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Decreasing costs of renewables – Insights on energy sector planning and climate policy from three country case studies

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Abstract

This study builds on three case studies in Argentina, Indonesia and Mexico which analyse the implications of falling costs for renewable energy systems on the countries' energy sector planning and climate policy. Each case study consists of two country specific reports. The first report analyses how falling costs of renewable energy could impact country specific power sector development. The second report analyses the process of climate and renewable energy target setting, as well as the prevalent narrative around renewable energy integration. **Finally, the present report provides a cross-country synthesis of all case studies, providing insights into the question of how falling costs of renewable energy systems might support the achievement of the goals of the Paris Agreement.**

Globally falling cost figures for solar PV and wind energy do not naturally translate into increased ambition in planning. **The integration of these technologies to the energy system still face substantial barriers in our case study countries:**

- The integration of higher shares of renewable energy goes along with investments into transmission and distribution network modernisation, network expansion and interconnections between power grids. Though an important element, f**alling costs for renewable energy projects alone do not necessarily translate into overall reduced power system costs.**
- While globally falling costs for wind and solar PV are indicative for learning curve effects in the manufacturing of these technologies, the **LCOE of renewable projects is highly sensitive to financing costs. These are largely determined by the local political and regulatory framework and remain high in our case countries, representing a barrier**.
- We find that a **number of regulatory and administrative barriers hinder higher integration of solar PV and wind.** Frequently changing regulations and ill-designed support schemes often prevail over well-designed renewable energy auction schemes that are followed over several years.
- **We find the political economy fossil fuels to be pivotal in the energy sector and climate planning and target setting processes**. Fossil fuel endowments and a long history of natural resource exploitation lead to

strong **vested interests towards sustaining the use of fossil fuels** to satisfy a growing electricity demand.

We conclude that falling costs for key renewable energy technologies alone are no silver bullet for climate change mitigation in the energy sector. Putting the country case studies in perspective of a schematic pathway towards achieving net zero emissions we find our case study countries to be in an early phase, struggling to integrate increasing shares of (variable) renewable energy into their power systems. The future challenges coming along with a phase-out of fossil fuels, successful sector coupling and questions related to full decarbonisation still lie ahead. While these are dominant topics in Europe, more basic and fundamental questions of renewables integration still determine the discussion in emerging economies. These local topics need to be reflected in policies and measures taken to support full decarbonisation.

Nevertheless, as costs of renewables continue to fall, the balance of arguments will incline more strongly towards renewable energy. Overcoming key financial, technical, administrative and market related barriers will further support the integration of renewable energy technologies, thereby coming closer towards achieving the goals of the Paris Agreement.

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1 Introduction

The Paris Agreement stipulates the overall long-term temperature goal of ”holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels" (UNFCCC 2015). Countries defined their individual contributions to this global temperature goal in their Nationally Determined Contributions (NDCs). However, on aggregate, contributions from the first round of NDCs are not sufficient to limit global warming to well below 2°C but could lead to global warming of about 3°C instead (CAT (2019), UNEP (2019)).

The most rapid transition needs to occur in the electricity supply sector, given the sector’s high global share of emissions, the range of available low-carbon technologies, and the need for low-carbon electricity to decarbonise demand sectors like transport or buildings (Rogelj et al. 2018). The transition of the global energy system requires the rapid uptake of low-carbon electricity generation sources, while phasing-out of carbon-based electricity generation (Kuramochi et al. 2018).

The rapidly decreasing costs of key renewable energy technologies, most importantly solar PV and wind power, offer significant potential for Parties to the UNFCCC to actively engage in the transition process, adjust their energy sector targets and increase the ambition of their NDCs. This report builds on three case studies carried out in Argentina, Indonesia, and Mexico, which asses the implications of falling costs of solar PV and wind power on the countries' energy sector planning and climate policy. We present a summary of key findings in the form of a cross-country synthesis, and draw conclusions relevant for countries beyond our scope.

In the following, we first discuss the observed cost progressions in renewable energy technologies and their importance for raising ambition in light of the Paris Agreement (Section 2). The following Section 3 first introduces the methodology underlying the case studies before providing a summary of the results for each country. Section 4 presents a synopsis of results and discusses four pivotal dimensions beyond falling costs of key technologies that determine the integration of renewable energy in our countries of scope. Section 5 lays out five steps towards a fully decarbonised energy system and discusses where the case study countries currently stand. Section 6 draws general conclusions.

2 Cost progressions to support Paris-alignment

Costs for renewables are falling

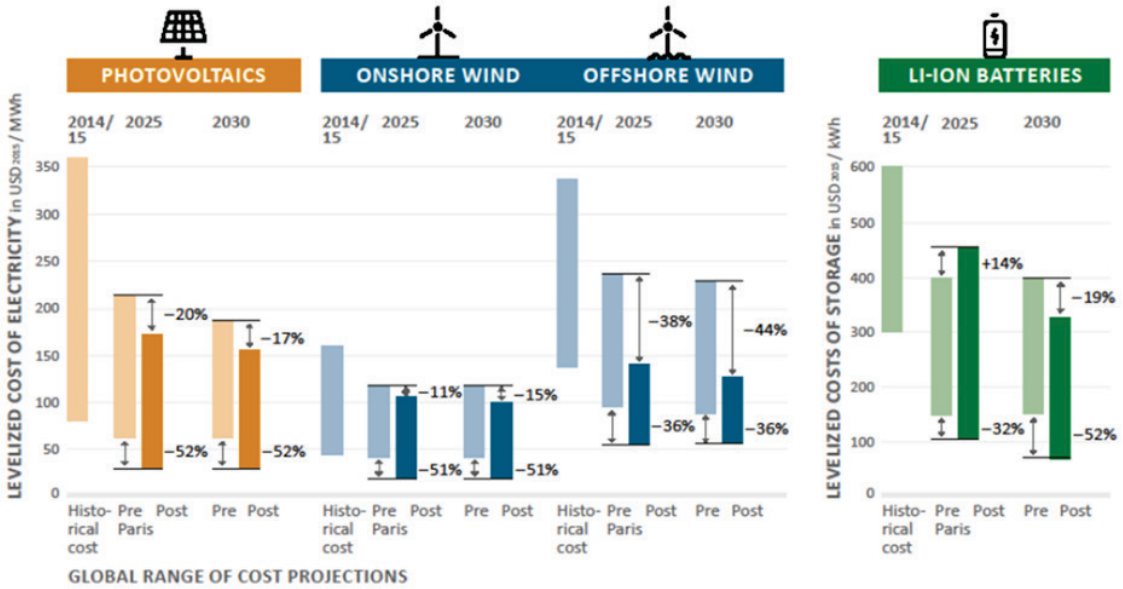
A larger-than-expected technology cost progression for certain renewable energy technologies observed worldwide enables the reduction of mitigation costs, and, consequently, of energy-related emissions (IRENA 2019). Wachsmuth et al. (2018) provide an overview of available data on Levelized Costs of Electricity (LCOEs) and auction outcomes for solar PV, wind energy and batteries before the Paris Agreement as well as more recent estimates.

Wachsmuth et al. (2018) show that projections for LCOEs in 2030 are substantially lower in recent estimates, showing a reduction of 52% for solar PV and onshore wind and of 36% for offshore wind (see Figure 1).

The authors estimate that for each Gigawatt (GW) of renewable energy expansion planned in an NDC, the same level of investment would lead to an additional capacity expansion of up to 0.9 GW. They conclude that current NDCs are based on outdated figures and that current cost estimates should be considered in the periodic NDC revisions.

Figure 1: Falling costs of renewable energy technologies

The figure shows the development of cost projections for 2025 and 2030, as projected before (Pre-PA) and after the Paris Agreement (Post-PA) for solar PV and wind energy given in terms of Levelized Costs of Electricity (LCOE) as global average ranges. The range of historic LCOEs just before the time of the Paris Agreement is also indicated. The right panel indicates similar figures for lithium-ion batteries.



Source: Wachsmuth et al. (2018)

Opportunities for climate change mitigation planning

The Paris Agreement recognises that its temperature goals shall be achieved over time, while implicitly establishing an ambition raising mechanism. It foresees regular revisions of the NDCs following a periodic global stocktake, with the objective to evaluate the implementation of the Paris Agreement. These NDC revisions shall be informed by the outcomes of the global stocktake and by up to date information on national circumstances (UNFCCC 2015). Parties ideally link their mid-term mitigation targets for 2030, as outlined in their NDC, to a long-term vision describing the pathway for each sector's decarbonisation, communicated via Long-Term Strategies (LTS) (Hans et al. 2020).

A robust planning process that includes mid- and long-term targets for renewable energy development is fundamental for anticipating main challenges and opportunities embedded in the energy sector transition. Periodic planning should consider most up-to-date technologies and cost figures to allow for the timely identification of key opportunities to reduce mitigation costs.

In conducting the planning, scientific principles should be followed. This requires assumptions to be plausible and methods and tools to be state-of-the-art. However, it also requires that recent technological and economic figures – e.g., on costs – are used in the analysis. Information on the underlying tools should be publicly available and verifiable, along with underlying data and assumptions. It is this scrutiny that guides our conducted analyses.

Costs for NDC implementation are considered a barrier to increasing ambition

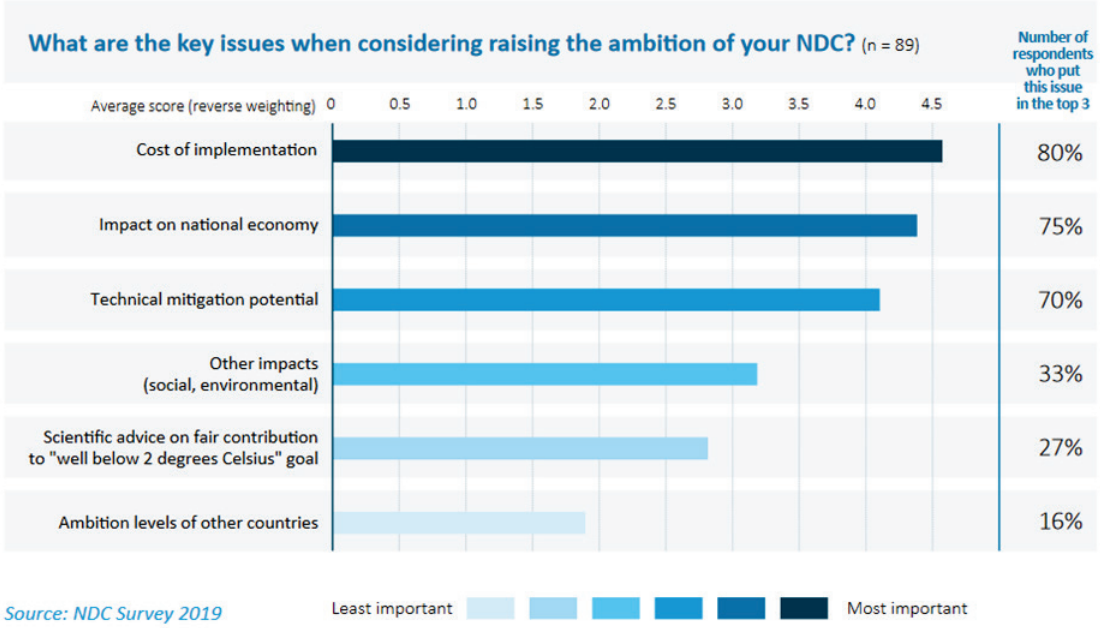
A survey carried out in 2019 to explore key barriers towards raising the mitigation ambition in the NDCs showed that the cost of implementation of mitigation measures is a central barrier (Roeser et al. (2019); Figure 2).

This demonstrates that there is still a mismatch between the concern of national planners and policy makers about mitigation costs and their readiness to take costs explicitly into account in both energy and climate mitigation planning and policy making.

To some degree, this barrier can be mitigated if recent cost projections of key renewable energy technologies are considered. For this purpose, tools and methodologies that allow to consider costs need to be applied in energy sector planning and climate policy.

Figure 2: Level of importance of different issues when considering ambition raising

The figure shows different issues to consider when raising a country's ambition. The average score given to each issue is shown as bars, while the percentage of respondents who rank the respective issue in the top three to consider is given to the right.



Source: Roeser et al. (2019)

3 Three country case studies: Implications of falling costs of renewables

In the following, we present main results from the three case studies on Mexico, Indonesia and Argentina, in which we investigate the role of decreasing costs of solar PV and wind energy for energy sector planning and climate policy. Each country case analysis is based on two individual studies.

The first study analyses how falling costs for renewable energy technologies could impact country specific power sector development. National planning instruments are investigated in conjunction with current and past cost estimates. The results show an opportunity for increasing renewable energy capacities and NDC ambition in each country.

The second study assesses the process of climate mitigation and renewable energy target setting, the modelling rationale, underlying assumptions, as well as the prevalent narrative around renewable energy integration. We analyse to what degree costs of different power sector technologies are considered in energy sector planning and in the preparation of NDCs. We furthermore analyse the political framework and country-specific processes around target setting. The study builds on semi-structured interviews with stakeholders of energy sector planning and climate policy in the three countries.

3.1 Argentina

Table 1: Overview of targets as stipulated in the NDC of Argentina and their possible revision based on recent cost estimates

NDC unconditional target	-18% rel. BAU, absolute emission target of 483 $MtCO_2eq$ in 2030
NDC energy sector target	103 $MtCO_2eq$ reduction in 2030
2030 cost decrease	Wind energy: 32–36%; Solar PV: 63–76%
Possible RE generation increase	From planned 26% to 38–43%
Absolute emissions savings in 2030 due to the possible increase	13–19 $MtCO_2eq$

Source: own compilation based on Nascimento et al. (2020). The possible RE generation increase is based on the average cost decrease.

The analysis presented by Kurdziel et al. (2020) describes the governance process underlying energy sector planning and climate policy in Argentina. Argentina has recently established a robust legal framework to address climate

change. While the Ministry of Environment steers overall climate-related planning and policy making, it has little influence on decision making processes in the relevant sectors. Observation of the current political debate suggests that climate change is not always driving the agenda and that climate policy makers need to find other narratives, for example co-benefits, to reach their audience.

Limited transparency around both climate-related and energy sector planning and policy making processes is prevalent in Argentina. It is not always clear which tools and methodologies are used to define sectoral contributions to climate change mitigation policy and whether or to what extent techno-economic analyses play a role in the processes. Specific opportunities to reduce mitigation costs by considering technology cost reductions seem to have not been seized in the context of the NDC update or LTS process, or in discussions around new renewable energy targets, even though they are considered relevant by stakeholders.

The reasons for not considering these cost reductions are varied. There are several challenges that often outweigh the importance of technology cost progressions and thus hamper the expansion of renewable energy despite the positive price development. The most predominant issues mentioned by stakeholders include Argentina's dire macro-economic situation, the availability of abundant domestic gas resources in the Vaca Muerta formation, the weak transmission infrastructure as well as a lack of clear political signals and leadership.

The analysis shows that the current situation in Argentina may compromise not only the successful development of the renewable energy sector but also the country's potential to raise its climate ambition and to ensure overall socio-economic development. Against his backdrop, it is important to enhance transparent and effective planning in the energy sector and to base this on robust tools and methods in the formulation of realistic targets. These targets are ideally embedded in a clear vision of the government towards the development of this sector and flanked by a policy and regulatory framework that shapes implementation. In this context, a sustainable approach towards stabilising the economy and propelling growth of the energy sector could embrace renewable energy development as a non-subsidised, safe and long-term investment opportunity for local and foreign investors. This could, in turn, decrease the dependency of energy sector development on government subsidies and reinstall the country as an attractive renewable energy market.

3.2 Indonesia

Table 2: Overview of targets as stipulated in the NDC of Indonesia and their possible revision based on recent cost estimates

NDC unconditional target	-29% rel. BAU, absolute emission target of 2034 MtCO2eq
NDC energy sector target	-19% rel. BAU
2030 cost decrease	Wind energy: 8–39%; Solar PV: 21–61%
Possible RE capacity increase	From 70 GW to 85 GW at constant budget
Absolute emissions savings in 2030 due to the possible increase	15–45 MtCO2eq

Source: own compilation based on Eckstein et al. (2020b). The possible RE capacity increase is based on the average cost decrease.

The analysis presented by Ordonez and Eckstein (2020) shows that the NDC should be considered a by-product of existing planning documents. More specifically, it has no influence on planning in the energy sector. The overall target of a 29% GHG emissions reductions unconditionally and 41% conditional to international support have been set by a non-public process. The sectoral shares of GHG reductions are determined by the responsible ministries, e.g. the Ministry for Energy and Mineral Resources (MEMR). The underlying modelling is performed by academic institutions, e.g. Bandung Technical Institute for the energy sector. This modelling is partly based on existing plans. The process is repeated for the current revision of the NDC and likely also for creation of the LTS. The ambition under the revised NDC will not be increased.

The share of renewable energy in the NDC follows from a cascade of energy planning documents (KEN, RUEN, RUKN, RUPTL, see Ordonez and Eckstein (2020) for details). These pass the target from the most overarching energy plans to the NDC. Apart from referencing the most important target related to renewable energy planning (to reach 23% renewable energy in each sector in total primary energy supply in 2025), these plans remain largely disconnected from each other.

Nearly all energy planning documents and the NDC make use of overestimated GDP growth assumptions for the future, which has implications for the relevance of target set relative to this baseline. Technological and economic assumptions remain undisclosed, data is not made available publicly. There is no evidence costs play a role in any of the planning documents and the underlying modelling is not cost-optimised.

To understand the perspective of renewable energy in Indonesia, it is essential to consider factors that go beyond planning documents: Costs of renewable energy projects are higher in Indonesia than global averages. Project costs are especially determined by high administrative and political barriers, and an elevated cost of finance. The discussions often revolve around the impossibility to integrate renewable energy sources to the power system due to their variability. This line of argumentation claims lacking grid stability, inflexible grid management and points to difficulties in developing interconnections between islands.

Implementation is not determined by following cost-optimised planning, but by a political agenda serving vested interests in the energy sector. The utility PLN continues to invest in coal fired power plants and policies foresee to maintain extraction, export and domestic use. This leads to an increased use of fossil fuels, in particular coal-fired power capacities.

3.3 Mexico

Table 3: Overview of targets as stipulated in the NDC of Mexico and their possible revision based on recent cost estimates

NDC unconditional target	-22% rel. BAU, absolute emission target of 762 MtCO2eq
NDC energy sector target	-31% rel. BAU
2030 cost decrease	Wind energy: 75–78%; Solar PV: 73–74%
Possible RE capacity increase	From 37 GW to 52 GW at constant budget
Absolute emissions savings in 2030 due to the possible increase	14–15 MtCO2eq

Source: own compilation based on Eckstein et al. (2020c). The possible RE capacity increase is based on the average cost decrease.

The analysis presented by Eckstein et al. (2020a) discusses the processes related to target setting and NDC revision in Mexico. The main responsibility for the NDC revision is with the Environment Ministry of Mexico (SEMARNAT). SEMARNAT is supported by the National Institute for Ecology and Climate Change (INECC), a body created under the climate change law. The highest level administrative body in the energy sector in Mexico is the Energy Ministry (SENER), responsible for the establishment of targets and strategic investments for renewable energy.

The target setting process underlying the NDC remains publicly undisclosed. The current revision reportedly considers only enhanced energy efficiency

measures and to a large extent disregards renewable energies in the power sector. The process is highly politicised, aligning with political interests of the López Obrador administration. Cost optimisation modelling exercises have been carried out by SENER and supported by international organisations, but power sector planning aligns to political interests and does not follow cost optimisation currently.

In 2013, Mexico launched a set of regulatory and administrative changes related to the energy sector that are referred to as the Energy Reform. This reform restructured the energy sector, moving away from state-owned enterprises for power generation (CFE) and oil extraction (PEMEX) to a liberalised market, open to private actors. This led to competitive bidding and record-low auction outcomes for solar PV projects in the Mexican power sector.

The López Obrador administration, however, builds on fossil resources and state-owned PEMEX as backbone of economic development. It perceives fossil fuel extraction as integral part of the Mexican national sentiment and therefore fosters its continued exploration. While the laws underlying the reform of 2013 have not been formally revoked, institutional, administrative and procedural practice undermine its effectiveness, making renewable energy projects in the power sector nearly impossible and creating high uncertainty with regard to the regulatory future. Under the current administration, government agencies such as INECC and SEMARNAT have experienced substantial budget cuts, undermining their institutional capacity to support climate change goals.

In conclusion, despite large potentials and record low costs for renewable energy projects in the past, key energy planning documents in Mexico largely disregard low costs of renewable energies. The energy planning paradigm is determined by a shift away from competitive energy markets towards political patronage, locking Mexico´s power sector into a future of higher costs and increased GHG emissions.

4 Four pivotal dimensions for increasing the RE share Revised renewable energy capacities

As is described in the previous chapter, cost-optimized planning plays a different role in the three countries of scope, Argentina, Indonesia and Mexico. Subsuming across countries, we observe that falling costs of renewables do not naturally translate into increased ambition in planning renewable electricity generation nor to the implementation of related projects. In fact, the three country case studies make it evident that a number of economic and non-economic factors and considerations besides technology costs and respective future cost reductions of renewables determine the integration of these technologies to the power mix. In the following, we discuss four dimensions which we identify to be pivotal for the integration of renewables across countries:

1. technical challenges to the integration of variable renewable energy
2. financing costs particular to RE projects
3. the market and regulatory structure in the power sector
4. political economy constraints at the core of energy sector planning

Table 4 provides an overview of these dimensions in the three case study countries. The subsequent section briefly exemplify how key challenges across the dimensions materialize in each country. A detailed discussion is found in Kurdziel et al. (2020) for Argentina, Eckstein et al. (2020a) for Mexico and Ordonez and Eckstein (2020) for Indonesia.

Table 4: Four pivotal dimensions related to the expansion of variable renewable energy

Overview of key insights related to four pivotal dimensions for the expansion of renewable energy uptake and expansion, reflected for the three case study countries Indonesia, Mexico and Argentina

	Argentina	Indonesia	Mexico
Technical challenges towards RE integration	The current state of transmission and distribution infrastructure hinders the development and uptake of larger renewable energy capacities.	Lack of transmission and distribution infrastructure, limited interconnection capabilities due to archipelago geography, manual dispatch	Existing interconnection to US market, flexibility to operate RE due to larger gas share in power sector
Financing costs particular to RE projects	Recurring economic crises and high political uncertainty increase the cost of capital, leading to high interest rates and LCOE for RE projects.	Double digit interest rates lead to higher than global average LCOE, high risk associated with numerous technical, administrative and political barriers	Auctions have resulted in world record low costs for solar PV, hinting at low interest rates and low risk premiums for RE projects in the past
Market and regulatory structure in the power sector	Liberalisation and privatisation of electricity market in 1991; generation, transmission and distribution vertically and horizontally disintegrated; transmission and distribution are monopolies regulated by the government while generation is less regulated and open to private actors	Monopolistic, determined by vertically integrated state-owned utility PLN, regulated by the Ministry of Energy and Natural Resources. Independent power producers can sell electricity to PLN, which has the sole right of acceptance or refusal.	Competitive wholesale market, unbundled, state owned CFE operates transmission and distribution, while wholesale market is operated by independent system operator CENACE
Political economy constraints	Oil and gas producer, vested interest towards exploiting abundant domestic gas resources in the Vaca Muerta formation	Second largest coal exporter, vested interest towards supporting the domestic coal mining industry, perception of coal as development capital towards an industrialized county	Large oil and gas producer, vested interest towards supporting the declining oil and gas company PEMEX, fossil resource extraction seen as part of national sentiment

4.1 Technical challenges to the integration of variable RE

Contrasting to other renewable energy sources such as hydropower, geothermal energy and biomass, solar PV and wind energy are characterised by stronger variability in their electricity production. Integrating larger shares of variable renewable energies must go hand in hand with network modernisation and expansion. Interconnectors between power grids and demand-side management must be considered in order to integrate higher shares of renewables. This requires an adequate dispatching system.

The countries of scope reflected technical challenges to the integration of variable RE to different degrees. **In Argentina,** building and financing the required long-distance transmission networks between the favourable areas for renewables in the north and south of the country and demand in cities in the centre is key to increasing the share of variable renewables in the power mix. **In Indonesia**, grid management and dispatch is reported to be done largely manually on a day to day basis, while the archipelago geography is perceived as a key challenge to long distance interconnections. **In Mexico** technical challenges were not reported to represent a central barrier to the development of renewables in the power sector.

In most countries, an increase in the share of variable renewables requires the modernisation and expansion of the electricity grid and respective grid management, which implies substantial investments. The corresponding costs need to be considered in an integrated way when planning solar PV and wind energy systems (Ueckerdt et al. 2013; Heptonstall and Gross 2020).

4.2 Financing costs particular for RE projects

High learning rates for large scale manufacturing of solar PV panels and wind turbines in China and Asia Pacific have led to falling technology costs. However, renewable energy projects are particularly sensitive to financing costs. This dependency can be explained by the comparably high upfront technology costs and no fuel expenditures during operation, which is contrasting to that of conventional power sector projects (Egli et al. 2018). The financing costs are reflected in the corresponding interest rate for equity and debt, which depend on the general risk premium in the country and specific project risk. The perception of risk in renewable energy projects depends on the political framework in which the projects operate.

The three focus countries put a spotlight on different aspects of this dimension. In **Argentina**, recurring economic crises and frequent changes of government increase the general cost of capital. While the RenovAr programme effectively reduced the financing costs for renewables, real market development was thwarted by poor economic conditions and underinvestment in supportive infrastructure. In **Indonesia**, frequently changing and ill-designed support schemes have undermined conditions for investments into renewable energy. This regulatory uncertainty results in higher risk profiles – renewable energy projects are associated with double digit interest rates. Following the Energy Reform in 2013, **Mexico** has shown record breaking low bids for renewable auctions, hinting to low financing costs.

For global cost reductions to materialise locally, financing costs and thus risks must be substantially reduced on a country-by-country basis. For this reason, the analysis of technical and administrative barriers remains key to understand the constraints which increase the risk profile and thereby drive-up financing costs.

4.3 Market and regulatory structure in the power sector

Translating falling costs of solar PV and wind into higher shares of these technologies in the power mix is highly dependent on the regulatory structure and incentive schemes present in the power sector. By implementing well-functioning auction schemes, Mexico and Argentina stand apart from the situation in Indonesia.

The power sector in **Argentina** is almost completely unbundled, with a competitive wholesale electricity market, as well as regulated transmission and distribution monopolies. At the same time, the market is subject to distortions such as government subsidies paid to the fossil fuel industry. The lack of a clear renewable energy strategy under the new Fernández administration undermines the development of a strong renewables market. **Indonesia**´s power market is organised through the vertically integrated monopolistic utility PLN. While the utility has the sole right of acceptance or refusal of power purchase agreements, independent power producers (IPPs) can enter the market. However, frequently changing regulations and ill-designed support schemes such as the Indonesian local content requirement have undermined conditions for renewable energy IPPs to enter the market. In **Mexico**, the power market structure was reformed in 2013 from a vertically integrated, state-owned utility, towards a competitive market open for private participation. The use of technology neutral “clean en-

ergy" auctions led to a considerable uptake of wind and solar PV in the power mix, incrementing their share in generation from 1.5% to 7% between 2013 and 2019.

The design of the electricity market and of support policies determine the uptake of renewables. In markets with clear rules of participation, falling technology costs of renewable energy systems are more probable to translate into higher shares of these technologies in the power sector.

4.4 Political economy challenges of fossil fuel endowments

All three countries have a long history of natural fossil fuel resource production. Indonesia has large coal endowments and production; Mexico and Argentina have considerable oil and gas production. A history of fossil resource extraction goes along with the presence of a long-established fossil fuel industry.

In **Argentina**, the availability of abundant domestic gas resources in the Vaca Muerta formation is seen as source of economic growth and a way to foster energy independency. The strong focus of economic recovery measures on the support of the fossil fuel industry, e.g. through a reinstallation of public subsidies, undermines the competitiveness of renewables. In **Indonesia**, the utility PLN is strongly driven by a political agenda serving vested interests in the coal sector. PLN continues to invest in coal fired power plants, as part of an agenda to support the domestic coal mining industry. This agenda is found to be deeply rooted in incentives to develop coal in key ministries governing the energy sector (Ordonez et al. 2020). In **Mexico**, the current administration has stopped the development of renewable energy sources, seeking to counteract financial struggles of state-owned oil and gas extraction company PEMEX. The current government perceives fossil fuel extraction as integral part of the Mexican national sentiment and therefore fosters its continued exploration, despite worldwide record low costs for renewables.

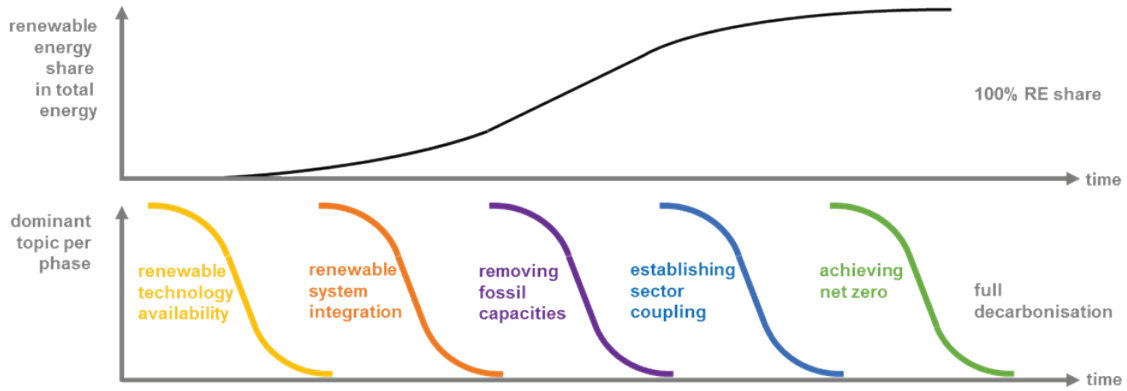
All three countries show a strong vested interest towards sustaining the use of fossil fuels. The absence of a local manufacturing and a value chain makes it difficult for renewable energy industry to take root, which is reflected in limited consideration of renewables in energy planning.

5 Outlook: A pathway towards full decarbonisation

In a broader perspective, the decarbonisation of the power sector is part of the overall decarbonisation of the energy system. Figure 3 gives a graphical representation of the path to full decarbonisation of the energy system. The share of renewable energy increases (top panel) as different topics dominate in subsequent phases, which are indicated in the lower panel of the figure. Each phase comes with challenges to the integration of renewable energy technologies, to which technical and administrative solutions must be found, thereby reducing technology and financing costs. Falling costs, in turn, can accelerate an increase of the share in renewable energy.

Figure 3: Global perspective to the energy system transition

The figure illustrates how the increase in the renewable energy share in total primary energy (top panel) is linked to several consecutive phases of the energy transition (bottom panel).



Source: own elaboration

In the following, the main phases that can be identified are shortly explained along with an indication of related policy topics.

1. *Achieving technology availability:* Technologies to harvest renewable energy sources need to be available, which is fostered by research and development policy. A favourable policy environment makes them accessible.

2. *Renewable system integration*: Renewable energy technologies need to be integrated into the power system. This integration needs to target different aspects, including the technical capabilities in transmission and distribution, the system operation, the institutional framework as well as

the regulatory and market design (e.g. IEA (2019) and Vivero et al. (2019)).

3. *Removing fossil capacities*: Most power systems around the world are based on conventional energy resources such as coal, gas and oil. Overcoming this dominance requires active policies to phase-out these technologies, while at the same time considering the societal implications this entails by just transition programmes.

4. *Establishing sector coupling*: It is widely agreed that a decarbonised power system serves as the basis to decarbonise other sectors (heating and cooling, transport, industry) through sector coupling. This requires novel technologies and infrastructure, e.g. charging stations to electrify transport, green hydrogen or green methane transport and distribution systems.

5. *Achieving net zero*: Remaining emissions must be mitigated by additional measures in order to allow for net zero emissions by mid of the century. In the energy sector, this could for instance be achieved through establishing new global markets, e.g. for green hydrogen.

Conceptually, these five phases build on each other in the presented order. They may, however, also run in parallel: Technology improvements will always happen, the market regulation continuously needs to be adjusted to an increasing share of renewable energy, phasing-out fossil fuels should be considered in the perspective of the second phase and then goes hand in hand with sector coupling, the radical changes required to achieve net zero emissions need to be tackled in parallel. Key to a successful decarbonisation of the power sector is the careful and timely planning of each phase, anticipating the main challenges and identifying appropriate measures for their solution early on. This ensures rapid progress from one phase to the next until ultimately achieving full sector decarbonisation Vivero et al. (2019).

The proposed phases allow to better situate our countries of scope are in the path to completely decarbonising their energy system. **We find all three countries of scope within this project to be situated around the second phase, i.e. the integration of renewable energies to the power sector**. All three countries seem to struggle with the integration of substantial shares of variable renewables into their power systems, despite globally falling LCOEs for solar PV and wind energy. Establishing roadmaps or strategies for phasing-out fossil fuels and promoting sector coupling – now a dominant topic in Europe – does

not play a role in our case study countries yet. This shows that while the European Union considers establishing a global (green) hydrogen market, other, more fundamental topics still dominate the discussion in emerging economies around the globe. A more systematic and timely perspective of the full transition, including the anticipation of challenges of each following phase before they appear, has the potential to facilitate the transition process in all countries.

In order to achieve a global transition of energy systems, the locally prevalent narrative towards renewable energy systems in different countries needs to be considered. Each country is in a unique position in this conceptual path towards decarbonisation that needs to be reflected in policies and measures taken to support full decarbonisation.

6 Conclusions

This study builds on three case studies in Argentina, Indonesia and Mexico and which analyse the implications of falling costs for renewable energy systems on the countries' energy sector planning and climate policy. Each case study consists of two country specific reports. The first report analyses how falling costs of renewable energy could impact country specific power sector development. The second report analyses the process of climate and renewable energy target setting, as well as the prevalent narrative around renewable energy integration. **Finally, the present report provides a cross country synthesis of all case studies, providing insights into the question of how falling costs of renewable energy systems might support the achievement of the goals of the Paris Agreement.**

Globally falling cost figures for solar PV and wind energy do not naturally translate into increased ambition in planning. **The integration of these technologies to the energy system still face substantial barriers in our case study countries:**

- The integration of higher shares of renewable energy goes along with investments into transmission and distribution network modernisation, network expansion and interconnections between power grids. **Falling costs for renewable energy projects alone do not necessarily translate into overall reduced power system costs.**
- While globally falling costs for wind and solar PV are indicative for learning curve effects in the manufacturing of these technologies, the **LCOE of renewable projects is highly sensitive to financing costs, which are determined by the local political and regulatory framework and remain high in our case countries, representing a barrier**.
- We find that a **number of regulatory and administrative barriers hinder higher integration of solar PV and wind.** Frequently changing regulations and ill-designed support schemes often prevail over well-designed renewable energy auction schemes that are followed over several years.
- **We find the political economy fossil fuels to be pivotal in the energy sector and climate planning and target setting processes**. Fossil fuel endowments and a long history of natural resource exploitation lead to strong **vested interests towards sustaining the use of fossil fuels** to satisfy a growing electricity demand.

We conclude that falling costs for key renewable energy technologies are no silver bullet for climate change mitigation in the energy sector. We find the integration of renewable energies to be a domain of energy policy, while

NDCs remain a domain of climate policy. We also find NDCs to often have a peripheral position in the country´s overall energy policy, either by being by-product of existing plans or by being disconnected from actual implementation. In order to enable progress in the energy system transformation, the locally prevalent narrative towards renewable energy integration in the different country contexts should be more strongly considered. **To evaluate a countries' alignment with the goals of the Paris Agreement, the sole focus on the NDC may thus not always be sufficient but require consideration of the broader context of energy policy.**

Putting the country case studies in perspective of a schematic pathway towards achieving net zero emissions, as is required to achieve the overarching goal of the Paris Agreement, we find our case study countries to be in an early phase of this pathway. While the examined countries struggle to integrate increasing shares of (variable) renewable energy into their power systems, the future challenges coming along with a phase-out of fossil fuels, successful sector coupling and questions related to full decarbonisation still lie ahead. While discussions in Europe revolve around establishing a global (green) hydrogen market and to foster sector coupling, more basic and fundamental topics of renewable´s integration still dominate the discussion in emerging economies.

Nevertheless, as costs of renewables continue to fall, the balance of arguments will incline more strongly towards renewable energy. This is underlined by the development in countries such as Mexico, Vietnam or India, which, despite substantial challenges and a strong fossil fuel dominance, still have seen ample integration of renewable power generation in recent years. Overcoming key financial, technical, administrative and market related barriers will further support the integration of renewable energy technologies, thereby coming closer towards achieving the goals of the Paris Agreement.

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