EEIST

APPENDIX 1

WIND ENERGY IN THE UK AND BRAZIL

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Global Trends

Global onshore and offshore wind capacity and electricity generation has increased dramatically in recent years.

For onshore wind, capacity increased from 16.8 GW in 2000 to 594 GW in 2019, while generation jumped from 30.8 TWh to 132 TWh in the same period. For offshore wind, growth was from 67 MW to 28 GW capacity and 0.12 TWh to 98 TWh generation in the same period (IRENA, 2021b). Meanwhile, costs for these technologies have reduced substantially, as demonstrated by Figure 1 and Figure 2 for onshore and offshore wind, respectively. For offshore wind, these cost reductions were mainly delivered post-2010, following a period of increasing costs as sites were increasingly further out to sea.

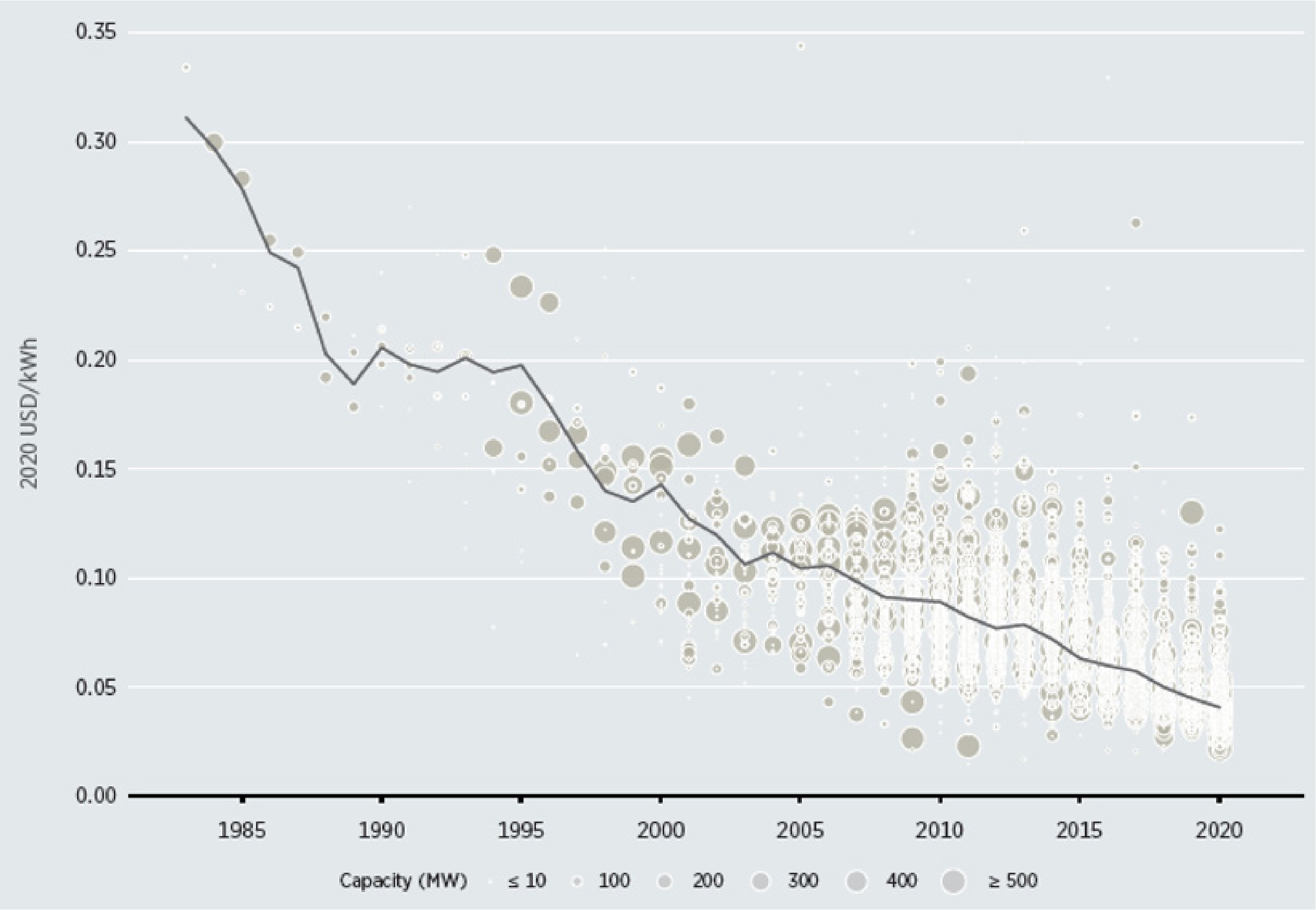

Figure 1 – Levelised cost of energy (LCOE) of onshore wind projects, with global weighted average (black line), 1983-2020 (Source: IRENA, 2021a)

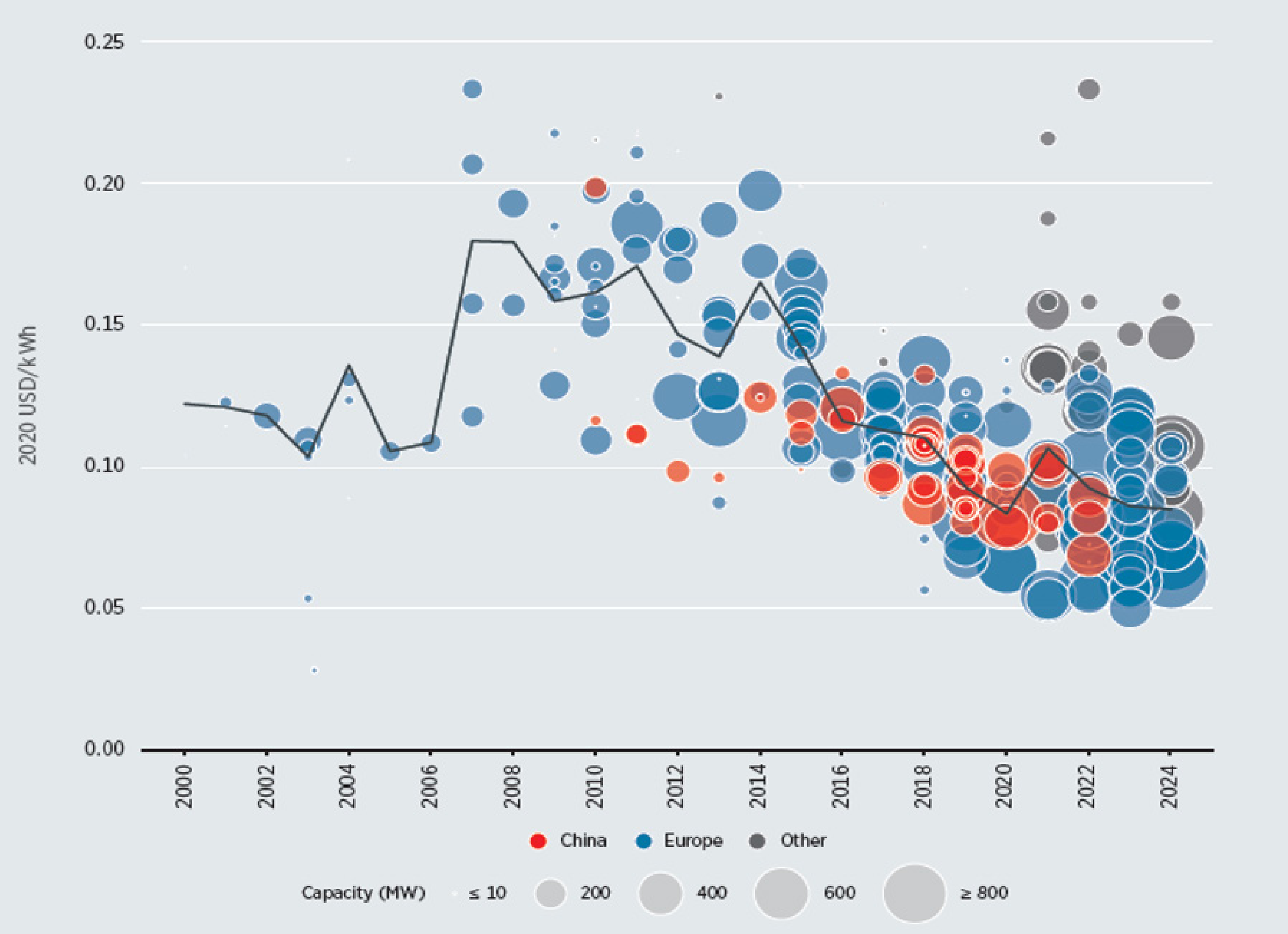

Figure 2 - Levelised cost of energy (LCOE) and auction/power purchase agreement (PPA) prices of offshore wind projects (with global weighted average (black line), 2000-2025 (Source: IRENA, 2021a)

These developments occurred not through policy put in place following traditional cost-benefit analysis, but as a result of strategic decisions and actions taken by policymakers and public institutions at different times in different places. Here we outline key examples in the development of both onshore and offshore wind.

US and Europe: Early development of modern wind markets

The development of modern, commercial onshore wind technology is rooted in California and Denmark, sparked in both cases by the oil crises of the 1970s. In California, it was facilitated by a combination of local demand, state and federal financial support, a favourable local political climate and geographic convenience, and was built substantially on Danish wind expertise and technology, which had grown out of the long historical use of wind power in the agricultural sector in that country. Although Denmark had initially aimed to diversify from oil toward coal and nuclear energy, developments including public opinion turning away from nuclear power meant wind was promoted as a key alternative. Building on the surplus capacity of the Danish agricultural machinery industry, a target was set in 1981 of having 1 GW of wind power installed by 2000, and this was supported by various government incentives.

Building on the technological developments during this time, across the late 1980s and 1990s other European countries (particularly Germany, but also the Netherlands and the UK), along with the EU, also began to support development and early deployment of wind energy (initially onshore, but later offshore) to meet early greenhouse gas and renewables targets, as well as for energy diversification and security purposes (Pasqualetti *et al,* 2004). These early markets allowed significant technological advances to occur, and as illustrated by Figure 1, a substantial reduction in technology costs.

Case study 1: Policy, innovation and cost reduction in offshore wind in the UK[1]

Paul Drummond

In 2000, electricity generation in the UK was dominated by coal and natural gas, at 32% and 39%, respectively, followed closely by nuclear, at nearly 23%. Renewable energies accounted for 3.4%, with (mainly onshore) wind energy just 0.3% (see Figure 3). This mix was in part the product of privatisation in the 1990s of the electricity market, with new economic incentives producing a 'dash for gas'. Gas-based generation grew rapidly from negligible levels, at the expense of coal-based generation, which declined from around 70% of generation (with nuclear accounting for most of the remainder in 1990). Privatisation also saw the number of generating companies grow from six in 1990 to 55 in 2000, although the largest three companies accounted for around half of all generation (Martin, 2019).

By 2000, although costs of onshore wind in the UK approximately halved to around £100/MWh since 1990, as a result of above and other developments? offshore wind remained a nascent technology, with the first demonstration project installed in December 2000. However, these two 2MW turbines, situated in 10m of water less than 2km from the coast, were the largest offshore turbines installed in the world at the time (OREC, 2021).

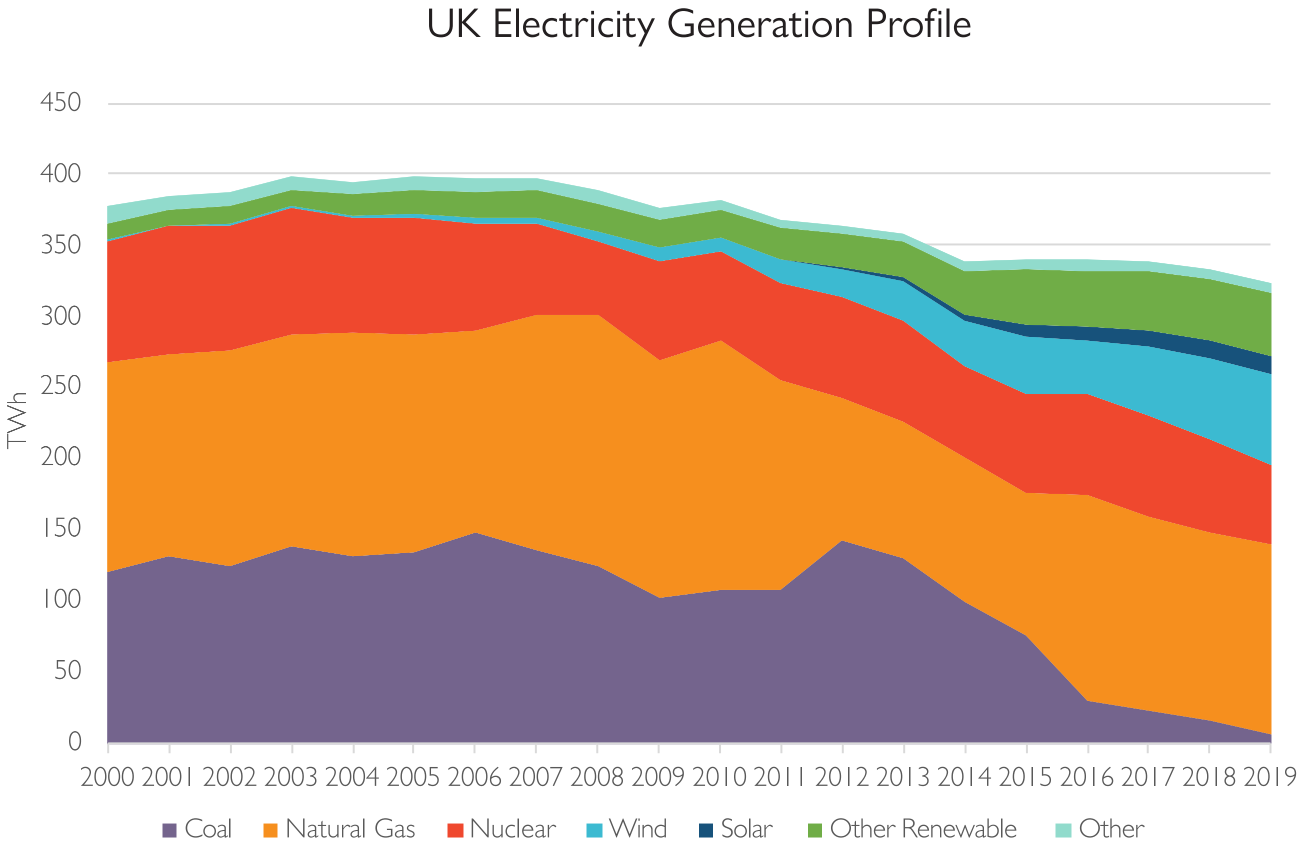

Figure 3 – UK Electricity generation profile (Source: IEA Statistics)

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Co-evolution of policy and technology

The first mechanism in the UK to encourage the deployment of renewable electricity was the Non-Fossil Fuel Obligation (NFFO), introduced in 1990 to subsidise non-fossil-based generation (principally nuclear, which at the time was still state-owned), but with a target to achieve 1.5 GW of renewable capacity by 2000. The NFFO obliged (then-public) electricity suppliers to purchase non-fossil fuel generation, with generators paid a fixed price for between five and 15 years, awarded via five competitive auctions, the last of which was in 1998. Costs were recovered by a Fossil Fuel Levy applied to electricity bills. The value of the levy was set by Parliament, which in turn determined the value of the total subsidy available. In this way, onshore wind achieved moderate growth, with rapid cost reductions as described above. Offshore wind projects were ineligible to bid due to their immaturity (Mitchell, 2000).

In 2002, the NFFO was succeeded by the Renewables Obligation (RO), a tradable green certificate introduced as the primary instrument to increase the contribution from renewables in electricity generation to 10% by 2010 (from 3.6% in 2000). This target was set unilaterally by the UK, but was intended to contribute to the non-binding EU-wide target of 21% set the previous year (HoL, 2008). Under the RO, energy suppliers were required to purchase an increase percentage of their electricity from renewable generation. The electricity market regulator (Ofgem) issued Renewable Obligation Certificates (ROCs) to renewable electricity operators to match their generation (for 20 years following accreditation), which were then sold to suppliers. If suppliers could not submit the required number of ROCs to meet their obligation level, they had to pay the 'buy-out' price to Ofgem. The buy-out price for the 2002-2003 obligation period was £30/MWh, increasing to £48.78 by 2019/20. ROCs were traded on the open market, although the government held levers to ensure the value remained at around £45 per ROC. The generator received the value of the ROC on top of the wholesale electricity price (Jennings *et al*, 2020).

In order to avoid 'picking winners', the RO was initially technology-neutral, with each generator receiving one ROC per MWh produced. As such, it favoured the construction of mature, lowest-cost renewable technologies – particularly onshore wind (from which generation increased from 0.7 GWh in 2002, to 6 GWh in 2008 (REF, 2021). In 2006, it was recognised that reforms were necessary to encourage the development and deployment of less mature technologies. In 2009, when the UK also formally agreed to achieve a 15% of final energy consumption from renewable sources under the EU's Renewable Energy Directive (to be achieved through, *inter alia*, 30% of electricity from renewables), the government introduced technology 'banding': awarding different numbers of ROCs (and thus, different levels of subsidy) according to their maturity. Offshore wind began to receive two ROCs per MWh generated (with onshore wind receiving 0.9 ROCs). This meant that offshore wind generators began to receive a price of £140-150/MWh, with an effective subsidy of around £100/MWh (once the wholesale price of electricity is subtracted).

In parallel to reform of the RO, three other key policy measures were introduced.

1. In June 2008, Round 3 of the Crown Estate 'leasing rounds' took place. The British Crown owns the seabed surrounding the UK up to 12 nautical miles, along with the rights to natural resources (excluding fossil fuels) and for the generation of electricity from wind, waves and tide on the continental shelf. Since 2001, via the 'The Crown Estate' (an independent commercial business created by Act of Parliament) auctioned rights for seabed space sufficient for more than 32 GW of offshore wind capacity, across nine zones.[2] In doing so, it also invested £80 million in co-funding for developments, and a range of other actions to improve understanding of offshore wind development.

2. In October 2008, the Offshore Wind Accelerator (OWA) was launched. The OWA was launched as a joint initiative between the government (via The Carbon Trust[3]) and nine leading offshore wind developers, with an aim to commercialise key technologies in the offshore wind supply chain and to bring down the LCOE by at least 10% by 2015 (in time for these innovations to be included in the installations constructed under Crown Estate Round 3 leases. When launched, the OWA was funded two-thirds by industry and one-third by the UK and Scottish governments.

3. Following the EU's Third Energy Package of 2009, which required electricity transmission and generation assets to have separate ownership, the UK regulator (Ofgem) began a new Offshore Transmission Owner (OFTO) regime, awarding transmission operator licences via competitive tendering.

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[2] Rounds 1 and 2, launched in 2001 and 2010 respectively, were much smaller, and largely intended for demonstration projects.

[3] The Carbon Trust was established in 2001 as a company limited by guarantee by the UK government, with an objective of accelerate the UK's move to a low carbon economy by helping business and the public sector cut their carbon emissions and help drive low carbon innovation. It was subsequently privatised in 2010.

The RO was unusual in that there was initially no overall budget cap, and no capacity cap. This meant that the only constraint was the amount of capacity that generators were able to bring forward. Although it held no explicit cost-reduction objective, the lack of competition between developers and relatively stable and generous subsidy allowed space for developers and actors in the supply chain to establish, experiment and develop core technical knowledge, including with technologies such as jacket foundations and new cable specifications that had not previously been deployed in offshore wind, therefore reducing barriers to market for new (including local) suppliers. It also allowed for collaboration and open knowledge exchange between developers and actors in the supply chain, both supported and driven by the OWA in particular (from which the innovations supported now provide an overall cost saving of £620 million over the lifetime of a 1 GW offshore wind project in the North Sea (The Carbon Trust, 2018)). Although the OFTO did little to reduce transmission costs itself, the separation of assets allowed low-risk transmission infrastructure to receive a much-reduced cost of capital. As transmission assets comprise 10-20% of the cost of offshore wind farms in the UK, this produced substantial savings.

Between 2009 and 2013, UK offshore wind capacity increased from 1GW to 4.2 GW, with annual generation increasing from 1.9 GWh to 11.5 GWh (REF, 2021). By 2013, the UK government judged that the market for renewable technologies was sufficiently mature to introduce a more competitive and market-responsive approach. This was supported by the results of the Offshore Wind Cost Reduction Taskforce, convened in 2011 by the UK government, which reported in 2012 that a target LCOE of £100/MWh for offshore wind by 2020 was feasible, and provided recommendations for how to achieve it – including increasing competition in the supply chain (OWCRTF, 2012).

As such, the RO began to be replaced by a Contracts-for-Difference (CfD) scheme – a bilateral legal contract between a low-carbon energy generator and the government-established Low Carbon Contracts Company (LCCC). The contract guarantees generators a fixed 'strike price' for electricity generation for 15 years, with the LCCC paying the generator the difference if the market price falls below this. Conversely, if the market price rises above the strike price, then the generator must pay the difference to the LCCC. As the strike price is typically fixed for 15 years, the generator can increase margins by reducing costs or generating more electricity (Jennings *et al*, 2020).

Pre-determined volumes of renewable electricity capacity are procured through 'allocation rounds', for different technology 'pots'; 'Pot 1' contains more mature technologies, such as onshore wind and solar PV, with 'Pot 2' containing less mature technologies, such as offshore wind.

The first procurement action under the CfDs was operated as an application process, where developers applied to receive predetermined strike prices. For offshore wind, this was set at between £140-150MWh – approximately the level of support provided by the RO. A total of 2.2 GW of capacity, or 70% of the total capacity supported, was for offshore wind (ibid).

In the 2014/15 allocation round (AR1), procurement became fully auction-based. Developers were invited to submit sealed bids, including a proposed strike price, details on technology type, costs, capacity, and the project delivery year. In each auction, National Grid ranks all submissions in order of the strike price, regardless of the year they plan to start generating. Where the sum total of applications for each year exceeds the National Grid budget for that year (as has been the case in all three rounds to date), a competitive auction is held to allocate the contracts. The auctions have a 'pay-as-cleared' format, meaning that all successful bidders receive the same remuneration as that of the highest strike price. In AR1, two offshore wind contracts with 1.2 GW of combined capacity were granted, representing 54% of all supported capacity. The largest offshore wind project – East Anglia 1 – received a strike price of £120/MWh[4], for delivery beginning in 2017/18 (DECC, 2015; Jennings *et al*, 2020).

In 2016, the government announced an effective moratorium on support for onshore wind and solar PV projects, introduced due to political pressure applied to the ruling Conservative Party at the time. As such, only Pot 2 technologies were eligible for support under the CfDs for AR2 in 2017 and AR3 in 2019. In AR2, 3.2 GW of offshore wind represented 96% of all newly contracted capacity, with strike prices of between £57.50 and £74.75/MWh for projects to be delivered in 2021-23 – a substantial reduction in cost from AR1. In AR3, offshore wind accounted for 93% of the total 4 GW of contracted capacity, reduced even further to between £39.65 and £41.61/MWh, for projects to be delivered in 2023-25. At these values, which approximates the wholesale price of electricity in Great Britain, offshore wind is effectively subsidy-free (Jennings *et al*, 2020). Between the start of the CfDs in 2013 and 2019, UK offshore wind capacity increased from 4.2 GW to 9.1 GW, with annual generation increasing from 11.5 GWh to 36.5 GWh – approximately 10% of all UK electricity generation (REF, 2021).

The scale, design and objectives of the CfD built upon the developments delivered under the RO to deliver substantial cost reductions through different mechanisms. Figure 4, below, illustrates the capital cost reductions experienced between 2010 and 2019 (left panel), and the processes that contributed to these reductions (right panel). 'Demand-pull' factors, specifically the CfD, are estimated to have driven around 80% of the cost reduction delivered across the decade.

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[4] In 2012 prices.

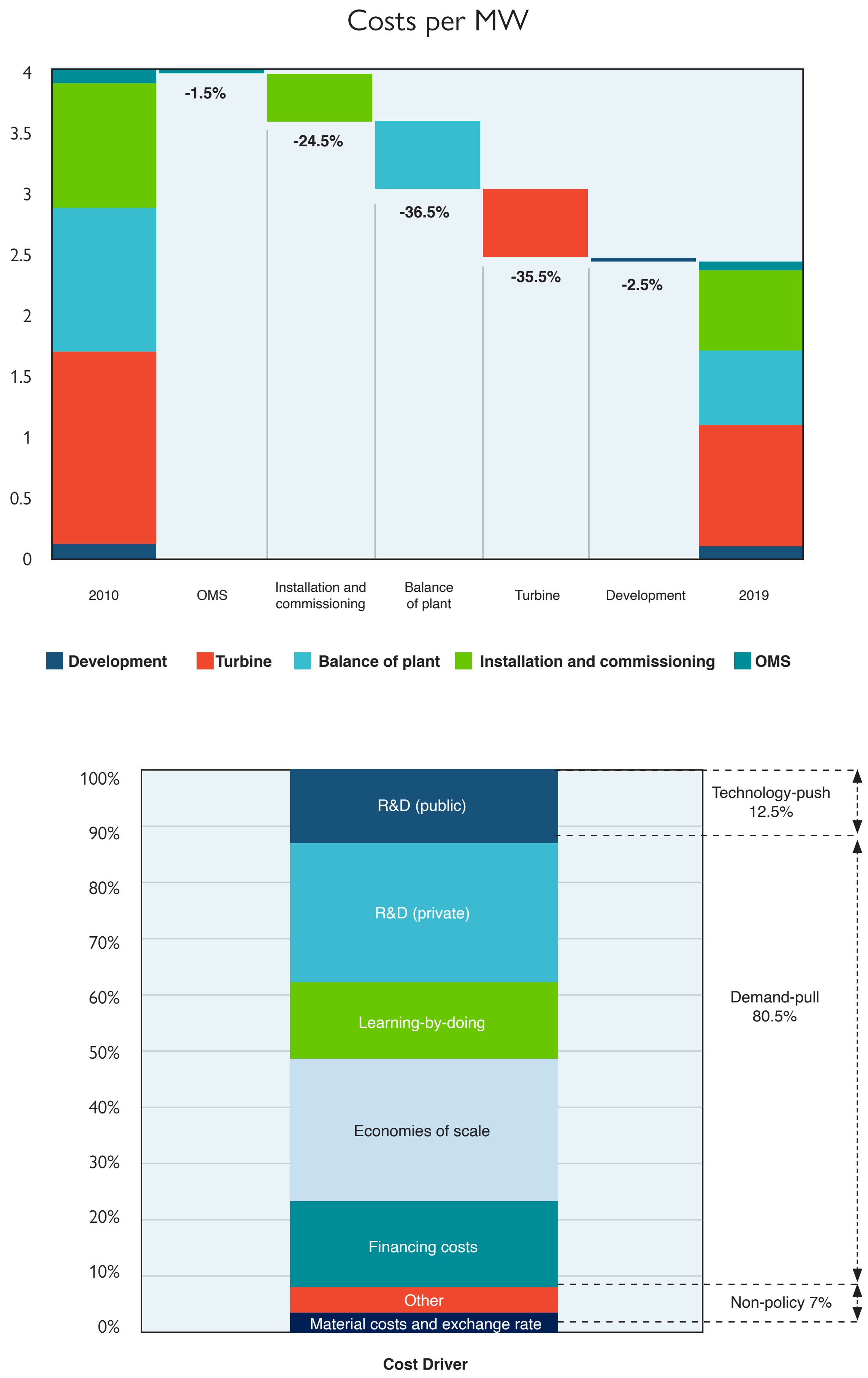

Figure 4 - Project cost reductions per MW (top panel) and drivers of cost reductions in offshore wind in the UK since 2010 (bottom panel) (Source: Jennings et al, 2020)

The competitive pressures, price and long-term certainty of the CfD encouraged industry to commit R&D to developing larger turbines, improved foundations and bespoke installation equipment (including, for example, bespoke vessels that were previously leased from oil and gas companies). Increasingly large turbines produced economies of scale (increasing turbine capacity required much reduced balance of plant and installation costs), alongside investment in new manufacturing and supply chain capacity. Ongoing installation pipelines also allowed for continued learning-by-doing, contributing to cost reductions through various means, including increased accuracy in cost forecasts, reduced investment risks/need for substantial contingency, and drawing more investors to these large, capital-intensive projects, providing finance at progressively lower rates (with investors also engaging earlier in the process). The CfD also sought to encourage local supply chain development through an obligation to submit a Supply Chain Plan for every bid over 300 MW of capacity, which must show how the project will promote competition, innovation and skills in the supply chain.

In 2019, as part of the government's wider 'Industrial Strategy', it agreed the Offshore Wind Sector Deal (OWSD) with the industry, the objective of which is to secure offshore wind's strategic position in the UK, and enable the continued development of supply chains and investment to ensure UK offshore wind reaches its full potential. The deal includes commitments to CfD rounds every two years to 2030, to achieve at least 30 GW of capacity by then, along with measures such as local content requirements and an aim to treble the size of the UK offshore wind workforce (with supporting initiatives).

Through these measures, the government projects that the domestic and export market for offshore wind is set to reach £4.9bn annually by 2030 and £8.9bn by 2050 (Jennings et al, 2020). In November 2020, the first 'point' in the British Prime Minister's 'ten point plan for a green industrial revolution' was to increase the offshore wind deployment target from 30 GW to 40 GW, including 1 GW of floating offshore wind (HM Government, 2020).

Reflections

Recent developments build on two decades of policies aimed at encouraging development of wind power in the UK, and mean that offshore wind in the UK will continue to expand rapidly, with costs likely to carry on declining as supply chains further develop and learning-by-doing and economies of scale continue to grow. This will reduce electricity costs to UK consumers through both the Merit Order Effect[5], but also by becoming effectively 'subsidy-negative' through the CfD mechanism; with strike prices below the average wholesale price of electricity, offshore wind operators will pay to generate, reducing the policy costs for renewable support more broadly, which are currently recovered through levies on electricity prices. It will also stimulate a growing domestic industry that can export knowledge and products to rapidly expanding markets around the world.

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[5] Describes the lowering of wholesale electricity prices due to an increased supply of renewable energies with very low marginal costs.

Case study 2: Development finance innovations and the evolution of Brazilian onshore wind [6,7]

João Carlos Ferraz and Luma Ramos

Between 2000 and 2016, Brazil doubled its electricity generation capacity from around 85 GW to around 170 GW. Onshore wind energy was responsible for 18% (15 GW) of this additional capacity. By 2020, Brazil's total onshore wind power generation capacity amounted to approximately 17 GW, delivering 9.5% of total generation, a more than 15-fold capacity increase from 2010 levels, which delivered just 0.5% of generation. This increase has avoided about 80 $MtCO_2$ of CO_2 emissions (Ferraz, Ramos and Plattek 2021), and has substantially outpaced the growth in wind energy in other BRICS countries (see Figure 5). By 2019, the country was placed eighth in global installed capacity for onshore wind, and fifth in newly installed capacity. The agency Energy Research and Planning (EPE, the Portuguese acronym), the planning arm of the Energy Ministry, expects onshore wind power capacity to continue growing, reaching more than 32 GW by 2030 (EPE, 2021). Brazil has favourable natural conditions for onshore wind energy, especially in the north-east region, demonstrated by an average capacity factor of 46% compared with a global average of 36.3%. There are currently no offshore wind installations operating on a commercial basis in Brazil.

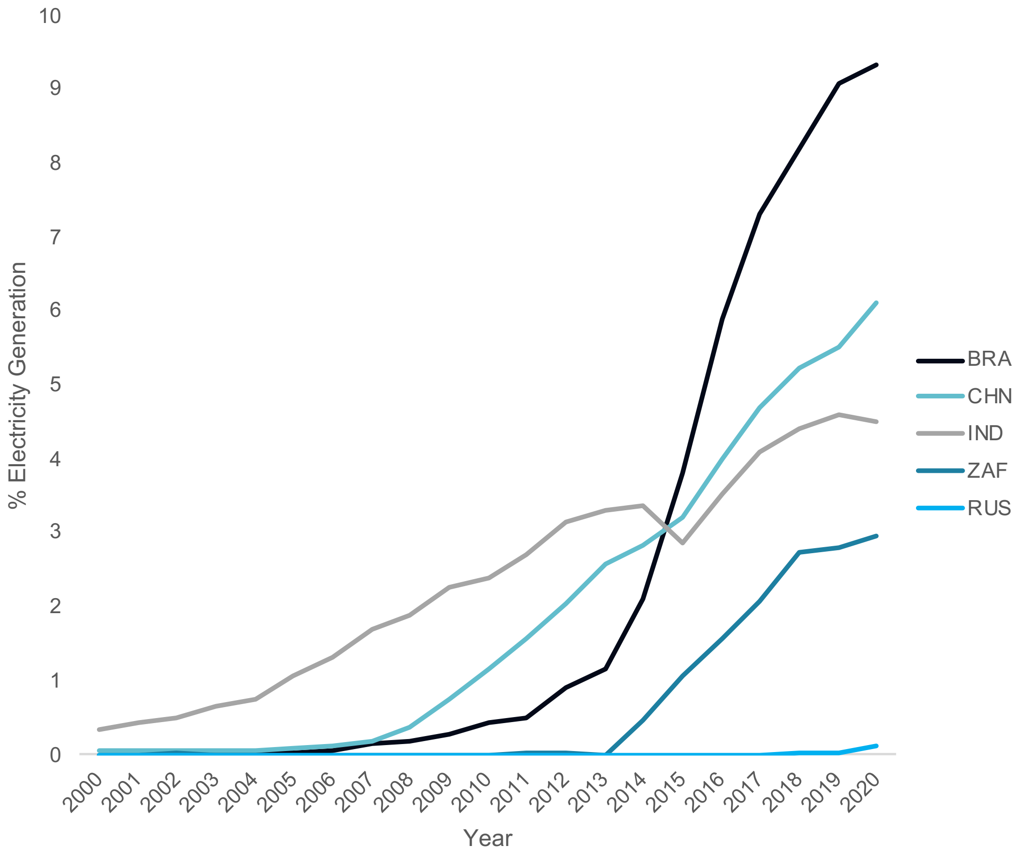

Figure 5 – Electricity generation from wind in BRICS countries (Brazil, Russia, Indica, China and South Africa) (Source: BP Statistical Review of World Energy). Data and chart supplied by Lilia Caiado Couto, PhD Candidate at ISR.

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[6] Authors: João Carlos Ferraz, Associate Professor, Instituto de Economia, Universidade Federal do Rio de Janeiro and Luma Ramos Post-doctoral Researcher, Boston University Global Development Policy Center, respectively.
[7] Based on Ferraz, J. C., Ramos, L. and Plattek, B. (2021). *Innovations in development finance and conditioning factors: BNDES and the fostering of sustainability-related industries in Brazil.* UCL Institute for Innovation and Public Purpose, Working Paper Series (IIPP WP 2021/02).

Total investments in onshore wind energy between 2006 and 2019 in Brazil amounted to US$35.64 billion, representing around 55% of all new renewable (excluding large hydropower) investments in this period (Ferraz, Ramos and Plattek 2021). Concurrent with expansion was the fall in unit investment costs: between 2001 and 2018, investment costs per kW decreased on average by 44%, from US$3,258 to US$1,823 (2018 US$/kW prices). In the meantime, the generation power capacity of each unit increased significantly, with average turbine ratings increasing from 1.3 MW in 2007 to 1.9 MW in 2010, and to 2.6 MW in 2018. Construction times also substantially reduced, from 13 months in 2007-08 to approximately four months by 2018-19. By 2016, 150,000 people were directly employed in the onshore wind industry, an equivalent of 15 jobs per MW (ABEEólica 2020). The industry supply chain also developed substantially, with more than 100 companies taking part in the onshore wind supply chain in Brazil by 2018, including six wind turbine producers, with a significant relocation of industrial capacity from the southeast to the underdeveloped northeast of the country. Brazilian wind turbine suppliers are competitive in quality and delivery time, and turbines incorporate the best available technologies. But turbine prices are still higher than the international average, and innovation capabilities – the ability to design and produce new devices nationally equivalent to international references – are still limited.

Windows of opportunity

The rapid developments outlined above are explained by the influences of converging market, technology, economic, local policy and institutional factors. As global wind power has developed substantially in recent years, with rapidly declining costs, a highly active industry and supply chain has grown in tandem. However, prior to 2008, most activity in this field was concentrated in Europe and North America. With the onset of the global financial crisis of 2008-09, endeavours in these regions decelerated, leaving the industry to explore new markets to maintain growth.

One such market was Brazil. Between 2004 and 2014, in a favourable macroeconomic scenario, Brazil's economy grew by an annual average of 3.7%, with investment as a proportion of GDP increasing from 16% to 19%. Consequently, the demand for energy was also expanding, and an institutional drive for energy diversification was gathering pace. In 2001, an extended period of drought led to lower power generation capacity due to decreases in the water levels of hydro plants – the most relevant energy source in Brazil, historically representing more than 75% of generation.

In response, by 2004, new policy directives were introduced with three objectives: to expand and diversify the energy matrix, ensure the security of supply, and expand access to energy by the Brazilian population at affordable tariffs.

Market regulations were introduced, under which distribution utilities contracted their demand for all energy sources through auctions based on the lowest price, and long-term power purchase agreements (PPA) awarded to generators. PPAs secured the sale of energy generated over a certain period for a fixed price (adjusted annually to the inflation rate), ensuring a steady income flow for generators. Concurrently, an 'unregulated market' was proposed, under which the terms of energy acquisition were left to bilateral, private agreements. Given the above international and local market trends, onshore wind energy was well placed to benefit from such new market regulations. In 2002, the Program for Alternative Sources of Energy (PROINFA – the Portuguese acronym) was launched and formally introduced renewable energies as a policy priority, providing advantages for renewables vis-à-vis other energy sources (Tomalsquin 2015).

This policy framework, and the growth in onshore wind it induced, was supported by a well-established and functioning institutional framework, with the participation of the policy-setting authority (Ministry of Energy), the research and planning agency (EPE), the regulatory agency (Agência Nacional de Energia Elétrica), a financing institution (BNDES), and operational state-owned enterprises commanded by its holding, Eletrobras. In addition, the expansion of onshore wind energy investments evolved alongside the implementation of infrastructure investment programmes: the Investment Pilot Project (2005); the Growth Acceleration Program (PAC) (2007); and the Logistics Investment Program (PIL) (2012). Following Dilma Rousseff's impeachment in 2016, further infrastructure policies were announced, but little has been yet translated into project investments.

The contribution of public development finance

Market, technology and institutional drivers created windows of opportunity for the onshore wind industry to establish in Brazil. Moreover, another key determinant that allowed this opportunity to be seized was the availability of finance from the Brazilian Development Bank (BNDES). Since its foundation in 1952, BNDES has provided finance under terms of credit adherent to the characteristics of different long-term investment projects and the development of the associated local capital goods and services. This was also the case with onshore wind farms. Investment mostly induced by PPAs, with long duration and foreseeable prices, provided a solid demand for relatively low-risk investment finance. In this case, BNDES's traditional credit instruments were suited to the sector emergence and ramp-up period. Loans had an average term suitable to the investment maturity of projects and borrowers' repayment capacity. At the same time, collaterals were the wind parks themselves (with payback capacity anchored in solid demand as defined by the auctions) since almost all disbursements were in the project finance mode.

Until very recently, high inflation and interest rates were a feature of the Brazilian economy. Brazil lacked a deep and mature private long-term financial market, and short maturities prevailed in most private debt instruments. For this reason, in 1994 a specific interest rate was introduced to guide BNDES loans, the long-term interest rate (TJLP, the Portuguese acronym). The TJLP was the reference rate for BNDES until 2017. It was defined by the Brazilian Monetary Council independently from, and was systematically lower than, the market rate (SELIC) defined by the Brazilian Central Bank. Over the years, the TJLP evolution did not follow the SELIC short-term rate, nor did it follow the term structure of the interest rate, based on rates charged on long-term federal government bonds (NTN-B). In fact, between 2002 and 2016, TJLP was always lower than the SELIC, the rate attached to their most liquid bonds, and only in a brief period did it exceed the rate of five-year NTN-Bs (see Figure 6, below).

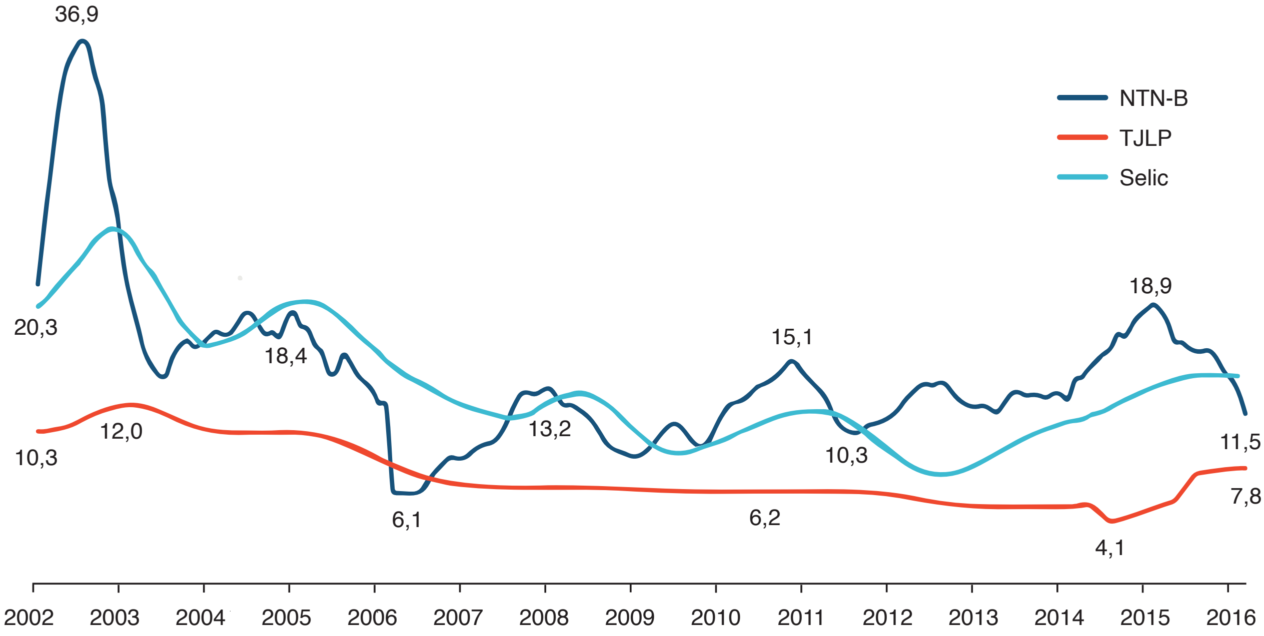

Figure 6: Financing costs linked to TJLP, SELIC and NTN-B between 2002 and 2016 (% yearly). Source: Torres Filho (2018).

BNDES participated, with some level of financing, in 80% of the 15.5 GW projects implemented between 2006 and 2019 (BNDES 2019). Its disbursements amounted to US$15.2 billion during this period, leveraging approximately US$28.5 billion in private investments.

Wind energy 2006-19: capacity, investments, and BNDES participation	GW and US$ billion	Features
Installed capacity in Brazil	15.5 GW	Accumulated capacity from all auctions
Installed capacity with some level of BNDES support	12.4 GW	BNDES participated in the financing of about 80% of all wind park projects
Total investments in wind parks in Brazil	35.6 US$	Project development, land lease, towers, blades, wind turbines, assembling services
BNDES loans for wind parks	15.2 US$	BNDES financed 53% of total investments

Table 1: Wind energy in Brazil 2006-19: capacity, investments, and BNDES financing
Source: Own elaboration based on BNDES information

As interest rates came down and energy market dynamics changed, with privately settled and shorter-term contracts coming to the fore, the private market started to emerge as a source of finance. In this new reality, BNDES changed its approach to financing. It took up riskier positions and incorporated market price references into its financial modelling to avoid a potential mismatch between investment maturity and contract duration. Such a market-oriented mode of finance is a significant change relative to the 'tranquil waters' of long-term power purchase agreements (PPA) contracts. This new type of agreement is likely to increase in the years to come and create more opportunities for market financing. BNDES is moving its strategy to remain both competitive and a relevant institution for supporting sustainability-related investment projects.

Besides BNDES's strategic role in providing investment finance and renewable energy as a policy priority, the onshore wind industry provided a unique opportunity for local industrial capacity development. Considering that the share of capital goods to total wind park investment is somewhere around 80% (BNDES, 2019), it is possible to deduce from Table 1 that, between 2006 and 2019, the size of the Brazilian market for wind energy suppliers amounted to US$28.5 billion. The association between infrastructure investment finance and local industrial development is a strategic mission that public institutions can pursue. Just from the figures above and taking the 80% capital goods to total investment as a reference, proportionally, out of BNDES US$15.2 billion disbursements, it is reasonable to assume that loans of around US$12.7 billion were directed towards equipment acquisition.

Throughout its history, BNDES has placed considerable importance on fostering local equipment suppliers. To benefit from the bank's terms of credit, investment projects must be sourced from accredited local suppliers. However, for the wind industry, accreditation modes changed substantially. During the industry´s initial years, a 40-year conventional policy, based on simple weight and sales parameters, was in place, with a minimal national content index of 60%, but with a limited number of local producers accredited. As wind energy investments expanded, such traditional instruments evolved to incorporate parameters such as quality and efficiency. They aimed to induce industrial learning and, at the same time, ensure pertinent delivery times as required by wind energy operators. Initially, accreditation was granted on a producer-by-producer basis, but gradually a sector-specific approach to accreditation evolved. Such experience with the wind industry, among others, led BNDES to abandon its traditional accreditation mode and to place local capabilities and efficiency at the core of new procedures to all equipment producers, but with the adequate flexibility to recognise different sectoral features.

Behind development finance innovations in Brazil lies a Weberian institution with substantial political and social capital, with strategic priorities aligned with policy directives. The institution enjoys a sound balance sheet, capable of taking risks and absorbing liabilities, while having sufficient funding on a scale to meet growing demand. Its organisational procedures were based on segregation between credit and project evaluation and impersonal collective decision-making processes. Most importantly, a qualified team of professionals with the knowledge and external network connections to learn, evaluate and explore economic, financial, market and technology opportunities is what makes BNDES an innovative, development-oriented institution.

Reflections

Within a relatively short period, the progress observed in the wind industry in Brazil is economically remarkable, and onshore wind farms have been one of the backbones of electricity generation in the country. This progress was linked to the presence of a series of positive drivers: a stable market, an established technology, and policy-related actions that designed an effective auction system, which included incentives for renewables. Moreover, and this was the focus of this case study, a strategic determinant factor behind the expansion of wind energy in Brazil was the provision of investment finance adequate to the needs of the industry and its suppliers by the Brazilian Development Bank, BNDES. For that, the institution had to innovate its traditional finance procedures. From a policy perspective, climate change, as an emerging societal development challenge, will require new stands and practices from public institutions. It is hoped that this work has provided some elements to inspire further work to bring to the fore additional evidence to understand the relevance of public institutions explicitly investing in innovative capabilities to better serve their missions.

Wind energy and the global energy transition: recent lessons and future prospects

In the UK and Brazil, significant wind generation capacity has been delivered alongside (and largely driven by) technological innovation and cost reductions. The UK analysis emphasises the role of public decision-makers in the regulatory domain; the Brazilian analysis underscores the role of public finance. The former demonstrated, in detail, how public authorities defined, implemented and eventually reduced pro-renewable cost advantage mechanisms when the wind industry showed a positive maturation process by offering increasingly competitive prices in public auctions. Moreover, and more recently, UK public authorities demonstrated an open concern and introduced proposals to support the local offshore wind supply industry. The Brazilian analysis showed that growth in onshore wind capacity in the country followed a similar track – a levy charged to consumers to provide cost advantages to renewables – and it brought to the fore the importance and the intricacies of development finance innovations in the fostering of wind energy and its local supply industry through the actions of a public finance institution.

This comparative analysis also reveals the importance of the complementary roles of public actors and decision-makers, and how appropriately assessing risks and rewards can serve as strategic guidance for energy-transition public actions.

The cost of onshore and offshore wind is likely to continue decreasing, becoming cost-competitive in an increasing number of geographies and jurisdictions. The International Energy Agency (IEA) expects annual global deployment to continue at at least 2020 levels (around 65 GW – nearly the total electricity generation capacity of the UK) to 2025, accelerating to around 90 GW per year with supportive policy environments tackling largely non-cost barriers, such as permitting, grid integration and social acceptance (IEA, 2020).

References

Associação Brasileira De Energia Eólica (ABEEólica). (2020). Boletim Anual de Geração Eólica 2019. São Paulo.

Banco Nacional De Desenvolvimento Econômico e Social (BNDES). (2019). Relatório de Avaliação de Efetividade. Avaliação de efeitos locais da construção de usinas eólicas nos municípios brasileiros.

Costa, R.; Casotti, B.; Azevedo, R. (2009). Um panorama da indústria de bens de capital relacionados à energia eólica. BNDES Setorial, Rio de Janeiro, n. 29.

DECC (2015) *Contracts for Difference (CFD) Allocation Round One Outcome*, [Online] Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/407059/Contracts_for_Difference_-_Auction_Results_-_Official_Statistics.pdf [Accessed 8 July 2021]

Empresa De Pesquisa Energética (EPE). (2021). Plano Decenal de Expansão de Energia 2030. Empresa de Pesquisa Energética.

HM Government (2020) *The Ten Point Plan for a Green Industrial Revolution*, HM Government, London

HoL (2008) *The EU's Target for Renewable Energy: 20% by 2020*, European Union Committee 27th Report of Session 2007-08, House of Lords, London

IEA (2020) *Renewables 2020*, International Energy Agency, Paris

IRENA (2021a) *Renewable power generation costs in 2020*, International Renewable Energy Agency, Abu Dhabi

IRENA (2021b) *Technologies*, [Online] Available at: https://www.irena.org/Statistics/View-Data-by-Topic/Capacity-and-Generation/Technologies [Accessed July 2021]

Jennings, T., Tipper, H.A., Daglish, J., Grubb, M., Drummond, P. (2020) *Policy, innovation and cost reduction in UK offshore wind*, The Carbon Trust, London

Martin, V. (2019) *Competition in UK electricity markets*, [Online] Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/920639/Competition_in_UK_Electricity_Markets.pdf [Accessed July 2021]

Mitchell, C. (2000) The England and Wales Non-Fossil Fuel Obligation: History and Lessons, *Annual Review of Energy and the Environment*, 25, 285-312

OREC (2021) *UK offshore wind history*, [Online] Available at: https://guidetoanoffshorewindfarm.com/offshore-wind-history [Accessed July 2021]

OWCRTF (2012) *Offshore Wind Cost Reduction Task Force Report*, Offshore Wind Cost Reduction Task Force.

Pasqualetti, M., Righter, R. and Gipe, P. (2004) History of Wind Energy, In: Encyclopaedia of Energy, Cleveland (Eds), Elsevier Science

REF (2021) *Grouped totals for Renewable Generation: 2002 to date*, [Online] Available at: https://www.ref.org.uk/generators/group/index.php?group=TechCode [Accessed July 2021]

Tolmasquim, M. (2015). Novo Modelo do Setor Elétrico Brasileiro. 2° Edição Revista e Ampliada. Rio de Janeiro: Synergia

TORRES FILHO, E. (2018). O BNDES em uma encruzilhada: como evitar sua desmontagem. São Paulo: IEDI

The Carbon Trust (2018) *10 years of accelerating innovation*, [Online] Available at: https://www.carbontrust.com/news-and-events/insights/10-years-of-accelerating-innovation [Accessed 8th July 2021]

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Economics of Energy Innovation and System Transition

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