of trying to balance new installed renewables with centralized “legacy” power gas plants, several Texan utilities are balancing their renewable generation with new balancing technologies, such as batteries, and state-of-the-art flexible power plants. These carry the major advantage of allowing utilities to hedge their green portfolios with firm fast starting natural gas power in the short-term, while also being future-proofed for future carbon neutral fuels, such as synthetic methane and hydrogen, when they come onstream.

Future carbon neutral fuels, which are not far around the corner, combined with highly efficient flexible power plants, can be a fulcrum for the US transition. Flexible carbon-neutral power plants – using these clean fuels - are a key ingredient of the transition, and the decarbonized power system, ensuring security of supply during weather patterns like heat waves, monsoons and winter darkness. The coming years will be critical for determining a future-proof, decarbonization path for all nations, including the USA. Today, California and Germany with already high shares of renewables offer us a window to peek into the future and to figure out ways to avoid the reliability, curtailment and other challenges, which are inevitable consequence of not replacing the inflexible large fossil fuel burning plants with flexible carbon-neutral gas power plants.”

Jussi Heikkinen
Growth & Development Director, Americas
Wärtsilä Energy

UNITED KINGDOM

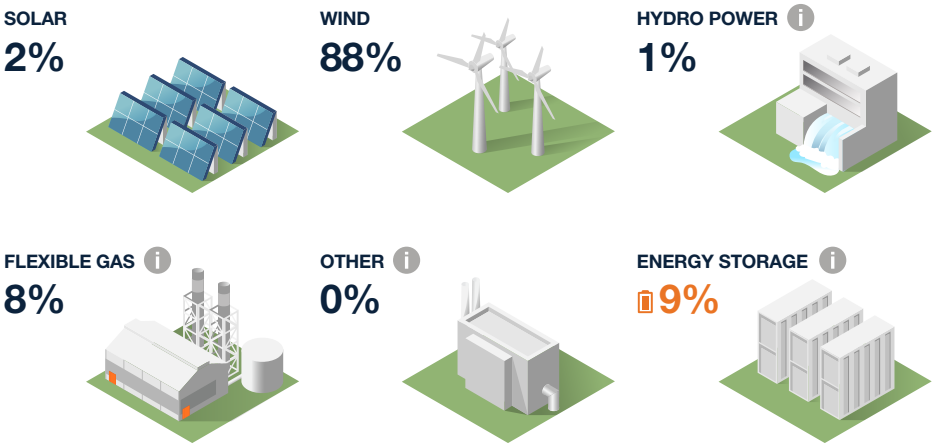
REALIGNING UK STIMULUS TO DRIVE CARBON NEUTRALITY

Buoyed by its position as the world's largest offshore wind market, in June 2019, the United Kingdom became the first major economy to set a target to hit net-zero carbon emissions by 2050. This puts the UK at the vanguard of worldwide commitments to address the climate emergency and transition to sustainable economies. However, the UK has yet to establish a clearly defined roadmap for how the country will meet its net-zero goal.

By overlaying the UK energy stimulus announced to date[13] with the cost-optimal renewable energy mix shown by the Atlas of 100% Renewable Energy, we have modelled a scenario where, by maximising energy stimulus and utilising it as a leverage for private sector investment, the UK could make a quantum leap from a 37% share of renewable energy (RE) now, to a 60% RE system and lower power sector emissions by 58%. A 60% renewable energy system would take the UK a long way towards the optimal 100% renewable energy system, as illustrated in our Atlas of 100% Renewable Energy.

UNITED KINGDOM RUNNING ON 100 % RENEWABLES

SHARE OF ANNUAL ELECTRICITY GENERATION



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The UK has world-leading greenhouse gas targets (GHG) and considerable renewable energy capacity[14]

The UK has set a target to reduce its domestic GHG emissions by 57% by 2030 compared to 1990 levels, under the Paris Agreement. Additionally, in 2019, the country set a legal commitment to achieve net-zero GHG emissions by 2050.

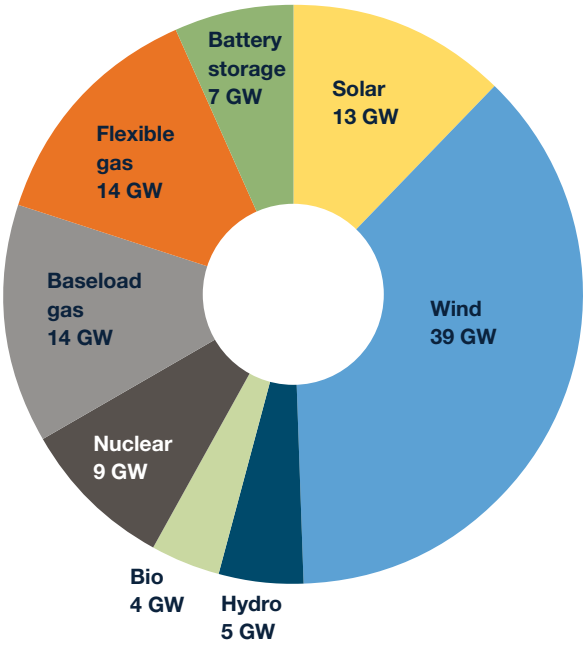
The share of renewable generation in the UK energy system reached 37% in 2019[15], with a total renewable capacity of 47 GW. Out of this, 22 GW consists of wind energy capacity. Total renewable generation reached 121 TWh (2019). This renewable energy capacity offers a platform for further growth.[16]

Current stimulus investment is weighted towards reviving the fossil fuel sector, not to renewable energy:

As of September 2020, $5 billion USD of stimulus commitments in the UK has been allocated to fossil fuels. Only $158 million USD stimulus has been allocated for clean power generation. This demonstrates how the current stimulus weighting is not aligned with the UK's ambitious 57% GHG reduction by 2030 and net-zero by 2050 targets.

Leveraging stimulus to unlock private sector investment could create a 60% renewable energy system:

By diverting stimulus to fund green policy incentive measures, such as tax credits, permitting, new technology innovation support, alongside aligning energy market structures with national climate targets, governments can expect to leverage additional private investment for RE by a factor of 3-4[17]. Assessing the leverage impact with a factor of three, the UK's current fossil and power generation stimulus ($5.5 billion USD) could leverage private sector funds to total investments of up to $16.5 billion USD. This could deliver 60% renewable penetration if stimulus is focused on renewable energy investment. A 60% RE system has 58% lower power sector emissions compared to the current level, putting the UK well on track to meet its net-zero commitments.



SCENARIO

"$16.5 billion transition supercharge"

Allocating all announced fossil energy stimulus to renewable energy plus leveraging private sector investment by a factor of three (total up to $16.5 billion USD) could achieve:

- Over 120,000 renewable energy jobs
- Almost 180% more jobs than if focusing same investment on fossil fuels
- 60% share of RE, with 58% lower emissions compared to the current level.

60% RENEWABLE ENERGY SYSTEM

TOTAL CAPACITY OF 105 GW

In addition to new renewable energy, the vital role of flexible capacity in supporting the efficient integration of large quantities of new renewable energy generation would need to be addressed. A cost-optimal power system for the UK, with 60% renewable energy penetration, would also require significant investment into energy storage and new flexible gas-based technologies, capable of operating on bio- and renewable synthetic fuels. 14 GW flexible thermal and 7 GW battery energy storage would be required to support the system. The full power capacity mix of a cost-optimised 60% renewable energy system for the UK is illustrated in the pie chart above.

More jobs from renewable energy investments:
Almost 180% more energy jobs could be created if the stimulus currently earmarked for the legacy fossil fuel sector was directed to support the renewable energy transition, leveraging private sector investment by a factor of three. Overall, it is expected that over 120,000 jobs could be created in renewable energy industry from a $16.5 billion USD investment in RE. By comparison only 45,00 jobs could be created in traditional fossil energy sector with the same investment.

VIEWPOINT

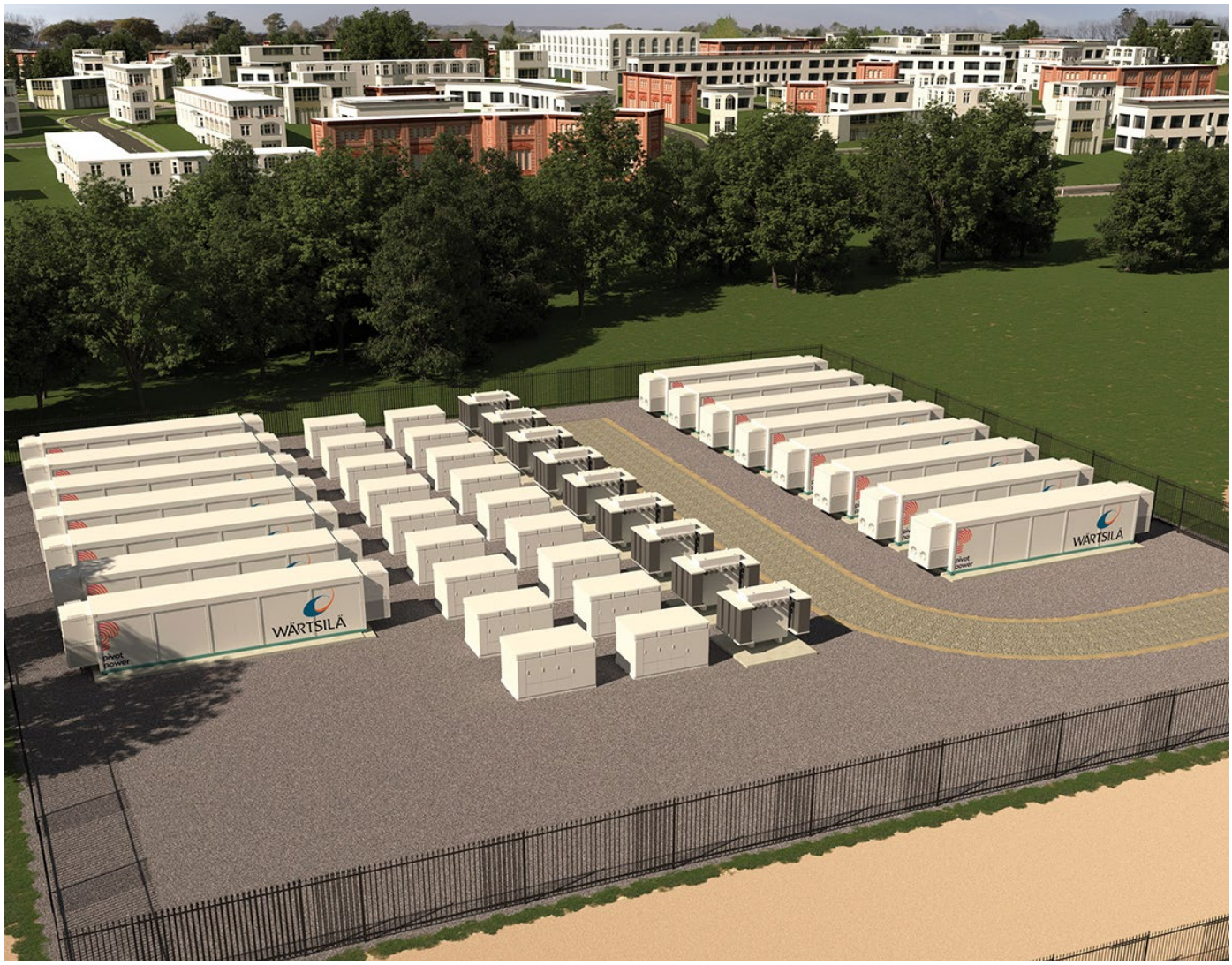
Ville Rimali
Growth & Development Director,
Africa and Europe
Wärtsilä Energy

"The UK energy system is at a fork in the road. The current road promises to lock-in traditional inflexible energy system with energy stimulus, creating 60%[18] less jobs and missing the UK's net-zero target. The alternative road leverages economic stimulus to unlock massive private sector investment, clearly putting the UK on a net-zero trajectory – potentially cutting emissions intensity by 58% by achieving a 60% share of renewables by 2025.

Today, energy stimulus is focused on reviving the UK's existing fossil fuel-based economy, not building the net-zero economy that the country wants to drive. The current approach is not aligned with the UK's ambitious 57% GHG reduction by 2030 and net-zero by 2050 targets. Refocusing stimulus towards renewable energy and flexibility would accelerate the UK energy transition and support a sustainable recovery and jobs.

Based on the UK's commitment to offshore wind, by 2050 wind could contribute as much as 90% of total power generation. To unlock that potential efficiently, the UK's system must be reinforced with a significant volume of flexible assets, such as battery storage and modular flexible power plant, to enable it to absorb and balance intermittent wind energy in a cost-optimal system. Future synthetic fuels, such as hydrogen and hydrogen-based renewable synthetic methane, promise to be an important piece of the puzzle. Creating such a flexible power system would put the UK at the vanguard of the global energy transition.

The UK has enormous potential to accelerate to net-zero and present a blueprint for other countries to follow, stimulating investment, jobs, technology, intellectual property and economic growth."



Energy storage accelerates a clean electric future in the UK

Pivot Power's nationwide network of transmission-connected battery storage will provide balancing services to enable more renewables and accelerate the transition to a clean energy future in the UK.

Wärtsilä is supplying two 50 MW lithium-ion batteries, the first projects to be completed as part of Pivot Power's programme to develop, own and operate up to 2 GW of grid-scale energy storage and high volume power connections directly connected to the UK high-voltage transmission system. The projects will provide flexible capacity and reliability to support increased renewable energy generation and electric vehicle (EV) charging infrastructure.

The systems are based on Wärtsilä's advanced energy management software platform GEMS, which leverages artificial intelligence, forecasting and machine learning to smartly manage various assets — storage, EV charging, grid fluctuations — in the UK market. The versatility of GEMS to optimise various assets in changing market conditions is particularly important, enabling Pivot Power to future-proof resources under a single portfolio and benefit from multiple revenue streams.

"At Pivot Power, we are committed to enabling a clean electric future and accelerating the expansion of electric vehicles across the UK, and as part of EDF Renewables we are making this vision a reality. These Wärtsilä energy storage systems allow us to harness cutting-edge technology to future-proof our investments in a changing energy market, supporting our long-term goal to reduce the UK's carbon footprint and bring us closer to net-zero."

Adrien Lebrun
Engineering Director
Pivot Power

GERMANY

DIRECTING STIMULUS TO SUPPORT THE ENERGY TRANSITION

CASE STUDY

Replacing coal-fired plant with flexible baseload innovation

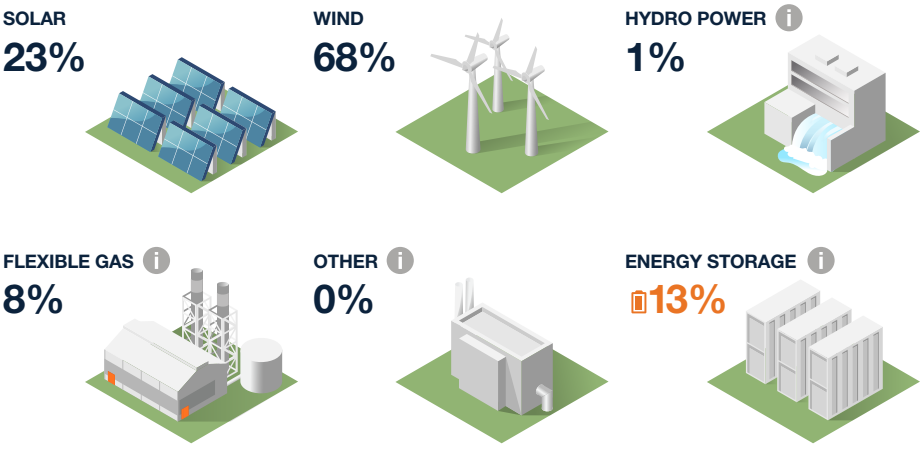
In Bremen, public utility swb Erzeugung is paving the way for renewable generation by replacing an old coal-fired combined heat and power (CHP) plant with flexible gas generation. Powered by the latest Wärtsilä technology, the new CHP gas engine power plant offers heat and flexible baseload in the winter and shaves peaks in energy demand in the summer, all the while making great economic sense for its owners.

'Flexibility' being the key word in this cutting-edge technology, the Bremen plant can be run at any load with outstanding performance in both CHP- and power-only mode. With its modular design and easy ramp-up, the power plant quickly responds to market demand and can produce as much power and heat as needed. The modular design also significantly reduces the plant's maintenance time and costs, improving its availability and reducing the need for spare parts.

Wärtsilä has modelled the cost-optimal 100% renewable energy mix for countries around the world with the Atlas of 100% Renewable Energy. The Atlas modelling illustrates how Germany's power system would look if it was optimally built from scratch[19], not considering the burden of existing inflexible thermal power plants. This frames the opportunity that countries now have to leverage COVID-19 pandemic stimulus to kickstart the transition from their existing share of renewable energy assets towards 100% renewable energy.

GERMANY RUNNING ON 100% RENEWABLES

Share of annual electricity generation



See page 26

PARIS AGREEMENT COMMITTMENT

Germany has committed to at least a 55% domestic reduction in greenhouse gases by 2030 compared to 1990 levels. In 2019, Germany announced its commitment to reach net-zero emissions by 2050, alongside other EU countries.

RENEWABLE ENERGY GENERATION[20]

42% gross electricity consumption from renewables (2019)[21] .
244 TWh renewable generation (2019).
124 GW total renewable electricity capacity (2019).

ECONOMIC STIMULUS FOR ENERGY

AT LEAST

$22 billion USD

SUPPORTING FOSSIL FUEL ENERGY

$260

PER CAPITA

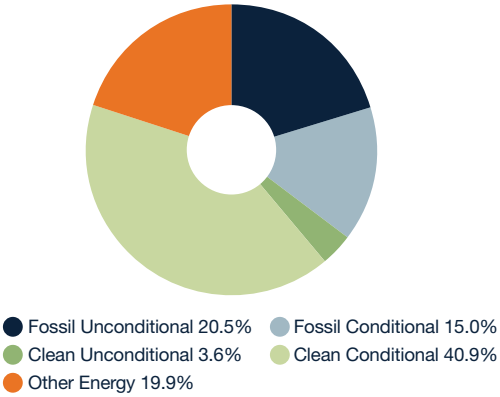
AT LEAST

$27 billion USD

SUPPORTING CLEAN ENERGY

$326

PER CAPITA



Since the beginning of the pandemic in early 2020, Germany has committed at least $60.85 billion USD to supporting different energy types through new or amended policies, according to official government sources and other publicly available information.

These public money commitments include:

- At least USD $22 billion USD for legacy fossil fuels
- At least USD $27 billion USD for clean energy
- At least USD $12 billion USD for other energy

VIEWPOINT

"Germany, being the largest economy, as well as carbon emitter, in Europe, is looking to maximise the impact of stimulus-related policy by supporting the energy transition. For example, it has raised the target for offshore wind power from 15 to 20 GW in 2030. The recently passed Coal Phase-Out Act alone paves the way for a massive €40 billion support programme up until 2050. Our studies show that by investing in flexibility, renewable energy, sector coupling and decarbonised fuels, Germany can reach net-zero without over-burdening taxpayers."

Jan Andersson
Market Development Manager, Europe
Wärtsilä Energy

BRAZIL'S TRANSITION TO A 100% RENEWABLE SYSTEM

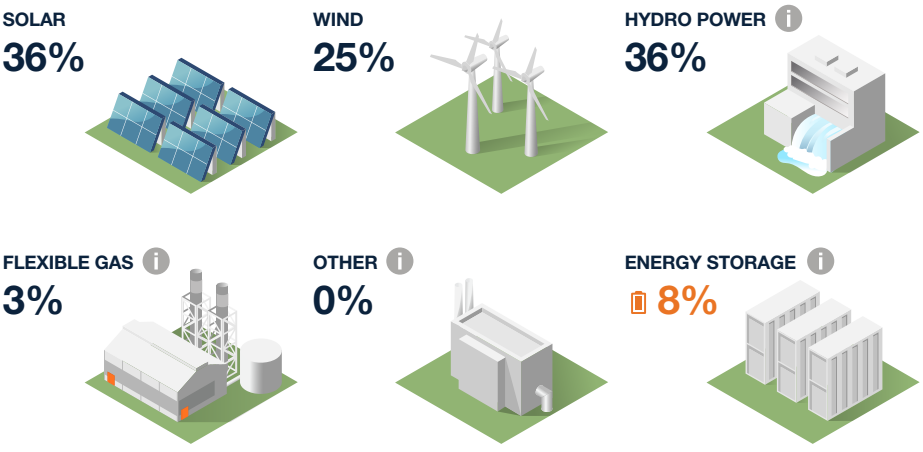
Wärtsilä has modelled the cost-optimal 100% renewable energy mix for countries around the world with the Atlas of 100% Renewable Energy. The Atlas modelling illustrates how Brazil's power system would look if it was optimally built from scratch[22], not considering the burden of existing inflexible thermal power plants. This frames the opportunity that the country has to leverage COVID-19 stimulus to kickstart the transition from the existing share of renewable energy assets to 100% renewable energy.

The Atlas subdivides some countries, including Brazil, into key regions to capture specific regional conditions affecting the cost-optimal mix for 100% renewable energy. Below, Brazil South East is highlighted, based on its high potential for wind and solar energy adoption, plus the high levels of electricity demand due to proximity to cities and industrial areas.

Brazil South East is highlighted as a region with significant potential as a centre for the generation of affordable, clean energy – aligned with the potential to meet national climate commitments and create jobs – within a sustainable economic recovery.

BRAZIL SOUTH EAST RUNNING ON 100% RENEWABLES

Share of annual electricity generation



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PARIS AGREEMENT COMMITMENT

Brazil has committed to a 37% reduction in emissions by 2025, compared to 2005 levels, with a further indicative target of a 43% reduction in emissions by 2030.[23] Even though this committment is mostly related to deforestation, the power system can further contribute to achieving the target by avoiding unnecessary emissions.

RENEWABLE ENERGY GENERATION

79% of domestically produced electricity is renewable (2019).
515 TWh total renewable generation (2019)[24].

ECONOMIC STIMULUS FOR ENERGY

AT LEAST

$600 USD

SUPPORTING FOSSIL FUEL ENERGY

$2.9

PER CAPITA

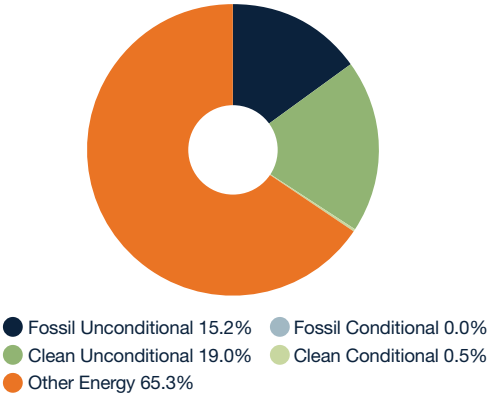
AT LEAST

$780 million USD

SUPPORTING CLEAN ENERGY

$3.7

PER CAPITA



Since the beginning of the pandemic in early 2020, Brazil has committed at least $4 billion USD to supporting different energy types through new or amended policies, according to official government sources and other publicly available information.

These public money commitments include:

- At least $780 million USD for clean energy.
- At least $2 billion USD for other energy.
- At least 600 billion USD for legacy fossil fuels.

VIEWPOINT

"“Over the past years, the share of wind and solar in Brazil has grown significantly. We live in a transition period which will inevitably take Brazil to a path close to a 100% renewable system. There is no step back, the deployment of green energy has been extremely fast and this comes with a new challenge: the intermittency generated by renewable energy and the need to increase power systems flexibility. For Brazil to optimally accelerate the deployment of renewable energy, flexible solutions must play a vital role in maintaining grid stability and reliability at all times”.

Jorge Alcaide
Energy Business Director and Managing Director
Americas South Region
Wärtsilä Energy

AUSTRALIA

CAPITALISING ON UNPARALLELED RENEWABLE ENERGY RESOURCES

CASE STUDY

Balancing Rising Renewables with Flexible Generation at AGL Energy's Barker Inlet Power Station

In December 2019, the 211 MW Barker Inlet Power Station delivered by Wärtsilä on an EPC (engineering, procurement and construction) basis became operational in South Australia. The flexible gas-fired power plant, owned by AGL, requires 28% less fuel than its predecessor turbine plant and will play the important role of ensuring reliability in the renewable-heavy South Australian power system.

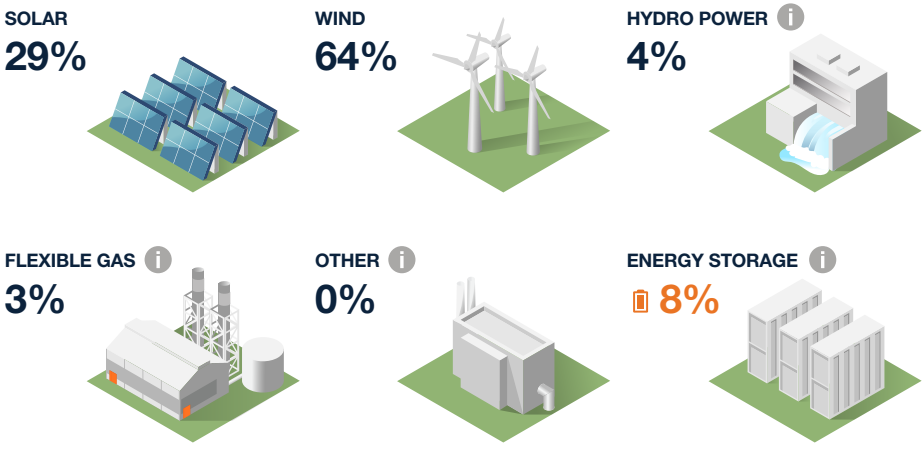
Aside from hydro-driven Tasmania, South Australia has the largest share of renewable generation in the grid. Power generation in South Australia consists of gas-based generation, wind, solar, and energy storage. Gas plants are needed to meet daily peaks, to balance renewables, and to ensure security of supply. In recent years demand for gas-based generation has seen a change, with a reduction in baseload, and an increase in peaking requirements. Barker Inlet, as a highly flexible and efficient reciprocating engine plant, is a prime example of this increasing need for plants to be adept at peaking, fast ramping, and multiple starts and stops to balance the growing share of renewables.

Wärtsilä has modelled the cost-optimal 100% renewable energy mix for countries around the world with the Atlas of 100% Renewable Energy. The Atlas modelling illustrates how Australia's power system would look if it was optimally built from scratch[25], not considering the burden of existing inflexible thermal power plants. This frames the opportunity the countries now have to leverage COVID-19 pandemic stimulus to kickstart the transition from their existing share of renewable energy assets to 100% renewable energy.

The Atlas subdivides some countries, including Australia, into regions to capture specific regional conditions affecting the cost-optimal mix for 100% renewable energy. Below, Australia East is highlighted, based on its high potential for wind and solar energy adoption, plus high levels of electricity demand due to proximity to major cities and industrial areas.

AUSTRALIA EAST RUNNING ON 100% RENEWABLES

Share of annual electricity generation



See page 26

PARIS AGREEMENT COMMITMENT

Australia has committed to a 26 to 28% reduction in emissions by 2030 on 2005 levels.

RENEWABLE ENERGY GENERATION[26]

21% of total electricity generation from renewables (2019).
55 TWh total renewable generation (2019).

ECONOMIC STIMULUS FOR ENERGY

AT LEAST

$480 million USD

SUPPORTING FOSSIL FUEL ENERGY

$19

PER CAPITA

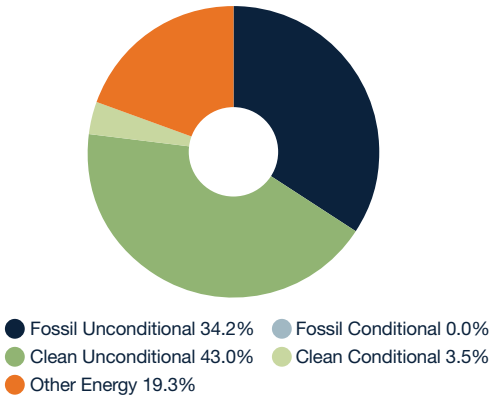
AT LEAST

$660 million USD

SUPPORTING CLEAN ENERGY

$26

PER CAPITA



Since the beginning of the pandemic in early 2020, Australia has committed at least $1.4 billion USD to supporting different energy types through new or amended policies, according to official government sources and other publicly available information.

These public money commitments include:

- At least $480 million USD for legacy fossil fuels.
- At least $660 million USD for clean energy.
- At least $270 million USD for other energy.

Over $660 million USD of stimulus was pledged in 2020 to support clean energy, plus a $300 million AUD ($196 MUSD) 'Advancing Hydrogen Fund' to grow Australia's renewable hydrogen sector, including developing new domestic supply chains, export infrastructure and to help grow domestic demand for hydrogen (note: the 'Advancing Hydrogen Fund' is included in 'other energy' in the summary above).

VIEWPOINT

"Australia is a country with unparalleled renewable energy resources and with a unique opportunity to swiftly decarbonise and move towards 100% renewable energy. The green stimulus announced for clean energy and for hydrogen shows that there is room to further speed up this transition. An optimal 100% renewable energy mix will be based on wind and solar, but energy storage and flexible bio- or synthetic gas will be crucial for balancing."

Kari Punnonen
Energy Business Director, Australasia
Wärtsilä Energy

Kingsmill Bond, CFA
Energy Strategist
Carbon Tracker

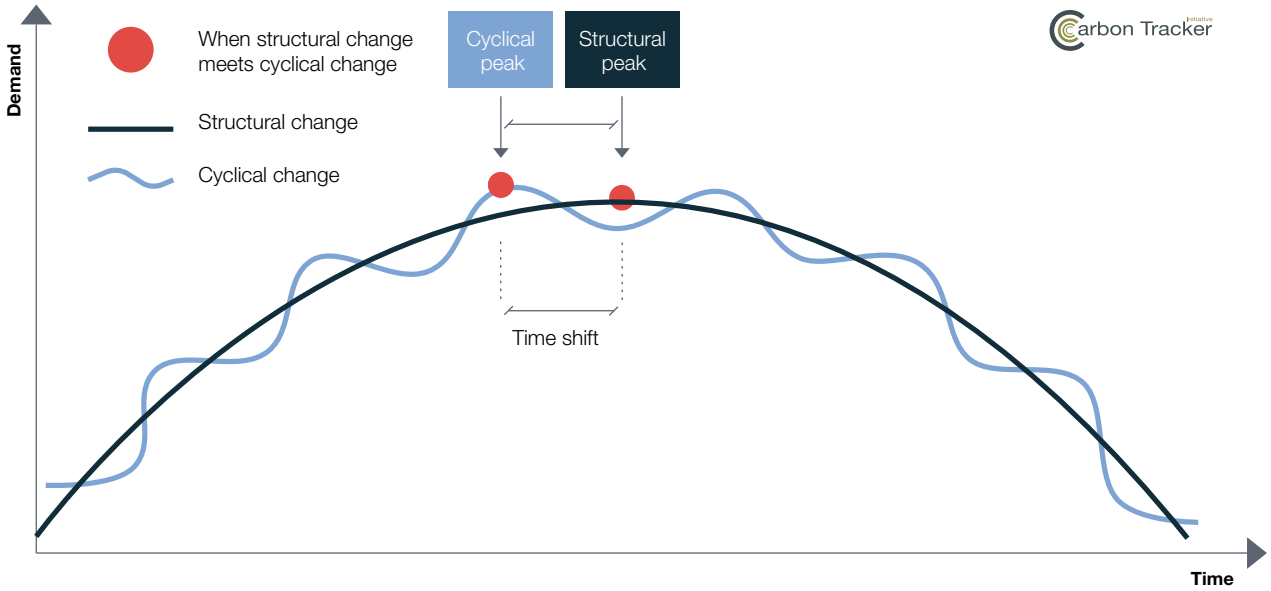
THE ENERGY TRANSITION – THE TIME IS NOW

A key tipping point was reached in 2019. Global demand for fossil fuels peaked, and is unlikely ever to recover to its pre-crisis levels. The consequences are extremely profound for energy companies, financial markets and policymakers.

At heart, this is a technology transition. Look around you at the impact of the internet on the media sector or Amazon on the retail sector to get a sense of how rapid and profound are the impacts of a technology transition. The key driver of the transition in the electricity sector has been the collapse in the price of renewable energy technologies. The price of wind and solar electricity has fallen by up to 90% in the last decade. Most importantly, solar and wind electricity prices are at levels below that of fossil fuel based electricity in 80% of the world and continue to fall. At the same time, engineers and innovators have been coming up with new ways to incorporate an ever rising share of variable renewables into electricity systems. In 2019 three quarters of new investment in electricity went into renewables, the utilisation rates of coal generators fell to 53%, and fossil fuel demand for electricity fell by 1%.

And then came the COVID-19 pandemic. According to the IEA, demand for fossil fuels is likely to collapse in 2020 by 8% at the same time as renewables keep on growing by 15%. By the time electricity demand recovers, all of the growth will be taken by renewables.

What happens when you reach the top and start to decline? Companies that plan for growth have too much capacity. Excess capacity leads to low prices, which reduce profits for companies across the systems and leads to huge amounts of stranded assets. There is a huge legacy fossil fuel system with over $30 trillion USD of fixed assets, and thousands of companies whose business plan is based on rising demand. And yet this is all vulnerable to disruption as you move from growth to decline.



Infrastructure and generation plants last for decades. As investors realise that the era of business as usual is over, so they decide not to invest in continued expansion of the legacy fossil fuel system. The impact is felt immediately if you are a company which builds new machinery for coal plants or offshore oil exploration platforms.

Financial markets are well aware of what is going on, and are exiting the most vulnerable parts of the fossil fuel system. The European electricity sector collapsed in value in 2008 and spent the next decade in massive sector restructuring and the write-down of $150 billion USD of fixed assets. General Electric's gas turbine division took a $23 billion USD write-down in 2018 as the share price of the company fell by two thirds. Coal stocks have been falling since 2011, two years before coal demand peaked. Business models based on high power plant utilisation rates and inflexible base load provision are not needed in this environment. The companies who are feeling the shock are those that refused to accept the pace of change, or are incapable of adjusting their technologies and business models to meet the energy transition.

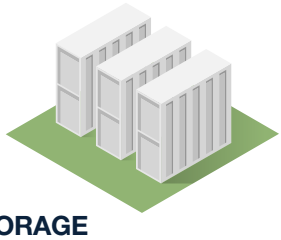
The key hope of the incumbent fossil fuel companies was that the intermittency of renewables would be too hard for power systems to handle and somehow put a cap on their growth. They said this at 2% renewable penetration, again at 10%, and have kept on making the same argument in spite of the ever-rising share of renewables in the electricity system. In 2019, variable renewables supplied 8% of global electricity and 28% in Germany. In 2020 they have risen at times to supply over 50% of German electricity.

The solutions are complicated. They require demand and supply flexibility, new regulatory structures, new technologies and new ideas. Everywhere is different. And this is where Wärtsilä's Atlas of 100% Renewable Energy is so important, to give direction to help to envision and enact the ultimate end-state for energy systems around the world in the most cost-optimal way.

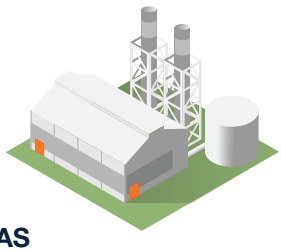
What does this peak mean for policymakers? It would be deeply irresponsible to try to build back the old system. You may be certain that if you try to do so, the companies at the top end of the cost curve will dump their assets on the taxpayer, and you will have to pay to clean them up and close them down. As you stimulate to drive economic growth, then invest in industries like solar, wind or electric vehicles, and flexibility to keep the lights on in all weather conditions. Invest in efficiency and clean up our cities. Now is precisely the moment to forge the industries of the future, to invest in the new areas which will create jobs, opportunity and growth. Business as usual is well and truly over.

ATLAS ICONS EXPLAINED

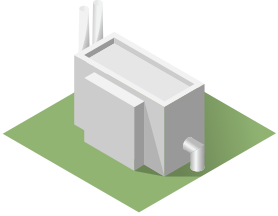
HYDRO POWER
Existing hydro power plants have been included in the capacity mix



ENERGY STORAGE
Share of all produced electricity shifted for use at a later time using batteries or Power-to-X.



FLEXIBLE GAS
Flexible engine power plant running on carbon neutral synthetic fuels produced with renewable energy (Power-to-X).



OTHER
Other renewable energy sources, e.g. geothermal. Existing geothermal power plants have been included in the capacity mix.

METHODOLOGY

This report examines the potential for governments' energy stimulus to be focused explicitly on measures to foster an accelerated transition towards 100% renewable energy, simultaneously spurring economic recovery and growth, creating millions of jobs and putting emissions into structural decline.

The analysis in the report is founded on two key sources:

1. **Wärtsilä's Atlas of 100% Renewable Energy**[27] , developed based on the database from the Lappeenranta-Lahti University of Technology[28] , on 100% Renewable Energy Systems, plus Bloomberg New Energy Finance estimates[29] on technology cost reductions over time. The Atlas of 100% Renewable Energy models 145 countries and regions around the world to provide an illustrative guide as to the cost-optimal potential of 100% renewable electricity systems. Detailed hourly modelling takes into account intermittency and seasonality of renewables. The modelling shows the cost-optimal energy mix for a 100% renewable energy system in all regions with unique conditions for renewable energy. It also shows the mix of flexibility technology, short-term and long-term, needed to support renewable energy in each case. In each country, the capacity of power generation technologies adds up to 100% - as they actually generate electricity. When adding energy storage the capacity numbers exceed 100%, as each energy storage shows the share of all produced electricity shifted for use at a later time, using batteries or Power-to-X technology.

   The Atlas models energy systems from a hypothetical fresh start, or greenfield state, to illustrate the ideal renewable energy scenario: only hydro-power and geothermal are included from today's power systems. The modelling presents the option of allowing all renewable technologies (including synthetic, renewable and carbon neutral fuels that have been produced through Power-to-X) into the future capacity mix, as well as an alternative scenario where only wind, solar and battery energy storage can be added to the system. For the purposes of this report, existing capacity, renewables and fossil fuels, were included in the Atlas model and the systems were optimized by gradually increasing the share of renewables in the system until 100% Renewable Energy Systems (RES) were reached.

2. **The Energy Policy Tracker**[30] , a detailed, real-world snapshot of individual public funding commitments related to the production and consumption of energy in the G20 countries since the beginning of the pandemic. The Energy Policy Tracker registered over 200 individual policies from G20 countries, combining the amounts committed through each policy to generate total aggregate figures. To provide a detailed, real-world picture of the current state of support for different energy types, the data for both fossil fuels and clean energy is split into sub-categories—unconditional and conditional. The policies have been classified according to different criteria. One of the key criteria is a policy's environmental profile that depends on 1) which energy types it benefits, and 2) whether it has any environmental conditionality attached. Throughout the Tracker, information is split across five categories:

    1. **"Fossil unconditional":** Policies that support production and consumption of fossil fuels (oil, gas, coal, "grey" hydrogen or fossil fuel-based electricity) without any climate targets or additional pollution reduction requirements.

    2. **"Fossil conditional":** Policies that support production or consumption of fossil fuels (oil, gas, coal, "blue" hydrogen or fossil fuel-based electricity) with climate targets or additional pollution reduction requirements. The conditionality includes climate and pollution reduction targets as well as support to measures reducing environmental damage through carbon capture, utilization and storage (CCUS), end-of-the-pipe solutions such as reduction of methane leakages, extractive sites clean-up and other measures.

    3. **"Clean unconditional":** Policies that support production or consumption of energy that is both low-carbon and has negligible impacts on the environment if implemented with appropriate safeguards. These policies support energy efficiency and renewable energy coming from naturally replenished resources such as sunlight, wind, small hydropower, rain, tides, and geothermal heat. "Green" hydrogen is included.

    4. **"Clean conditional":** Policies that are "potentially clean", i.e. they are stated to support the transition away from fossil fuels, but unspecific about the implementation of appropriate environmental safeguards. Examples include: large-hydropower; rail public transport and electric vehicles using multiple energy types; smart grids and technologies to better integrate renewables; hydrogen in the case of mixed, but predominantly clean sources (e.g. under Germany's hydrogen strategy); and biofuels, biomass and biogas with a proven minimum negative impact on the environment (sometimes referred to as "advanced: or "second" or "third generation"). Without appropriate environmental safeguards, such policies can still have significant impacts. For instance, if powered with coal- or gas-based electricity, EVs can have a significant impact on the environment.

5. **"Other energy":** Policies outside of the two "fossil" and two "clean" buckets, or in both of them, fall in this umbrella category. These policies support nuclear energy (including uranium mining), "first generation" biofuels, biomass and biogas (with proven negative impact on the environment), incineration, hydrogen of unspecified origin, and multiple energy types, e.g. intertwined fossil fuels and clean energy (a sizeable group, since many policies benefit both fossil and clean energy across the board).

Energy Types and stages

Energy Policy Tracker provides a breakdown of policies by energy type and energy stage. Energy types include: coal; oil and oil products: gas and gas products; oil and gas; multiple fossil; biofuels and waste; wind; solar; hydropower; hydrogen; other renewable; multiple renewable; energy efficiency; active transport; nuclear; multiple energy types; other energy type.

Energy stages include: exploration or production or processing or storage or transportation; electricity generation; electricity storage or transmission or distribution; energy use (all energy types, including consumption in transport, household use, buildings etc); energy efficiency; reduced environmental damage; several energy stages (many policies apply to several energy stages); active transport (cycling or walking); and other energy stage.

Energy efficiency (a "hidden fuel") and active transport are categories for both energy type and energy stage.

Wärtsilä's approach to modelling the deep dive analyses of the United States and the United Kingdom was:

1. **Review current situation:** Review each country's current renewable energy capacity mix within the Atlas model and add the existing capacity to the model.

2. **Input available stimulus:** Calculate the MWs of renewable energy capacity achievable from stimulus value in $ USD from the model results. The energy scenarios modelled were based on a cost optimal mix of renewable energy, plus required capacity, such as energy storage or flexible thermal generation, that would be needed to balance the grid to ensure reliability. The proposed theoretical system optimized by increasing the share of RES gradually until a 100% RES system was reached.

3. **Model the economic case:** Extrapolate the jobs potential of stimulus investment in renewable energy compared to that of the fossil fuel sector[31] (McKinsey). Additionally, the UK model shows the potential to divert stimulus to fund policy incentive measures, such as tax credits and permitting, alongside aligning energy market structures, which is expected to leverage additional private investment for Renewable Energy by a factor of 3-4[32] .

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2 https://www.smithschool.ox.ac.uk/publications/wpapers/workingpaper20-02.pdf

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4 IEA Sustainable Recovery report June 2020

5 https://www.globaldata.com/investment-in-renewable-energy-transition-could-act-as-a-powerful-recovery-mechanism-from-covid-19-says-globaldata/

6 https://www.theguardian.com/environment/2020/jun/18/world-has-six-months-to-avert-climate-crisis-says-energy-expert

7 http://wartsila.com/atlas

8 https://www.energypolicytracker.org/

9 Bloomberg New Energy Finance

10 Note: the US Presidential Administration has committed to pull out of current US commitments under the Paris Agreement in November 2020.

11 Figures taken from the US Energy Information Administration: https://www.eia.gov/tools/faqs/faq.php?id=427&t=3

12 Based on 75 RE jobs created per $10m USD and 27 fossil jobs per $10m USD. https://www.mckinsey.com/business-functions/sustainability/our-insights/how-a-post-pandemic-stimulus-can-both-create-jobs-and-help-the-climate.

13 The analysis is based on data downloaded from Energy policy tracker on 22 Sept.

14 https://www.wartsila.com/atlas

15 Figures taken from the UK Department for Business, Energy and Industrial Strategy: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/905060/DUKES_2020_MASTER.pdf

16 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/877047/Press_Notice_March_2020.pdf

17 IRENA

18 Based on 41,207 clean energy job creation potential from full energy stimulus and 16,185 from fossil fuel job creation potential from same figure.

19 The Atlas modelling does not provide 'greenfield' modelling of hydropower, since its availability is highly dependent on geographical conditions.

20 Figures taken from the German Federal Ministry for Economic Affairs and Energy: https://www.erneuerbare-energien.de/EE/Redaktion/DE/Downloads/zeitreihen-zur-entwicklung-der-erneuerbaren-energien-in-deutschland-1990-2019-en.pdf?__blob=publicationFile&v=10

21 https://www.umweltbundesamt.de/en/topics/climate-energy/renewable-energies/renewable-energies-in-figures

22 The Atlas modelling does not provide 'greenfield' modelling of hydropower, since its availability is highly dependent on geographical conditions.

23 https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Brazil%20First/BRAZIL%20iNDC%20english%20FINAL.pdf

24 https://www.iea.org/countries/brazil

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26 Figures taken from the Australian Department of Industry, Science, Energy and Resources https://www.energy.gov.au/publications/australian-energy-statistics-table-o-electricity-generation-fuel-type-2018-19-and-2019.

27 https://www.wartsila.com/atlas

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29 https://www.lut.fi/web/en

30 https://www.energypolicytracker.org

31 https://www.mckinsey.com/business-functions/sustainability/our-insights/how-a-post-pandemic-stimulus-can-both-create-jobs-and-help-the-climate

32 https://irena.org/-/media/Files/IRENA/Agency/Publication/2020/Jun/IRENA_Post-COVID_Recovery_2020.pdf

Note: the Energy Policy Tracker data used in the Wärtsilä report is accurate as of 26 October. The data used specifically for the UK and US modelling and analysis is based on data originally compiled as of 22 September, due to the time required to model and analyse the scenarios provided in the report. The underlying data used in the UK and US modelling has been assessed against Energy Policy Tracker data as at 26 October and remains accurate as of 26 October.

WÄRTSILÄ ENERGY

Wärtsilä Energy leads the transition towards a 100% renewable energy future. We help our customers unlock the value of the energy transition by optimising their energy systems and future-proofing their assets. Our offering comprises flexible power plants, energy management systems, and storage, as well as lifecycle services that ensure increased efficiency and guaranteed performance. Wärtsilä has delivered 73 GW of power plant capacity and over 80 energy storage systems in 180 countries around the world.