RE-TRANSITION

TRANSITIONING TO POLICY FRAMEWORKS FOR COST-COMPETITIVE RENEWABLES

Final Report, March 2016

IEA-RETD
Renewable Energy
Technology Deployment

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EXECUTIVE SUMMARY

	Key Messages
1	This report presents a **novel, overarching framework to help policymakers understand the evolution of renewable energy policy**, one that attempts to outline a number of potential pathways forward to adapt to the rise of rapidly scalable and increasingly cost-competitive renewable energy technologies like solar photovoltaics (PV) and onshore wind power.
2	The report identifies **three key pillars** that are critical to ensure the continued scale-up of renewable energy projects: projects will need to remain **bankable**; the power system as a whole will need to become more **flexible**; and policymakers will need to provide long-term signals to investors and other stakeholders by establishing a **clear long-term vision** for the development of the power system.
3	Although renewable energy technologies like hydropower, solar PV, some forms of bio-energy, as well as onshore wind power are now **increasingly cost-competitive** with the levelised cost of alternatives like coal, natural gas, or nuclear, **this does not indicate that policymakers can withdraw all forms of policy that support investment in these technologies and still achieve sustained growth**. A stable, long-term policy framework is needed to **ensure a continued scale-up** in investments and project deployment.

As the cost-competitiveness of rapidly scalable renewable energy technologies, such as solar PV and wind power, continues to improve, we are entering a new phase of renewable energy policy. Solar PV is now the cheapest source of new electricity generation in a wide range of different jurisdictions, as recent procurement processes in South Africa (Steyn, 2015), parts of Latin America (Dezem, 2015; Burger, 2014), and much of the Middle East have demonstrated (Mills, 2015; Parkinson, 2015a).

Similarly, onshore wind power has long been the lowest cost source of new supply in many jurisdictions, particularly those with strong wind resources, such as Cape Verde (IRENA 2014), Denmark (IRENA 2012), as well as parts of Canada (PEI, 2009), and the United States (U.S.) (BNEF, 2016). In some areas of the U.S., wind power is beginning to be financed on a merchant basis (i.e., without power purchase agreements, or PPAs), indicating that in regions with good resource potential and the right institutional environment, technologies like wind power are beginning to be fully cost-competitive (Bailey, 2015).[1] This cost-competitiveness has been achieved even in markets where the negative externalities of conventional power generation technologies have not been internalized.

[1] Note, however, that wind power development in Texas benefits from a number of direct and indirect policy supports, including the federal Production Tax Credit (PTC), accelerated depreciation, as well as a streamlined transmission planning and zoning framework.

This fundamental shift in the competitive landscape of renewable energy technologies is poised to trigger significant changes in electricity markets around the world, and points to an important shift in the underlying *rationale* for renewable energy policy. When the costs of renewable energy technologies were significantly higher than the costs of conventional generation options, the rationale was clear, namely to help **bridge the gap between the cost of existing renewable energy technologies and that of alternatives**. However, as that cost gap has narrowed and even begun to move in the other direction, the debate has begun to shift, underscoring the need for policymakers to reconceptualize the future of renewable energy policy.[2]

The report on "*Transitioning to Policy Frameworks for Cost-Competitive Renewables*" distinguishes three main phases of renewable energy policy development, each of which is related to a technology's cost-competitiveness:

1. **The Early Commercialization Phase** refers to the stage of market development in which a given technology is beginning to be deployed. Typically, the objective for RE policies at this stage is to demonstrate the technology's viability and assess its performance. This phase is characterized by the use of direct subsidies or support in the form of targeted research funding, cash grants, and other direct financial support to support a particular renewable energy technology's introduction into market.

2. The Policy Support Phase, which refers to the stage of market development in which a given RE technology begins to scale-up and become more established in the marketplace. The Policy Support Phase sees the emergence of a range of support mechanisms such as a feed-in tariffs, feed-in premiums, auctions, and net metering. The major objective during this phase is to bridge the cost gap between renewables and fossil-based generation.

3. The Policy *Framework* Phase, which refers to the phase in which a renewable energy technology has **become cheaper than the** Levelised Cost of Electricity **(LCOE) of conventional new-build generation**. In the Policy Framework Phase, the focus shifts away from offering direct "policy support", and toward establishing (or maintaining) an overall enabling environment that supports **bankability** and **continued scale-up** of renewables in the coming decades,. In the case of variable renewables like solar PV and wind power, the focus shifts increasingly to how their output can be appropriately integrated to the grid, and how overall system flexibility can be increased. Finally, the Policy Framework Phase involves sending clear long-term signals to investors about the overall vision for the development of the sector. In this last phase, the objective of renewable energy policy becomes more about **creating an appropriate policy framework that supports a continued scale-up of investment in the sector.**

Figure ES 1 provides an overview of the three Phases, and how they relate to the evolving cost-competitiveness of a given technology.

[2] This reconceptualization may also include a rethinking of the functioning of electricity markets; this issue is discussed in more detail in the IEA-RETD RES-E-MARKET report (forthcoming).

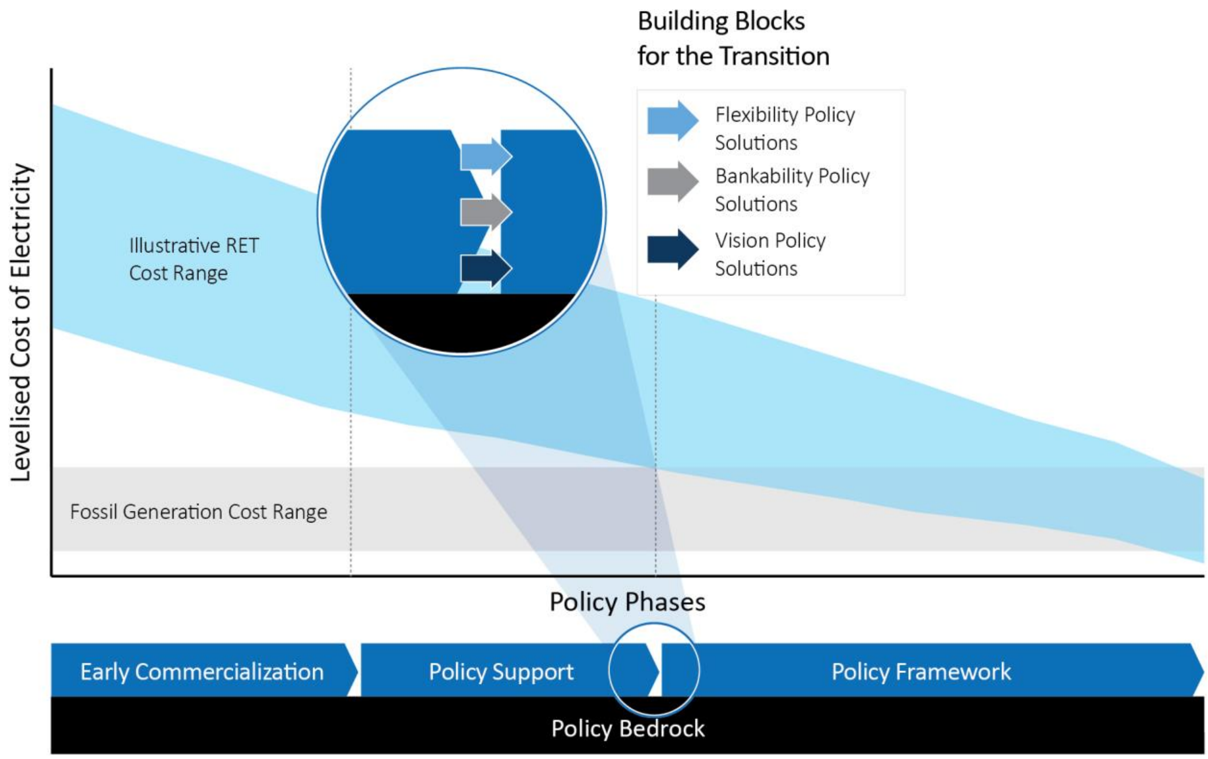

Figure ES 1. Illustration of evolutionary phases in relation to LCOE ranges

In addition to the introducing the concept of the Policy Framework Phase, this report introduces the notion of a "**Policy Bedrock**", which is defined as the set of core elements that applies to all generation technologies and that governs certain basic aspects such as grid access, project permitting, planning, and zoning rules. The Policy Bedrock is also frequently characterized by continuous government support for technology research, development, demonstration and deployment (RD3) activities. Such activities need not be limited to spurring technological innovation, but also innovation across policy, regulation, operation, planning, market design, business models, and finance.

In short, the Policy Bedrock includes a range of elements that establishes open market access, reduces soft costs, and ensures that project-specific investments can occur in a timely manner. In practice, the Bedrock also includes the basic technical standards required to govern the components that can be used to interface with the grid, such as standards for inverters, the establishment of a grid code, and other related aspects. In the absence of such common technical standards, a sustained scale-up in RE deployment would not be possible.

As such, **the core function of the Policy Bedrock is to provide a foundation for electricity sector development and investment**, and to help strengthen the long-term stability and predictability of the market.

Pillars of the Policy Framework Phase

One of the main questions that this report investigates is what constitutes an appropriate Policy Framework for a particular renewable energy technology once it has become cost-competitive with conventional alternatives. In other words, what kinds of policies (if any) are still needed to enable a sustained scale-up in investment in that technology?

In order to provide a basic organizing framework for understanding the Policy Framework Phase and shedding light on this question, this report outlines three key requirements that electricity markets will need to demonstrate in order to ensure the sustained scale-up of renewable energy, and in particular variable renewables like solar PV and wind power.

BANKABILITY (Section 4)	FLEXIBILITY (Section 5)	LONG-TERM VISION (Section 6)
Maintain the bankability of new investments in renewable energy technologies	Enable a high level of power system flexibility, specifically in order to adapt to growing shares of variable renewables	Establish a long-term vision for a clean and sustainable power sector

These pillars encompass the three most basic and common characteristics that future power systems will need to share to enable the sustained growth and scale-up of renewables.

Maintaining the Bankability of Renewable Energy Projects

In order to ensure continued investment in renewable energy technologies, investments in new power projects must first and foremost remain bankable. This means that investors (both traditional lenders and equity providers) must be able to have a high level of confidence that any investments made will be recovered within a reasonable timeframe. Failure to maintain conditions that enable project-specific bankability will likely lead to a significant decline in investments, as investors seek out bankable projects elsewhere. Thus, **maintaining bankability is critical;** this remains the case across all power market types. Toward the end of the report, bankability is suggested as a potential litmus test that can be used to assess whether a given policy and regulatory environment is likely to support a sustained scale-up in renewable energy project investment.

Enhancing the Flexibility of the Power System

Flexibility is identified as the second key pillar of the Policy Framework Phase because as variable resources increase in penetration levels, the system must be sufficiently flexible to accommodate the added variability and uncertainty while still maintaining reliability. An *inflexible* power system is more likely to rely on renewable energy curtailments to balance demand and supply, which in turn would limit the amount of economically desirable variable renewable energy that can be added to the grid.

All power systems possess some degree of flexibility to balance the variability and uncertainty of demand and conventional sources of energy. As power systems increase the share of variable RE, the need for flexibility from both demand and supply is likely to become increasingly important (IEA, 2015). As this report addresses transitions affecting renewable electricity policy, **we focus on how renewable energy policies can harness the flexibility that renewable energy producers, in particular, can provide.**

To increase system flexibility, market signals, such as negative prices, can be used to help increase load or decrease supply during these periods. In addition, renewable energy policies and contracts can be designed to reflect the value of non-variable renewable energy technologies' flexibility capabilities.

Establishing a Long-term Vision for a Clean and Sustainable Power System

The third pillar of the Policy Framework Phase is the establishment of a long-term vision for the sector. Policymakers have various options to steer the power systems towards sustainability, and decarbonisation, and other long-term objectives. The relevance of potential combinations of these policy solutions will depend on national regulatory traditions, priorities of policy objectives, and political feasibility of implementation. This report breaks down the key elements of a long-term vision into four basic categories:

1. **Introduce binding renewable energy targets:**
   Binding renewable energy targets will remain critical in the coming decades, since changes that are likely to occur to other framework conditions (e.g. market design) are difficult to predict and thus introduce additional policy and regulatory risks for investors.

2. **Introduce phase out policies for non-renewable technologies**:
   Phase out policies can be an adequate solution to **reduce carbon emissions of carbon intensive technologies and over-capacities**, especially in market with stable or declining electricity demand.

3. **Introduce carbon pricing**:
   Carbon pricing policies can be important mechanisms for **internalizing the negative external cost** of fossil fuels, thus creating a more level playing field for low or zero-carbon technologies.

4. **Introduce emission standards for existing or new power plants**:
   Emission standards for existing power plants can help to **phase out the oldest and most polluting power generation plants**, thus freeing parts of the market for new renewable energy capacity.

The rise of highly scalable, cost-competitive renewables is likely to fuel far-reaching changes in electricity market design, operations, and investment patterns. In the process, the field of renewable energy policy (and perhaps energy policy more broadly) is also undergoing its own evolution, as it constantly attempts to adapt itself to this rapidly changing landscape. In response to these changes, this report attempts to integrate the wide range of different policy innovations and the most recent thinking and analysis to put forward an overarching framework that depicts both where we are in the evolution of renewable energy policy, as well as where we are likely to go in the years ahead.

In light of the increasingly urgent need to scale-up renewable energy finance in jurisdictions around the world, understanding this evolution is critical to designing stronger, better adapted, and more bankable frameworks.

0. INTRODUCTION

Over the last four decades, a wide range of approaches have been used to support and encourage renewable energy (RE) deployment. Policymakers have revised and adapted RE policy tools to address ever-changing circumstances—reduced technology costs, new political priorities, impacts of higher renewable energy market shares, and restructured electricity markets, to name a few. As a result, renewable energy policy has been in a state of constant flux, transitioning from one form to another as the market and technology landscape has changed. Yet despite the myriad policy developments, one consistent objective of RE policy has been to reduce the cost differential between renewable and conventional technologies. With this cost gap narrowing and even disappearing in some jurisdictions, it is important to consider what the future role for renewable energy policy is, and to explore how policymakers can best adapt their strategies to both respond to and anticipate the changes ahead.

0.1. BACKGROUND AND CONTEXT: RENEWABLE ENERGY TECHNOLOGIES BECOMING THE LEAST-COST OPTION

As the cost-competitiveness of a number of rapidly scalable renewable energy technologies like solar photovoltaics (PV) and onshore wind continues to improve (IRENA, 2014), it is becoming clear that we are entering a new phase of renewable energy policy (Couture et al., 2015). At the heart of this new transition is the fact that **renewable energy technologies are increasingly becoming the least-cost options for new electricity supply**.

Solar PV is now the cheapest source of new generation capacity (on a levelised basis) in a wide range of different markets, as recent procurement processes in South Africa (Steyn, 2015), parts of Latin America (Dezem, 2015; Burger, 2014), and much of the Middle East (Parkinson, 2015a; Mills, 2015) have indicated. Remarkably, this cost-competitiveness has been achieved even in markets where the negative external effects of conventional power generation technologies have not been internalized.

Similarly, onshore wind power has long been the lowest cost source of new supply in many jurisdictions, particularly those with strong wind resources, such as Cape Verde and Denmark (IRENA 2014; IRENA 2012), as well as parts of Canada (PEI, 2009), and the United States (U.S.) (BNEF, 2016). In some areas of the U.S., wind power is beginning to be financed on a merchant basis (i.e., without power purchase agreements, or PPAs), indicating that in regions with good resource potential and the right institutional environment, technologies like wind power are beginning to be bankable (after tax incentives) on the basis of existing wholesale market prices (Bailey, 2015).[3]

In response to this new market reality, policymakers have begun scaling back policy support or putting more stringent caps on overall market growth. To draw on one recent example, the United Kingdom (UK) has recently proposed withdrawing its traditional policy support (including the renewable obligation certificates scheme (ROCs) and its contracts for differences (CfDs)) for these technologies, arguing that these technologies are now mature and that policy support should only be preserved for less mature (i.e., costlier) technologies (Rudd 2015).

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[3] Note, however, that wind power development in Texas benefits from a number of direct and indirect policy supports, including the federal Production Tax Credit (PTC), accelerated depreciation, as well as a streamlined transmission planning and zoning framework.

However, this sudden shift has caused a significant disruption in the investment environment in the UK (EY, 2015; Yeo, 2015). This example points to the need to examine more closely what Policy Frameworks for increasingly cost-competitive renewable energy technologies like onshore wind and solar PV could look like.

Such sudden shifts in the policy landscape point to an important shift in the underlying *rationale* for renewable energy policy. When the costs of renewable energy technologies were significantly higher than the costs of conventional generation options, the rationale was clear: to help **bridge the gap between the cost of existing renewable energy technologies and that of the alternatives**. However, as that cost gap has narrowed and even begun to shift in the other direction, some have called into question the need for preserving policy support for renewables, while some key decision-makers have discussed the possibility that we may soon be **transitioning to a "post-subsidy" renewable electricity market for certain technologies** (Hornby, 2015). However, it remains unclear what such an electricity market should look like, particularly if the long-term goal remains, as this report assumes, maintaining the continued scale-up of renewable energy technologies. Indeed, as the recent Conference of the Parties in Paris demonstrated, **establishing a clear vision for a more sustainable and lower-carbon future has become a near-universal policy priority for governments around the world,** spanning the least-developed, middle-income, as well as highly industrialized countries (UNFCCC, 2015). This analysis aims to provide a tentative answer to the question of what a sustainable long-term policy framework for RE technologies might look like.

0.2. SCOPE AND OBJECTIVES OF THIS REPORT

This report will help to guide policymakers through the ongoing and forthcoming transitions taking place in the field of renewable electricity policy as renewable energy technologies become increasingly cost-competitive.

While technologies like large-scale hydroelectric projects, landfill gas, and geothermal power have long been cost-competitive in certain markets, each of these technologies has typically been too limited in its ability to scale-up to significantly redefine electricity policy, or even renewable energy policy, at a global level. Also, these so-called "mature" renewable energy technologies are also either base load or dispatchable, which has made it easier for them to be integrated into existing electricity markets or traditional utility planning processes. In contrast, the combined potential of solar PV and wind power technologies is sufficient to meet global energy (not just electricity) demand many times over, and the variable, weather-dependent character of the solar and wind generation requires new considerations for power system operations and planning (Jacobson and Delucci, 2011; The Wharton School, 2015).

This report will focus primarily (though not exclusively) on solar photovoltaics and wind technologies[4]. **With the growing cost-competitiveness of both solar PV and onshore wind, policymakers in a growing number of regions now have the means to transition to a cleaner and more sustainable energy system and to do so economically**.

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[4] As mentioned above, one key difference remains that both solar PV and wind power are variable, their output is weather dependent, and as such, they may experience strong co-incidence effects: an extremely windy or sunny day can generate significant peaks in supply, which in turn can lead to a significant decline in wholesale market prices, or in the overall value of electricity across a particular region. These effects are sometimes referred to as "cannibalization" effects, as the surge in supply from variable renewables can significantly erode the revenues that power plants receive on the open market (Ciarreta, Espinosa et al., 2014). The negative impacts on project revenues are particularly acute in the case of solar and wind, as these technologies generally rely on their windiest and sunniest days to generate the revenues required to cover their debt service,

Some of the key questions that will be examined in this report are:

- What lessons can policymakers draw from the previous deployment of other cost-competitive technologies, where the continued presence of certain framework conditions (including stable offtaker contracts, access to the grid, and clear permitting procedures) are often still necessary to secure financing?
- In what ways do renewable energy technologies differ from fossil fuel-based technologies or large hydropower projects in access to these framework conditions?
- And more specifically, **what will the future policy and regulatory environment for highly scalable, variable renewable energy technologies like solar PV and onshore wind look like**?
- In short, **what are we transitioning to**?

As the case of large-scale hydropower demonstrates, the continued presence of certain basic framework conditions is likely to remain necessary for all generation technologies, regardless of their position on the cost curve. In other words, the technological "maturity" and overall cost-competitiveness of a particular generation technology (renewable or otherwise) may not necessarily imply that policymakers can remove all forms of policy and still expect markets to grow in line with historical trends, or be sufficient for jurisdictions to meet existing objectives (e.g. renewable energy targets). Indeed, conventional power producers still require a stable Policy Framework even though they have been in the market for many decades.

In the case of variable renewables, a sudden withdrawal of policy support without substituting (or simply preserving) a basic set of framework conditions that support bankability and maintain a high level of system flexibility is likely to limit key renewable energy technologies like solar PV and onshore wind to a relatively small market share (EY, 2015). **Given the key role that PV and wind are expected to play in transitioning to power systems with higher shares of RE, developing appropriate Policy Frameworks for these technologies is likely to remain a key priority for jurisdictions around the world.**

As a result of these broad trends, **this report presents the case that what is likely to matter most for rapidly scalable technologies like onshore wind and solar PV is not locking-in generous subsidies, but rather, maintaining a stable Policy Framework that ensures access to the grid, provides some degree of revenue stability for producers (and investors), and ensures that the system remains sufficiently flexible to integrate growing shares of variable electricity supply.** In some cases, these framework conditions will continue to be provided by government, regulators, or incumbent utilities; in other cases, third-party actors such as aggregators, new business models, or large power consumers may come to play a larger role in supporting the continued bankability of renewable energy projects, whether by signing long-term contracts or by investing in projects directly.

Moreover, there is a growing recognition that the existing renewable energy policy toolkit may need to be expanded, refined, and perhaps even re-conceptualized to adapt to these changing market and technological realities; this points to a set of deeper underlying questions that the current literature on RE policy has not yet properly addressed.

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and overall operating costs, and to compensate for calmer, cloudier days. As will be explained later in the report, such co-incidence effects are likely to have significant implications for the future of electricity markets) (most notably in regions with high and growing shares of solar PV and wind power), as well as for the kinds of policies that will likely be required to support continued investment in the future (see IEA-RETD 2016b).

This report on "Transitioning to Policy Frameworks for Cost-Competitive Renewables" will help policymakers in their efforts to design a robust Policy Framework for continuous scale-up of renewables in the coming decades. The report seeks to:

- Provide an accurate analysis of innovative policy instruments and possible alternative approaches on how to continue supporting renewable energy deployment in market contexts in which the costs of renewable electricity generation are increasingly below those of newly constructed conventional alternatives;
- Assist policymakers in better understanding the ongoing transitions in renewable energy policy by providing a new framework for considering the changes taking place;
- Understand how enabling frameworks that support existing mature technologies may need to be modified to allow a level playing field for renewable energy technologies without direct subsidy.

0.3. PREVIEW OF SECTIONS

Section 1 more closely examines the levelised cost of electricity (LCOE) of renewable energy technologies and provides more perspective and nuance to the debate around RE "cost-competitiveness". It also outlines the three benchmarks that renewable energy can technically "compete" with 1) retail electricity prices 2) the LCOE of conventional new-build technologies; and 3) the prevailing wholesale market price, or utility avoided cost of generation in a given region. Moreover, the section outlines how none of these benchmarks are necessarily fixed; each changes in response to overall market development as well as specific policy decisions (e.g. introducing carbon pricing).

Section 2 of the report introduces a new conceptual framework for understanding renewable energy policy transitions. It distinguishes among three main phases of renewable energy policy development, each of which is related to a technology's cost-competitiveness (i.e., its position on the cost curve):

1. **The Early Commercialization Phase** refers to the phase of policy meant to introduce a particular renewable energy technology into the market.
2. **The Policy Support Phase** refers to the phase when a renewable energy technology begins to scale-up and become more established in the marketplace.
3. **The Policy Framework Phase** refers to the phase in which a renewable energy technology has become cheaper than the LCOE of conventional new-build generation.

Section 3 of the report outlines three key pillars of the Policy Framework Phase These pillars can be summarized briefly as follows:

1. Maintaining the **Bankability** of Renewable Energy Projects
2. Enabling the **Flexibility** of the Power System
3. Establishing a **Long-term Vision** for a Clean and Sustainable Power System

Section 4, Section 5, and Section 6 discuss the pillars of Bankability, Flexibility and Long-term Vision respectively in substantially more detail, each section concluding by offering a brief menu of potential policy solutions that constitute the overall Policy Framework for a given setting and renewable technology.

Section 7 presents the full menu of potential policy solutions outlined in the previous sections, and applies this menu to discuss what the Policy Framework Phase might look like for a series of illustrative contexts where renewable energy technologies have become cost-competitive with conventional new-build generation.

Section 8 provides a synthesis of the report and concludes.

1. UNDERSTANDING COST-COMPETITIVENESS

1.1. ANALYSIS OF THE LEVELISED COST OF ELECTRICITY OF RENEWABLE ENERGY TECHNOLOGIES

The Levelised Cost of Electricity (LCOE) is a commonly used metric to compare the cost-competitiveness of power sector generation technologies – it provides policymakers, citizens, journalists and others with a supposed "apples-to-apples" comparison of generation costs and is typically framed in $ USD/kWh or $ USD/MWh. It is ubiquitous in global dialogues on renewable energy technologies and on power sector transformation, as it is relatively easy to understand, quote, and track over time.

While LCOE is undoubtedly a useful metric, it remains a convenient simplification of a complex reality.[5] Generally, **LCOE is best understood as a calculation that applies to a single hypothetical project**, or to a group of projects of a single technology with identical input assumptions. Looking across the LCOE of multiple technologies should therefore be done with sufficient caution, and ideally with an understanding of its many limitations. **LCOE is ultimately a forward-looking, hypothetical quantity that forecasts the expected cost of generation of a project over a fixed period of time** (e.g., the 20-year economic lifetime of a project).[6] The LCOE calculation relies on a multitude of assumptions beyond a technology's capital-, fuel-, and maintenance-related costs, including:

the assumed mix and cost of debt and equity financing for the project, comprising a weighted average cost of capital (WACC);

the assumed hours of operation (i.e., capacity factor, or the annual specific yield of the wind turbine) over the analysis period. The total output of the project has a direct bearing on the LCOE.

It is important to underscore that LCOE is distinct from contract price, or the final PPA price awarded, which may reflect the unique circumstances of a given project, including certain aspects (including tax and depreciation assumptions) that may differ from those made in a generic financial model or LCOE calculator. As well, LCOE calculations typically do not include changes in system costs associated with integrating renewables to the grid.

Generally speaking, there is a wide range of models used to calculate LCOE, including models with varying levels of complexity and sophistication, each of which may provide different results for the LCOE of a given project, or technology. The mathematical equation and list of required inputs for an LCOE calculation is ultimately the same regardless of the specific project or technology. However, in practice, there is significant room for diversity in how LCOEs are calculated, particularly with respect to how input assumptions are formulated, and the uncertainty associated with those inputs over the projected lifetime of an asset. Thus, a true "apples-to-apples" comparison may be more elusive than is widely believed.

[5] For policymakers tasked with developing a cost-efficient, clean and reliable power system, accurate LCOE data is only one consideration, and may not even be the most important one from a power system planning perspective.[5] Along the same lines, for financiers evaluating potential generation investments, a low LCOE may be only one component of the overall decision-making process, which may include a wide range of factors such as political, regulatory, price, and currency risks, location, proximity to the grid and potential transmission constraints, and environmental and social impacts, among others.

[6]LCOE could also hypothetically be calculated in a retrospective manner, perhaps as an *ex-post* evaluation of a generator's life cycle performance. Such a calculation could rely on actual operational and cost data to provide a "true" LCOE, rather than an expectation or projection.

As a result of these and many other considerations, **it is advisable to speak in terms of LCOE "ranges"** rather than specific or unitary numbers[7]. For instance, the LCOE of wind power in a given country might vary from USD $70/MWh to over $130/MWh, depending on the particular site, project design, the orientation and layout of the wind turbines in relation to one another, and the overall operation of the project. Table 1.1. Select LCOE Ranges for Various Renewable Technologies in 2014 below provides global LCOE ranges for various renewable energy technologies in 2014.

Table 1.1. Select LCOE Ranges for Various Renewable Technologies in 2014 (IEA, 2015)

Technology	**LCOE Range [USD 2014 / MWh]**
Onshore Wind	$64 – $154
Offshore Wind	$195 – $252
Utility-scale Photovoltaics	$97 – $220
Residential Photovoltaics	$97 – $395
CSP (no storage)	$147 – $295
Geothermal	$35 – $200
Hydropower	$20 – $230

Table 1.2 below raises a number of key questions that policymakers might ask when presented with LCOE data, in order to better inform decision making.

[7] Given the diversity and uncertainty of input assumptions, LCOEs are often stated in ranges (i.e., low, mid, high).

Table 1.2. Key Questions to Ask About LCOE Data

When comparing LCOEs:	Key questions to ask include:
Across a single technology in a single context	• What differences besides changes in technology capital costs might explain movement in prices? • Does the LCOE represent a single project, or a group of projects? If a group, how were they combined together? • Were LCOEs calculated with uniform input assumptions? • Are contract prices being presented as LCOE? • What is the assumed weighted average cost of capital (WACC)? • Is the WACC used as the discount rate in the financial model, or does the discount rate differ over the course of the project's life?
Across a single technology in multiple contexts	• To what extent are technology availability and capital cost the key differences between contexts? • What market conditions (e.g., market design, financing availability, currency inflation) could contribute to diversity in LCOEs? • Have direct tax (and other government) incentives been accounted for appropriately harmonize the comparison?
Across multiple technologies in a single context	• What are the key differences in how operating hours are assumed for the various technologies? • For technologies using fuel, what long-term costs were assumed? • How might local market conditions distort the LCOE of specific technologies, but not others?

While LCOE may only provide a one-dimensional window into cost-competitiveness, it is nevertheless a useful metric for describing evolutions in technology cost and performance over time. The charts below provide a forward-looking snapshot of different LCOEs for different renewable energy technologies, as reported by the International Energy Agency's 2015 Medium-Term Energy Market Report (IEA, 2015).

Figure 1.1 illustrates recent and expected future levelised cost reductions in onshore wind, utility-scale photovoltaics, and residential-scale photovoltaics. Levelised costs for photovoltaic technologies have come down significantly in recent years, beginning to converge upon onshore wind costs in many contexts.

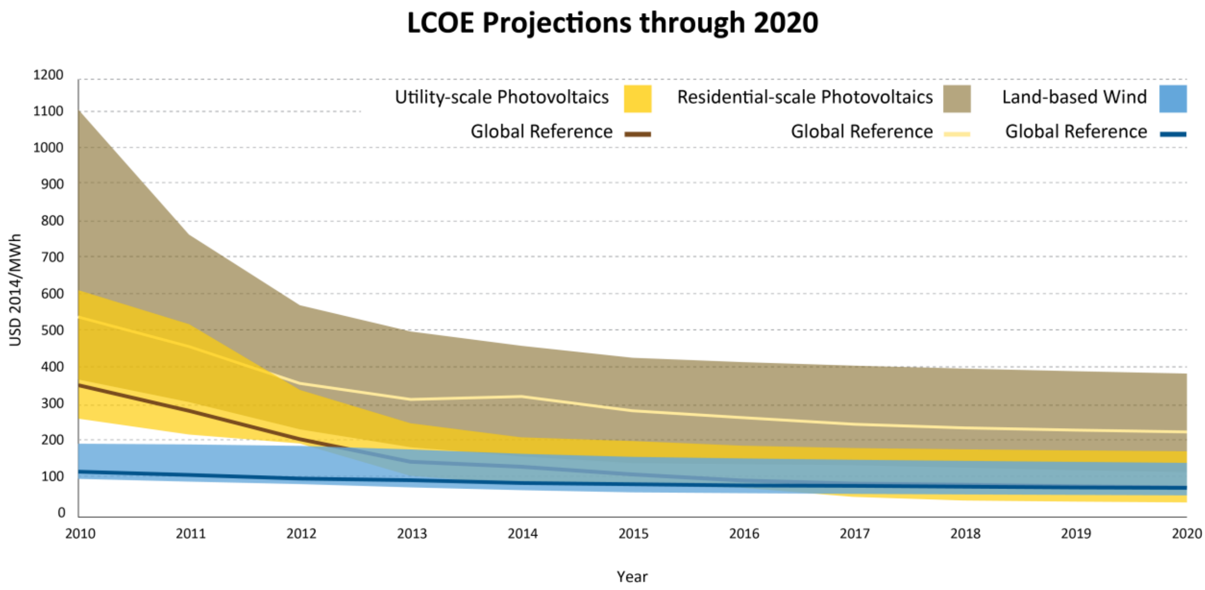

Figure 1.1. LCOE Projections for Onshore Wind, Utility-scale Photovoltaics, and Residential-scale Photovoltaics
Source: IEA (2015)

Figure 1.2 illustrates the expected future levelised cost reductions in offshore wind and concentrating solar power (CSP). CSP and offshore wind have not yet arrived at LCOE cost-competitiveness in most markets throughout the world, but are certainly well on their way in many contexts.

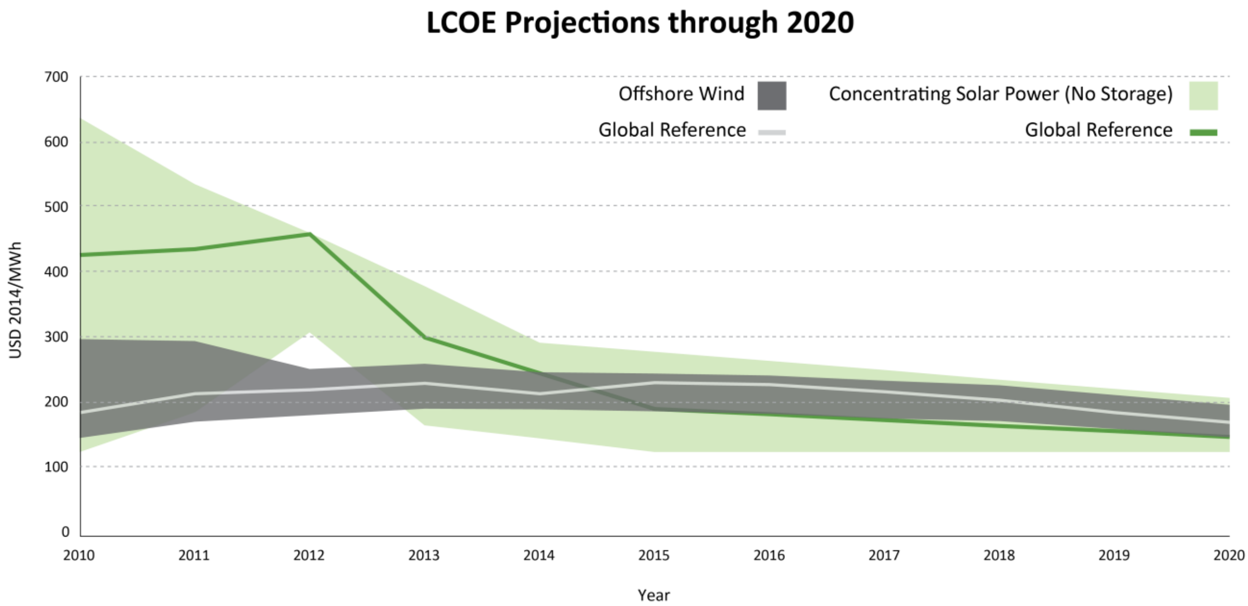

Figure 1.2. LCOE Projections for Offshore Wind and Concentrating Solar Power (no storage)
Source: IEA (2015)

Some technologies are still in an early stage of commercialization, such as marine power. Without substantial experience deploying these technologies, formulating LCOE projections with high degrees of certainty may prove difficult. Figure 1.3 illustrates how average LCOE estimates for wave and tidal power have recently *increased* over time, reflecting analysts' evolving understanding of the technologies being deployed, their projected operational lifespans, and declining expectations of annual project output.

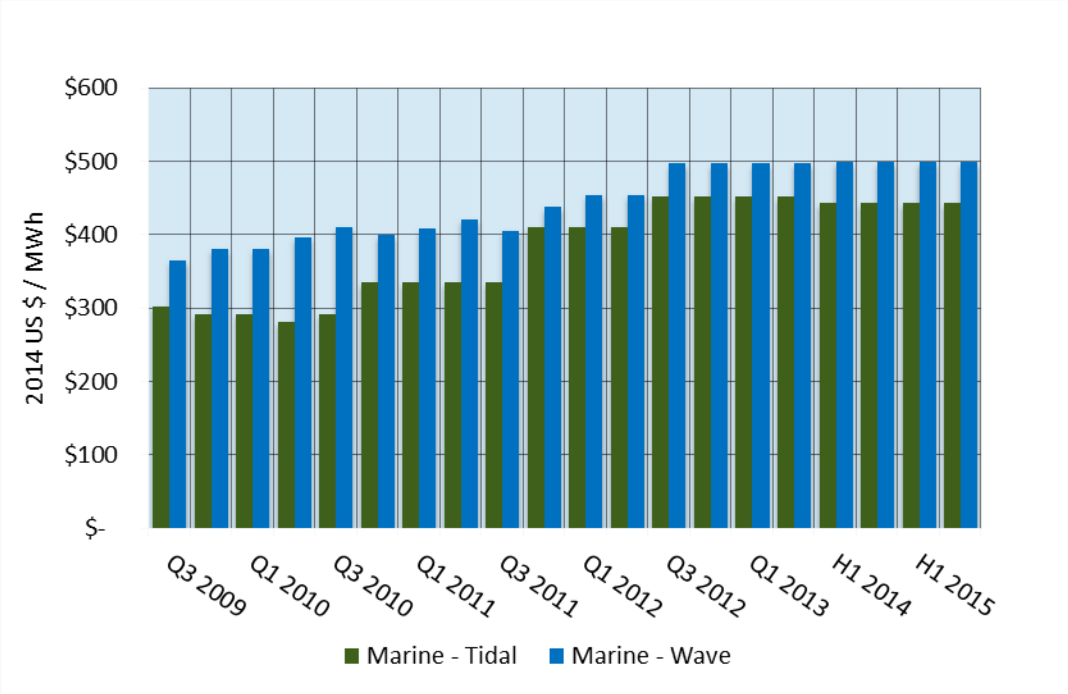

Figure 1.3. Evolving Average LCOE Estimates for Marine Power
Source: BNEF (2015)

While LCOE analyses are certainly useful constructs, they are best contextualized within relevant cost-competitiveness benchmarks in order to understand their relative position within the market. Better understanding these benchmarks can also shed light on how evolving cost-competitiveness influences which policy tools are appropriate for different technologies, and different market segments.

1.2. RENEWABLE ENERGY COST-COMPETITIVENESS BENCHMARKS

In order to understand the ongoing and future transition of Policy Frameworks for renewable energy, the cost-competitiveness of renewable energy technologies needs to be clearly understood and defined. Several terms have been used to refer to the cost-competitiveness of renewable energy technologies, including grid parity and socket parity among others (IEA-RETD, 2014). For the sake of clarity, we differentiate and define three distinct cost-competitiveness benchmarks:

Table 1.3 provides a more detailed overview of the different applicability or relevance of each of the key benchmarks. The 'Definition' column describes the term, and the 'Relevance of the Benchmark' column describes the applicability of the benchmark to various market contexts.

Table 1.3. Relevance of the Different Cost-Competitiveness Benchmarks

	Definition	Relevance of the Benchmark
RETAIL	**Retail Competitiveness:** Competitiveness with the prevailing retail price, often referred to as "socket parity" or "grid parity".	This benchmark is relevant primarily to **distributed renewable energy technologies** such as rooftop solar PV. When behind-the-meter renewable energy technologies like solar PV reach retail competitiveness, customers may have a stronger incentive to begin self-supplying a portion of their electricity needs, becoming **prosumers** in the process.
LCOE	**LCOE Competitiveness:** Competitiveness with the LCOE of conventional, new-build alternatives.	This benchmark is relevant primarily for **renewable energy technologies being developed in traditionally regulated electricity markets**, where the costs of different generation alternatives are compared on the basis of their LCOE within national, state, or utility-level planning (e.g., Integrated Resource Plans, or IRPs), or within centralized procurement processes where generation technologies compete against one another in open tenders.
WHOLESALE	**Wholesale Competitiveness:** Competitiveness with prevailing wholesale energy market prices, or the utility average cost of energy production (i.e., avoided cost).	The benchmark is relevant for **all renewable energy technologies that are operating in competitive electricity markets** where producers need to sell their power on the wholesale market. In single buyer markets that do not have competitive wholesale markets, utilities may rely on utility avoided costs instead to compare whether a particular technology is "cost-competitive" or not. Thus, avoided costs may be considered analogous to "wholesale market competitiveness" in single buyer markets.

1.2.1. Retail Competitiveness

Retail competitiveness occurs when the generation costs of renewable electricity technologies are lower than the retail electricity price. Retail competitiveness has also been termed "grid party" or "socket parity", though both of these terms have given rise to a host of misunderstandings (IEA-RETD, 2014). The related cost-benchmarks and policy implications were discussed at length in two recent IEA-RETD publications on the rise of prosumers (IEA-RETD, 2014; IEA-RETD, 2015a; IEA-RETD 2016a). Thus, although the achievement of retail competitiveness represents a significant transition in its own right, it is not examined in depth in this report.

When small-scale PV systems reach and surpass grid parity, consumers begin to have a greater incentive to produce electricity themselves instead of buying it from their distribution utility. This is reflected by traditional net metering design, where prosumers receive the same compensation for each kilowatt-hour fed into the grid as they would pay for buying one kilowatt-hour from the utility (Auck et al., 2014).

In many countries around the world, renewable energy technologies have reached retail competitiveness. For instance, the latest REN21 Global Status Report states that the LCOE of small-scale distributed PV is now below retail electricity prices in over 30 countries worldwide (REN21, 2015). Other renewable energy technologies, such as onshore wind, landfill gas, and large-scale hydropower, have reached and surpassed this benchmark years ago. However, as mentioned above, **the retail price benchmark is only directly relevant for distributed renewable energy technologies**, as these are the only technologies in which electricity customers can invest directly in order to offset onsite use.[8]

The retail competitiveness benchmark is in itself inherently complex. Therefore, policies for the prosumer market segment have become increasingly detailed. This involves controversies regarding new structures for network charges, payment levels for excess electricity and levies or taxes on self-consumed electricity. These policy modifications can delay or accelerate renewables reaching the retail cost-competitiveness benchmark (see IEA-RETD, 2014; IEA-RETD 2016a).

In sum, it is important to understand that retail competitiveness is not a fixed benchmark. **Policymakers are indirectly influencing the retail cost-competitiveness of renewable energy power generation technologies by:**

- Regulating the prices for excess electricity from prosumers (potentially reflecting certain components of the retail electricity price)
- Introducing surcharges on self-consumed electricity
- Adjusting network tariffs (e.g. moving from kWh related price to kW related payments) (Martinot et al., 2015).
- Calibrations of the basic retail electricity rate design (e.g. categorization of consumer groups, cross-subsidies)

In addition, carbon pricing policies can have an indirect effect on the cost-competitiveness of distributed renewable energy generation. It should be noted that reaching retail-competitiveness does not necessarily trigger a sudden surge in investment in onsite generation, as a host of other factors often stand in the way of a sustained scale-up in the market, including the high upfront costs (see IEA-RETD 2014; IEA-RETD 2016a).

1.2.2. LCOE Competitiveness

As indicated in Section 1.1, the LCOE of power generation technologies is typically a forward-looking, calculated quantity that allows comparing power generation costs of various technologies. Once renewable energy technologies reach LCOE competitiveness their deployment costs are in the same cost range as the costs of new fossil-fuel based power generation.

[8] Large commercial and industrial customers can self-supply with larger technologies such as wind power and combined heat and power (CHP) systems, among others, but these kinds of projects may be considered a special case and are not sufficient to drive a significant scale-up in renewable energy deployment, in contrast to distributed solar, which is already reaching significant levels of penetration in many markets, including Japan, Australia, Germany, and parts of the U.S. (IEA-RETD, 2014).

In single buyer markets, the costs of different generation alternatives are typically compared on the basis of their LCOE within utility planning processes in an attempt to deliver "cost-optimal" system development. These approaches are typically informed by numerical modelling exercises, which use technology cost data to understand how electricity demand can me met in the most cost-effective way, taking system constraints/requirements into account.[9] However, since increasing shares of wind and solar PV can add additional system integration costs, these are now frequently taken into account when calculating cost-optimal system development.[10] In most jurisdictions, the externalities of fossil fuels are usually not taken into account.

Whereas the LCOE applies to a single hypothetical project of a given technology, policymakers can also analyse the actual contract prices that RE projects realized in the recent past. Here, the very specific regional or national conditions can be taken into account, including financing costs, and tax and depreciation rates. As RE technology costs continue to decline, updated cost inputs frequently result in an increased projected role for renewable energy in future systems. In practice, policymakers frequently update their capacity or generation targets for various renewable energy technologies in order to reflect these new cost realities. China, for instance, has increased its solar PV target several times in the past years, now targeting a cumulative installed PV capacity of 150 GW by 2020, up from a 50 GW 2020-target established in 2012 (Parkinson, 2015b). In addition, several RE technologies have reached LCOEs that are comparable (or below) the LCOE of conventional power generation technologies (see IEA, 2015).

As already discussed in the previous section (1.1) and laid out in more detail in Section 2.3, **policymakers are indirectly influencing LCOE cost-competitiveness of renewable energy power generation technologies by:**

- Scaling up renewable energy markets via support programs during the Policy Support Phase (see Section 2.3)
- Removing subsidies for fossil fuels
- Internalizing the negative externalities (e.g. by implementing a carbon price, or charging for other externalities such as SOx, NOx, water pollution, etc., see Section 6)
- Using more comprehensive input parameters in LCOE calculations (see Section 1.1).

1.2.3. Wholesale Competitiveness

Wholesale competitiveness is reached once RE technologies reach cost levels in the range of average wholesale market prices or the utility's avoided cost of generation, depending on whether the market has a functioning spot market or whether it is still part of a single buyer market, or a jurisdiction with a vertically integrated utility. In the latter two cases, utility avoided costs can be considered to be the "wholesale" benchmark against which RE technologies compete.

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[9] System constraints/requirements might include *inter alia* operational constraints (e.g., reliability requirements), policy goals (e.g. carbon caps), and other technical considerations (e.g. grid capacity, geographic diversity of renewable resources)

[10] Integrating increasing shares of variable renewables can lead to additional system integration costs, primarily related to grid and balancing costs. Grid costs are related to necessary grid expansions or re-enforcements. Balancing costs occur if the forecasts for power generation from wind and PV are not accurate and increasing amounts of balancing power are needed. Costs can be negative when only small shares of wind and PV are added to the existing grid (Sijm, 2014). With increasing shares, these costs are relatively low; they can range from +5 to +13 EUR/MWh (Agora Energiewende, 2015a).

Even though several RE technologies have reached LCOE competitiveness with fossil-fuel based power generation technologies, wholesale competitiveness remains a more challenging and in many ways more complex benchmark to surpass, not least because wholesale market prices (at least in many developed country markets) are currently flat and/or declining, partially due to increasing share of renewables (see Textbox 1.1 and Section 4.3.2 on achieving bankability in wholesale markets). This notwithstanding, the wholesale benchmark is becoming increasingly important in determining the way renewable energy projects are designed and financed in liberalized markets (as well as in many vertically integrated markets).

Textbox 1.1: The Cannibalization Effect and the Market Value of Wind and PV Energy

In some cases, full competitiveness with the wholesale price benchmark may be achieved for a period of time and then slip away as the share of variable RE technologies grows. This is due to the so-called merit order effect, which sees variable, weather-dependent renewable energy projects such as solar PV and wind power cannibalize their own revenues as spot market prices collapse across entire regions during sunny and/or windy days. This is known as the “cannibalization effect”. In the case of wind and PV, the timing of power output cannot be controlled and frequently coincides time-wise with other generators within the same jurisdiction. Consequently, the market value of variable RE technologies decreases with an increasing share of deployment. This effect has been analysed in many countries around the world (Sensfuß, Ragwitz et al., 2008; Ray, Munksgaard et al., 2010; Ciarreta, Espinosa et al., 2014).

In other words, within jurisdictions with competitive wholesale markets, what wind and solar producers earn is not average wholesale market prices (on which basis they may be “cost-competitive”), but rather the real-time spot market prices. Wholesale market prices fluctuate constantly. Therefore, revenues change from one power producer to the next, depending on the timing of power generation.

In Germany, for instance, in the years 2000 until 2010, solar PV was able to obtain above-average revenues on wholesale markets since production partly coincided with peak demand and therefore higher prices. In recent years, higher midday prices disappeared due to a rapidly increasing share of PV. As of 2014, the so-called “market value” of PV is already below average wholesale market prices. The market value is expected to decline further in the coming years. A study commissioned by the German Ministry of Economic Affairs and Energy assumes a market value of as low as 76% of average market prices in 2030 (Winkler et al., 2015).

Once wholesale competitiveness is reached, RE projects should (in theory) be able to secure financing for new RE projects simply by selling power on existing wholesale markets or at avoided utility generation costs. However, this assumption neglects some of the revenue and market related risks inherent to liberalized markets (e.g. price risk and volume risk), which are discussed in more detail in Section 4.3. There are a few recent examples of RE projects being financed on the back of wholesale market prices when combined with financial hedges, e.g. wind energy plants built in the U.S. state of Texas, indicating that within certain markets, renewable energy technologies like wind power can be considered broadly cost-competitive (after tax incentives) even with prevailing wholesale market prices (Bailey, 2015). Wholesale competitiveness has also been achieved in other U.S. states (though typically with additional revenue streams from the sale of renewable energy certificates, or RECs). In addition, in some island regions, project developers have been able to secure financing for projects in which the PPA is linked to the utility’s avoided costs (see IEA-RETD, 2012).

It is noteworthy that this benchmark has been reached in many jurisdictions without the internalization of the externalities of fossil fuels. With further price decreases of RE technologies and carbon policies (see Section 6), this benchmark is likely to be reached in an increasing number of jurisdictions in the years ahead. In many European markets the situation is markedly different: wholesale prices are currently very low due to a range of factors, including overcapacities and an increasingly interconnected market, low carbon prices, low or negative demand growth, as well as the surge in variable renewables. As a result, almost no new power plants, whether renewable or fossil based, can be financed on the basis of wholesale revenues alone (EU Commission, 2015a). This suggests that even if RE technologies were to remain the least-cost options (on a levelised basis) for new electricity supply, certain policies may still be required for new projects to be bankable under current market conditions. These measures will be discussed further in this report in Section 4.

In addition, in single buyer and fully monopolized markets, incumbent utilities often adopt a very narrow definition of "avoided costs", focusing only on avoided fuel costs which artificially understate the value of new generation to the system. Avoided costs may often ignore some of the other related benefits of RE technologies, such as energy security, reduced exposure to fuel price volatility, as well as improved environmental performance. Similarly, wholesale market prices can be heavily influenced by factors beyond policymakers' and investors' control such as recessions, global fossil fuel prices, and geopolitical factors. **Added to the cannibalization effect, as well as the implicit biases that continue to persist in many electricity markets, achieving stable, long-term conditions that support the bankability of RE projects is likely to remain difficult for the foreseeable future in many markets**.

As laid out in more detail in Section 4 and Section 6, **policymakers can directly or indirectly influence wholesale cost-competitiveness of RE power generation technologies in a range of ways, including:**

- Reducing overcapacities during the system transformation phase (phase out policies, see Section 6.2.2)
- Taking measures to make the power system more flexible (see Section 5). The more flexibility there is in the system, the more stable wholesale market prices and the market value of RE gets. Low or negative wholesale prices can be avoided. Revenues for RE producers are more stable and more foreseeable and curtailment can be reduced.
- Introducing carbon pricing to price in negative externalities of fossil fuels (see Section 6.2.3)
- Diversifying revenue streams for RE producers (see Section 4)

2. UNDERSTANDING POLICY TRANSITIONS

A core thesis of this Report is that **policies best suited to encourage the deployment of renewable energy technologies evolve based on the level of each technology's maturity and cost-competitiveness**. The three major evolutionary phases of renewable energy policy are presented below. Note that because the phases are based on a technology's cost-competitiveness, a given country may have different technologies that are in each of the three phases at the same; as a result, it would be inaccurate to say that a country as a whole has "transitioned" to the Policy Framework Phase; rather, one can say that certain technologies like wind and solar have entered the Policy Framework Phase, based on their relative cost-competitiveness in that particular market. Figure 2.1 graphically depicts this concept in more detail.

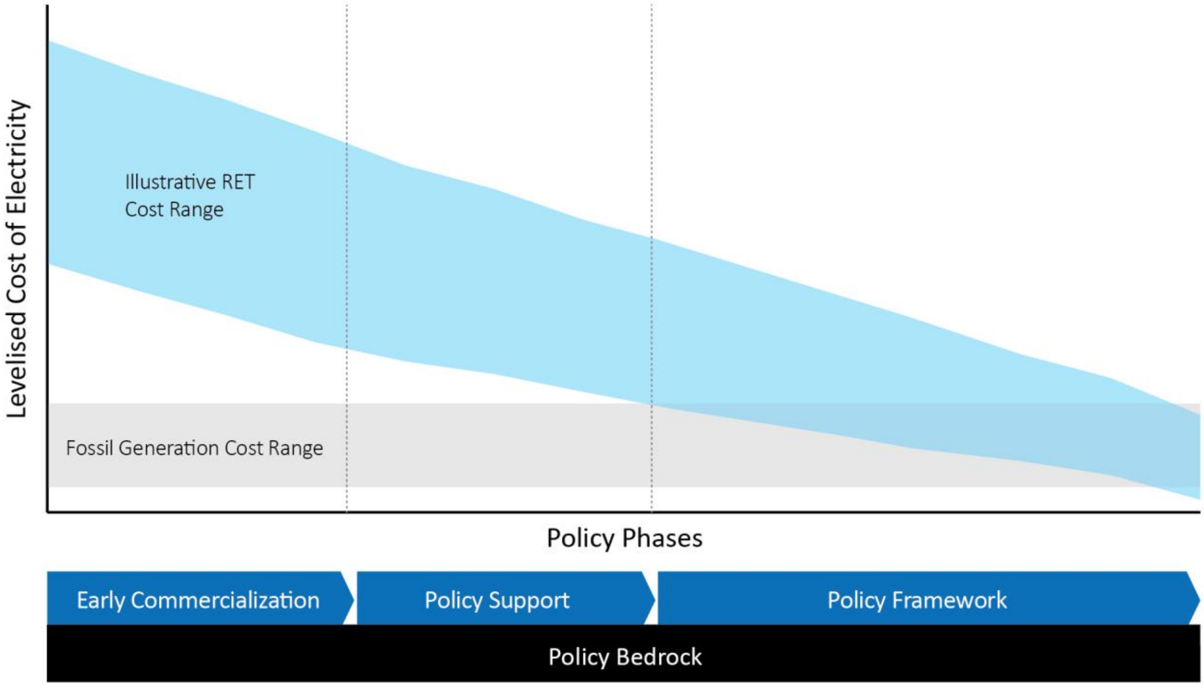

Figure 2.1. Illustration of evolutionary phases in relation to LCOE ranges

This conceptual framework is designed to provide an easy and intuitive way to understand the transitions of RE policy over time, and to trace lines of continuity between historical, current, and potential future pathways for RE policy. This section provides a brief overview of three phases of renewable energy policy, *Early Commercialization*, *Policy Support*, and the *Policy Framework.* We will explain the nature of policy solutions that have been (and continue to be) employed through the three phases of RE policy. In addition, the report introduces the concept of the Policy Bedrock (see below).

2.1. POLICY BEDROCK

Underlying all three phases of renewable energy policy is the Policy Bedrock, a suite of elements that establishes open market access, reduces soft costs, and ensures that project-specific investments can occur in a timely manner. These elements include, among others:[11]

- Continued research, development, demonstration and deployment (RD3) funding for advancing the state of various technologies
- Policies supporting open grid access for all renewable generation technologies and project sizes
- Clear project permitting, siting and interconnection procedures12
- Policy, regulatory and legal stability (e.g., no retroactive changes to policies, long-term objectives, and targets)
- Cost accounting of the external costs of generation (including impacts on climate, water, air quality, and human health, among others)
- Clear technical standards for all power system components (e.g., generators, inverters)
- Technical assistance from local or national research institutes, e.g., for RE technology component testing (see e.g., DTU in Denmark, ECN in the Netherlands, NREL in the U.S.A.)
- Clearly delineated cost allocation among ratepayers, utilities, investors and other stakeholders for investments required to interconnect projects
- Clear land access rules

While the specific elements that comprise the Policy Bedrock may differ by jurisdiction, and by technology, we present Policy Bedrock as the foundation that underlies all three phases.

In practice, the Bedrock helps to establish open market access and provide clear legal and regulatory structures governing investment, including streamlined procedures for permitting, siting, and grid interconnection. The Bedrock also includes the basic technical standards required to govern the components that can be used to interface with the grid, such as standards for inverters, the establishment of a grid code, and other aspects. In the absence of such common technical standards, a sustained scale-up in RE deployment would not be possible. As such, **the core function of the Policy Bedrock is to provide a foundation for electricity sector development and investment, and to help strengthen the long-term stability and predictability of the market**.

As a result, the notion of maintaining a Policy Bedrock would be inconsistent with the introduction of retroactive changes to policies; as seen in certain markets (Couture, 2011; del Rio and Mir-Artigues, 2014), retroactive changes to existing policy and regulatory conditions have been detrimental to investor certainty, and have negatively impacted the overall availability and cost of finance (IEA-RETD 2008; UNDP 2012). In addition, by pushing up the cost of capital, retroactive changes in turn negatively impact the cost-competitiveness of renewable energy technologies.

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[11] As the literature is quite extensive on such elements, we choose not to explain them in this Report.

[12] While many aspects of permitting, siting and interconnection procedures are distinct for RE technologies, the general principle of establishing clear and transparent guidelines applies to all technologies.

As a result, **one of the most important measures that governments can take to create a stable foundation that supports a sustained scale-up in renewable energy finance is to avoid retroactive changes.** An important but less appreciated corollary of this point is that policy makers should strive to avoid policy and regulatory decisions that run the risk of needing to be retroactively changed.

2.2. EARLY COMMERCIALIZATION

Renewable energy policy effectively began in the 1970s and early 1980s, driven primarily by growing concerns over energy security triggered by the 1970s oil crises. In the United States, these policies led to substantial new investments in foundational research and development, as well as in a range of targeted investments in the establishment of national research laboratories (NREL, 2015). A related driver that played an important catalytic role in certain countries such as Germany was mounting opposition to nuclear power, which led to a greater desire for local control over energy decision-making and the use of more local and sustainable energy sources (Hockenos, 2015). In countries like Denmark, which opted against nuclear power as an energy option (IRENA, 2012) and had limited domestic fossil resources, the focus shifted swiftly toward investment in wind power technologies in order to improve national energy security and reduce reliance on costly energy imports (Maegaard et al., 2013; Kruse and Maegaard, 2002).

During this early phase of renewable energy development, policymakers experimented with a wide range of approaches to support investment in renewable energy technologies. **This report refers to this phase as the Early Commercialization Phase**, emphasizing the role that direct research- and investment-related incentives play in reducing project risk and supporting the development of renewable energy technologies in early stages.

The **Early Commercialization Phase** is characterized by direct subsidies, government co-funding or co-financing, support for local research institutions, and other forms of policy and financial incentives aimed to spur investment, and bring demonstration projects into the market and reduce project risk. Due to the early stage of technology development, as well as the continued uncertainty over project output and the longevity of key project components, government support during the Early Commercialization Phase is often characterized by upfront or project based incentives rather than performance-based payments, as is common in the Policy Support Phase (see below). This process of bringing new technologies into the market enables policymakers as well as investors and entrepreneurs to learn valuable lessons, while gradually working to overcome a host of performance and cost barriers.

This Early Commercialization corresponds specifically to technologies that are in the early stages of deployment and likely higher up on the cost curve. As such, this phase has not yet ended for all renewable energy technologies: it can still be observed in the policies being used to encourage costlier technologies, *inter alia* wave and tidal power (EY, 2013), and underwater energy storage (Toronto Hydro, 2016).

Policies that are common during the **Early Commercialization Phase** include[13]:

- Development of technical standards for pilot projects (e.g., regarding grid connection, power system electronics);
- Establishment of permitting and other processes related to project approval and construction for pilot projects;
- Resource assessment activities targeted at project developers and/or grid operators;
- Loan guarantees and/or direct cash grants for investment

At this stage in the development of renewable energy technologies, policymakers typically experiment with a wide range of approaches to support deployment. Despite being separated in certain cases by several decades, there are common threads unifying the different policies used for different technologies:

- Policy is focused on supporting commercialization, or bringing technologies closer to commercialization, through targeted (and often project specific) support;
- The incentives are designed more to encourage the development of demonstration and pilot projects than to trigger a substantial scale-up in the market, as is the case in the **Policy Support Phase** (see below);
- The incentives often include direct government involvement, either via government-funded research, government-led stakeholder engagement and coordination; or direct cash grants rather than performance based payments.

Table 2.1 provides an overview of the policy incentives offered for specific technologies in several jurisdictions:

Table 2.1. Overview of Select Policies in the Early Commercialization Phase

Country (timeframe)	Technology	Description of Policies Used
Denmark (1970s – early 1990s)	Onshore Wind Power	• Tax incentives and rebates for local wind power production • Capital grants of up to 30% of total investment costs (reduced to 20%, then 10%, before being phased out in 1988) • Obligation imposed on utilities to connect wind power projects to the grid • Direct collaboration with government-funded research institutes
Germany (1970s – 1990s)	Solar PV	• Government financed pilot projects • Establishment of a 1000 roof program (and later 100,000 roof program).
Hawaii, U.S.A. (Ongoing)	Wave Power	• Government-funded wave energy test site (WETS) • Cash grants to private developers to pilot and monitor new wave technologies

[13] Policy support for foundational RD3 activities is critical during the Early Commercialization Phase; however, we classify such support as part of the Policy Bedrock, indicating that RD3 is an important element throughout *all* phases of renewable energy policy, though the exact nature of RD3 activities may evolve with technological maturity. .

Country (timeframe)	Technology	Description of Policies Used
		• Collaboration with universities and government-funded research laboratories • Government-funded resource assessments and resource mapping • Customized permitting process for wave energy devices
Nova Scotia, Canada (Ongoing)	Tidal Power	• Government-funded private sector engagement, training, and networking events for suppliers • Government support to study and monitor the impacts of tidal power on the marine environment • Cash grants from various levels of government (municipal, provincial, federal) • Long-term contract for project output

Denmark: "30 Years of Policies for Wind Energy: Lessons from Denmark," International Renewable Energy Agency (IRENA), accessed February 9, 2016, https://www.irena.org/documentdownloads/publications/gwec_denmark.pdf.

Germany: Bruns et al. 2009

Hawaii: "Renewable Power Generation," Hawaii Natural Energy Institute, accessed February 9, 2016, http://www.hnei.hawaii.edu/research/renewable-power-generation.

Nova Scotia: "News Release: Building Nova Scotia's Tidal Power Supply Chain," Marine Renewables Canada, last modified May 21, 2015, accessed February 9, 2016, http://www.marinerenewables.ca/news-release-building-nova-scotias-tidal-power-supply-chain/ and "International Partnership Advances Nova Scotia's Tidal Industry," last modified July 20, 2015, accessed February 9, 2016, http://novascotia.ca/news/release/?id=20150720002

2.3. POLICY SUPPORT PHASE

In contrast to the first Phase, the **Policy Support Phase** has a number of different characteristics and objectives:

- Close the cost gap between renewables and conventional alternatives
- Increased focus on scaling-up the market through large-scale procurement policies (feed-in tariffs, auctions);
- Policies aiming to expand the number of participating projects and/or spur greater competition;
- Standardization and streamlining of permitting and other related processes;
- Increasing focus on reducing non-hardware costs (i.e., soft costs);
- Incremental financing of scale-up via ratepayer or taxpayer-targeted surcharges / levies
- Increased public dialogue around how renewable energy technology support mechanisms are financed, the additional costs caused by the procurement of renewables, and how to allocate any renewable energy procurement related surcharges (e.g., exemptions for heavy industry, for low-income customers);
- A range of measures designed to control market growth and avoid over-payment: e.g., auctions, tariff degression, periodic reviews, volumetric degression (e.g. Malaysia, UK, Japan, Germany, California).

During the Early Commercialization Phase, public dialogue about the support offered to renewable energy technologies may be comparatively limited, as the interventions are typically lower cost than large-scale support mechanisms, and are not immediately threatening to the status quo or to incumbent generators in the market. This begins to change during the **Policy Support Phase**, as renewable energy technologies begin to scale-up and become a more substantial force in the market, triggering growing concerns over electricity rate impacts, industrial competitiveness, the role of incumbent generators, on one hand, as well as a growing recognition of what is possible on the other. As a result, growing public dialogue over policy goals, costs, and benefits can be seen as a defining feature of the Policy Support Phase in many markets.

During the **Policy Support Phase**, a number of additional elements begin to emerge that become fundamental for spurring future renewable energy investment. As markets scale-up, it becomes increasingly important to make efforts to standardize administrative procedures, mitigate the risk of regulatory delays, and reduce soft costs, among other items. This becomes particularly important as the market is no longer comprised of one or a few actors, but rather involves the participation and interaction among thousands if not millions of different individual actors. In short, as renewable energy technologies begin to scale-up, and deployment numbers grow in orders of magnitude relative to the small number of pilot projects, it becomes increasingly important to transition to overall policy environments that streamline institutional processes to facilitate project development.[14]

2.4. POLICY FRAMEWORK PHASE

This third and final phase refers to the kind of policy interventions that will be required for renewable energy technologies that are at or below the LCOE of conventional alternatives. **Fundamentally, this Policy Framework phase aims to maintain the paradigm of renewable energy project investability established in the Policy Support Phase, but is focused on transitioning away from explicit, subsidy-based interventions and toward the establishment of broad framework conditions that enable bankability, while also supporting the growing need for flexibility and the integration of variable supply into electricity markets.**

This Phase may also be characterized by indirect or complementary policies (as opposed to policies that apply to specific RE technologies) that guide the overall development of the power sector (e.g., the pricing of environmental externalities, the scheduled retirement of existing generation assets) and as well as related measures that advance the transition of the power system in a way that is consistent with its anticipated long-term needs (decarbonisation, reduced water use, etc.)

[14] The focus on reducing permitting barriers and other soft costs certainly increases as deployment scales-up, but nevertheless might be considered a policy priority at all stages, and for all technologies. As such, it can be also be considered part of the "Policy Bedrock."

The evolution beyond Policy Support for highly scalable, variable renewable energy technologies like solar PV and wind power is in many respects unchartered territory, requiring thoughtful approaches. In order to address this, Section 3 outlines a taxonomy for understanding the Policy Framework phase and organizes the various approaches according to three key pillars: Bankability, Flexibility, and Low-carbon Transformation. Section 3 will also identify specific stepping stone policies that can serve to help jurisdictions to transition toward this Policy Framework Phase. These stepping stones will be gathered together and presented as a broad "menu" or constellation of policy options.

3. KEY PILLARS OF THE POLICY FRAMEWORK PHASE

In the Policy Framework Phase, the objective of renewable energy policy is no longer primarily to bridge the cost gap between renewable energy technologies and conventional generation technologies, as pointed out previously, but becomes more about **creating an appropriate policy environment that supports a continued scale-up of investment in the sector**.[15] It is this last phase that is the focus of this section.

At the most basic level, in order to evolve toward power systems with increasing share of renewable energy technologies and to meet global climate commitments, future power systems in most[16] jurisdictions will need to share the following key pillars:

BANKABILITY (Section 4)	FLEXIBILITY (Section 5)	LONG-TERM VISION (Section 6)
Maintain the bankability of new investments in renewable energy technologies	Enhance the overall flexibility of the power system, specifically in order to adapt to growing shares of variable renewables	Establish a long-term vision for a clean, sustainable power sector

- **Bankability:** In order to ensure continued investment in renewable energy technologies, investments in new power projects must remain bankable. This means that investors (both traditional lenders and equity providers) must be able to have a high level of confidence that any investments made will be recovered within a reasonable timeframe. Failure to maintain conditions that enable project-specific bankability is likely (in most cases) to lead to a freeze in investments and to cause jurisdictions to fall short of their own near-term and long-term objectives. Thus, **maintaining bankability is critical. This remains the case across all power market types,** regardless of whether they are fully monopolized, single buyer or vertically integrated, with wholesale competition only, or with full retail and wholesale competition.

  However, in order to focus on the most common market types around the world and make the key messages clearer to policymakers, this study focuses primarily on two of these market types:

  1. Traditional single buyer markets, and
  2. Power markets with wholesale market competition (sometimes referred to as liberalized or "deregulated" markets).

[15] Note that while scaling up to a power system with high shares of renewable energy will require significant investment in generation, transmission, distribution, as well as in power system digitalization, this report focuses primarily on the need to scale up investments in renewable energy generation as well as the role that renewable energy technologies can play in supporting system flexibility. The regulatory frameworks governing investments in network infrastructure such as transmission and distribution is discussed in greater detail in IEA-RETD RES-E-MARKET, forthcoming.

[16] For some jurisdictions, certain characteristics will be less important than others. For instance, jurisdictions with high shares of flexible renewables (e.g., hydro) such as Norway or the Province of Quebec in Canada will likely need to invest less time and policy effort in securing additional system flexibility, as they already have abundant flexible generation. The relative importance of each of these three pillars will therefore depend on the specific national and even regional conditions in each market.

- **Flexibility:** With regard to flexibility, systems with high and growing shares of wind and solar power are required to develop greater sources of flexibility to improve the alignment of supply and demand, compensate for times of low solar and wind power output, adjust to sudden changes in net load, and improve the integration of higher levels of variability into power system planning and operations (see IEA-RETD 2015b). Similar to bankability, **the increased need for flexibility is present regardless of the individual structure of the power market –** moreover, the need for flexibility becomes more acute as the level of penetration of variable renewables rises, **making it critical to ensure sufficient flexibility is available as electricity markets transition to higher shares of variable renewables**. As such, flexibility is considered here another key pillar of the Policy Framework Phase.
- **Long-term vision:** Finally, with regard to establishing a long-term vision for a clean and sustainable power system, this has become increasingly important in recent decades in order to provide guidance to the growing number of actors and investors in the sector, and to improve long-term investment certainty for low-carbon technologies. Establishing a long-term vision includes a range of related policy objectives and priorities, including the use of renewable energy targets (IRENA, 2015), the phase out of excess generating capacity (Agora Energiewende, 2016), as well as policies to drive decarbonisation (World Bank, 2015) or reduce other negative environmental effects (e.g. air pollution, excess water use). Indeed, as the recent Conference of the Parties in Paris demonstrated, **establishing a clear vision for a more sustainable and lower-carbon future has become a near-universal policy priority for governments around the world,** spanning the least-developed, middle-income, as well as highly industrialized countries (UNFCCC, 2015). As such, developing such **a clear vision for the power system** is considered here as the third key pillar of the Policy Framework Phase.

While there are many other aspects that characterized this advanced phase of renewable energy policy development, this report proposes that **these three pillars encompass the three most basic and common characteristics that future power systems will need to share to enable the sustained growth and scale-up of renewables**. Other important challenges such as developing new policies to govern the rise of distributed generation, most notably distributed solar PV, have been addressed extensively in previous IEA-RETD reports including RE-PROSUMERS, RE-COM-PROSUMERS, as well as REMOTE PROSUMERS, and are therefore not discussed at length here.

This section will examine each of these three (3) key pillars. In some cases, there can be trade-offs between the pillars: for instance, if policymakers intend to expose renewable energy producers to wholesale market prices and away from fixed price contracts covering 100% of a project's output (e.g. FITs) in order to improve flexibility, this can negatively impact revenue certainty and increase the cost of capital. In other cases, however, establishing sound policies within different pillars can exhibit synergies, as when robust, long-term carbon policies improve the overall competitiveness of renewable energy technologies. **Finding nationally appropriate policy frameworks is a critical part of maintaining the continued scale-up of renewable energy technologies**.

Beneath the three key pillars of the Policy Framework Phase is the "**Policy Bedrock**" containing the foundational elements of electricity policy that are present in all three Policy Phases as described in Section 2.

The subsequent section will provide additional discussion around the three pillars of the Policy Framework Phase. Furthermore, it will highlight individual policy solutions within each of the three pillars. The policy solutions are not comprehensive but should be understood as potential stepping stones to be considered in the transition toward the *Policy Framework Phase*. Figure 3.1 graphically depicts this concept.

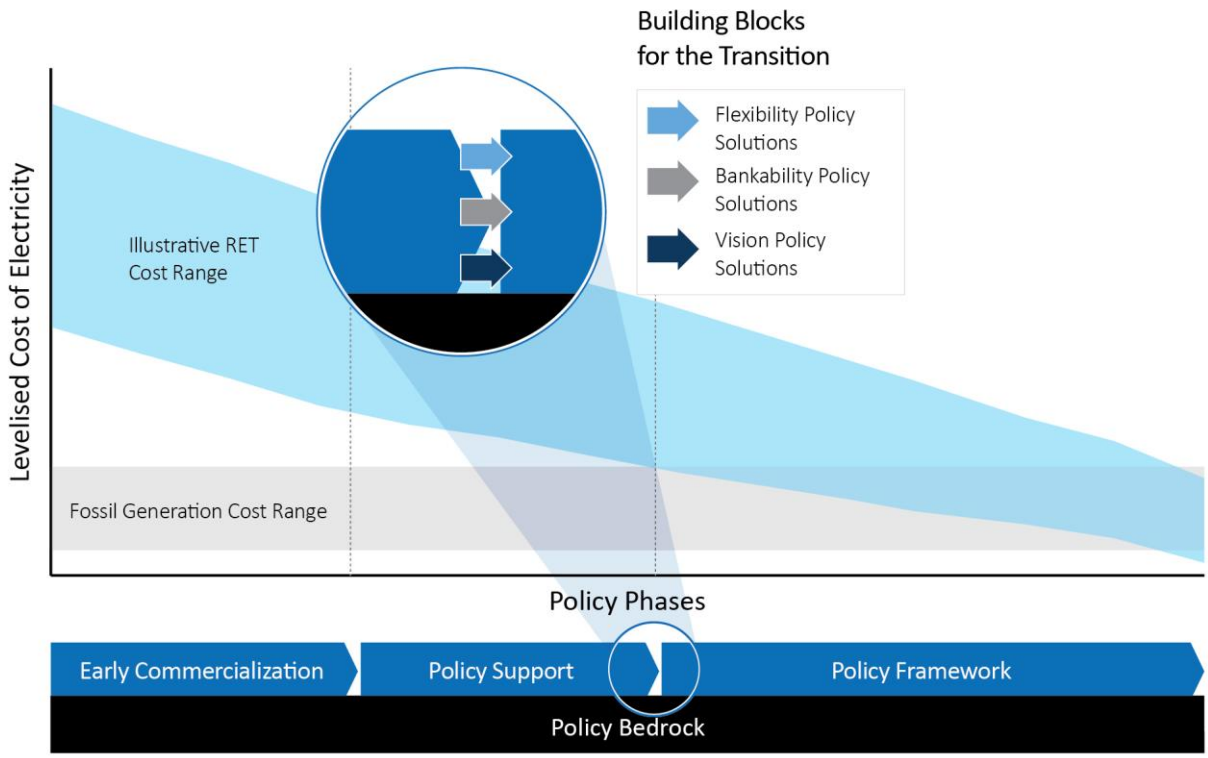

Figure 3.1. Key Pillars of the Transition to the Policy Framework Phase

The various policy solutions used to illustrate the Policy Framework Phase are introduced briefly at the end of each of the next three sections (Section 4, Section 5, and Section 6) and then examined in greater detail in the Appendix of the report.

4. MAINTAINING THE BANKABILITY OF RENEWABLE ENERGY PROJECTS

4.1. DESCRIPTION OF CHALLENGE

According to recent estimates, jurisdictions around the world will need to mobilize approximately $500 Billion per year in investments in renewable energy technologies by 2020, and up to $1 Trillion per year by 2030, in order to transition to a cleaner and more sustainable energy system worldwide (see IEA-RETD, 2011, IEA 2015). Thus, in order to advance to a more sustainable, decarbonized energy system, jurisdictions around the world will need to ensure that investments in renewable energy projects and other related infrastructure (e.g., demand response technologies, storage, transmission and distribution lines) remain bankable. Consequently, this section will discuss not only what is needed to maintain bankability at the individual project level, but also what is needed to ensure a sustained scale-up across an entire jurisdiction or region.

Textbox 4.1: What is Bankability?

In this study, bankable projects refers to investment opportunities that provide a sufficiently attractive risk/return profile to justify investment based on prevailing economic, policy and market conditions (e.g., prevailing interest rates, availability of other comparable investment opportunities). Thus, in order for a project to be deemed bankable, the overall policy and regulatory conditions governing it should also be seen to be sufficiently stable to ensure investors that the investment will be recovered over a reasonable timeframe (i.e. within 4-10 years).

However, what is deemed bankable differs by investor type, based on, *inter alia* their respective risk tolerance and their familiarity with the market:

Bank or traditional lender. Focus is more likely to be on the stability of future cash flows and the ability of the project to meet its debt service requirements;

Private equity investor. Focus is more likely on the actual equity return of the project, as well as the presence of associated factors such as tax incentives or the ability of the project to increase portfolio diversification;

Corporate investor. interested in investing “on balance sheet” (i.e. with their own funds), where the concerns are more likely to be focused on the project’s internal rate of return, how this particular return compares to other investment opportunities, as well as what kinds of related benefits (e.g. branding, visibility, diversification) a particular investment might bring.

Cooperative investor. Interested in obtaining a financial return, but may have lower return expectations and put a greater value on other aspects of the project such as community economic development, or citizen engagement.

Individual investor. Interested in a financial return, but like the cooperative investor, may have lower return expectations and may be motivated by a range of other non-financial factors (see IEA-RETD 2014).

Despite the growing awareness of the importance of maintaining bankability in renewable energy markets (Waissbein et al., 2013; Hampl et al., 2011; Glemarec et al., 2012; Zinaman et al., 2015), a number of policy and regulatory changes in key markets such as Spain and the UK have stunted renewable energy development. As highlighted at the outset, this scale-back of policy support has created significant turmoil and uncertainty for investors, leading to a notable deceleration of market growth (Bayar, 2015; Gurdin, 2015; Couture, 2011; del Rio and Mir-Artigues, 2014).

This kind of policy instability poses a direct and material risk for the continued scale-up of renewable energy technologies, and is precisely what policymakers should try to avoid in the Policy Framework Phase in order to ensure continued investment to meet long-term energy objectives.

Somewhat counter intuitively, the various changes that have occurred in these markets have been introduced precisely at the time when scalable technologies like solar PV and wind have become one of the most cost-competitive options for new electricity supply. This suggests that **even for technologies that are mature from a cost perspective (i.e., are lower than the LCOE of conventional alternatives), certain enabling conditions remain important in order to ensure a continued scale-up in investments.**

In response to this inconsistency, this section seeks to shed light on what remains necessary in order to maintain the bankability of renewable energy projects for technologies that are below the cost of conventional new-build alternatives. Framed as a question, policymakers may ask:

- **what policy and regulatory conditions are still needed (and therefore still appropriate) to sustain investments in renewable energy technologies once they have become cost-competitive?**
- Alternatively, **which risks become less important** as the costs of renewable energy technologies decline, **and which risks persist, or even become more important**?

For policymakers, the need to maintain robust and diverse markets for renewable energy investment translates into a clear need to ensure that renewable energy projects remain attractive (and continue to be deemed bankable) by a wide range of different investor types; this is likely to remain critical in order to ensure that the scale of capital investment flowing to the sector matches the level of scale-up required. Maintaining broad and diverse participation in RE investment is also likely to play an important role in reducing the total costs to society, and to ratepayers, by keeping overall financing costs low. This is one of the core reasons why **preserving long-term policy and regulatory stability is considered a cornerstone of successful renewable energy policies, and a defining feature of the Policy Framework Phase**.

4.2. UNDERSTANDING RISK

Managing risk is a key consideration underpinning all renewable energy investments worldwide, regardless of geographic region, institutional structure, degree of cost-competitiveness, or market type. When assessing a potential project, investors attempt to canvas the full range of risks that could negatively impact a project over the course of its life. These risks can occur at the permitting, site selection, or construction phases, as well as later in the project's operating life due to changes in exchange rates (currency risk), or in regulatory conditions (regulatory risk). Carefully assessing risks is particularly critical in renewable energy finance as the majority of the total project costs are borne upfront (see Section 4.1). As such, any unexpected changes in a project's ability to repay its debts, pay for operations and maintenance, or return cash to investors or shareholders can push a project into technical default, thereby increasing the risk profile of similar projects in the future. Maintaining an environment conducive to bankability over the course of a project's life is therefore critical to ensuring a sustained scale-up in investment.

Table 4.1 provides an overview of the key investment risks that investors face when investing in renewable energy projects.[17] **Note that the table below focuses on risks relevant to renewable energy finance; as such, it is not exhaustive.**

Table 4.1. Key Investment Risks for Renewable Energy Projects

Key Investment Risks	Brief Description
Offtaker risk (Counterparty risk)	Refers to the risk that the offtaker (i.e. utility) purchasing the power does not fulfil its obligations, fails to pay on time, defaults. In the electricity sector, this risk is also often referred to as "counterparty risk".
Curtailment risk	Refers to the risk that the power output will be curtailed unexpectedly and therefore fail to be fully remunerated. This is directly related to "revenue risk" (see below).
Revenue Risk	Refers to the risk that project cash flows will be negatively affected over the course of the project's life due to any of a range of factors, including changes to the power purchase price (or tariff), or to the project's output. This is closely related to what is sometimes simply called "tariff risk".
Currency risk	Refers to the risk that the currency in which remuneration is made depreciates significantly, thereby eroding the real value of revenues earned. This risk is also often referred to as "exchange rate risk".
Market Risk	Refers to the risk that changes in market circumstances will negatively impact a project's revenues, competitive positioning, or access to the market.
Macroeconomic Risk	Refers to the risk that significant economic shocks or changes negatively impact the profitability of a given power project, such as runaway inflation. This risk is also often referred to simply as "economic risk".
Political/Regulatory Risk	Refers to the risk that the political or regulatory conditions deteriorate and negatively impact the operations of a given project or the regulatory conditions that govern it (retroactive policy changes, international sanctions). In certain contexts, this is also referred to as "geopolitical risk".
Grid Access Risk	Refers to the risk that investors either fail to gain access to the grid, or fail to do so in a timely manner. In other contexts, this could be considered a part of "market risk", as it relates to the ability of investors to gain access to the market in order to sell their product.
Technology Risk	Refers to the risk that the particular technology chosen fails to perform as expected. This is particularly important in the Early Commercialization Phase, and becomes less important as renewable energy technologies improve over time.
Project Risk	Refers to the risk inherent to a particular project, such as site selection, construction-related delays, as well as the risk that actual project output is below what resource forecasts suggested. The latter is often referred to as either resource risk, or performance risk.
Social Acceptance Risk	Refers to the risk that the individual project will fail to obtain (or maintain) the social license to operate. Failure to maintain social acceptance for a project can directly contribute to a project's failure.

Source: Authors

[17] It is possible to subdivide these risks in various ways, and different reports use different terms to refer to the same underlying risks. For instance, certain terms are occasionally used interchangeably, such as construction risk and completion risk, both of which refer to the risk of completing the project on time, and on budget.

A key principle of risk management is that risks should ideally be transferred to the party (or parties) best able to manage them (Gatti, 2008). In practice this means that investors typically attempt to offload risks that they have little or no ability to control, or mitigate, such as risks of extreme weather events (force majeure risk) or major geopolitical disruptions (geopolitical risk). The latter risks are often transferred to insurance companies, as no individual investor or counterparty (e.g. the engineering, procurement, and construction company, or EPC) is able to assume and adequately hedge these risks. Similarly, there are certain risks that government policymakers have little control over and are traditionally left with private actors, such as project risk or construction risk.

As Table 4.1 shows, there is a wide range of risks impacting renewable energy finance. Investors and project developers rely on three primary solutions in order to mitigate risk (Gatti, 2008):

1. Retain the risk and attempt to mitigate it internally;
2. Transfer the risk by allocating it to another party;
3. Transfer the risk to an entity whose core business is risk management (e.g. an insurance company)

From the standpoint of a policymaker, reducing or eliminating unnecessary risks can be done through policy design; **one of the key challenges for policymakers is therefore risk allocation**. For instance, revenue risk can be mitigated by offering a long-term power purchase agreement, or PPA, that features a clear long-term price; similarly, grid access risk can be mitigated by introducing clear rules governing access to the network, including (as has been done at the EU level for renewable energy technologies) priority grid access for certain technologies (Fouquet and Nysten, 2014); market risk can be mitigated or even eliminated by offering a purchase guarantee for all output produced.

Risk related to Renewables' High Share of Fixed vs. Variable Costs. One of the main reasons for the continued need for a Policy Framework that ensures bankability is due to the high capital intensity of renewable energy technologies; most of the costs of generation are tied up in upfront capital expenditure, or CAPEX, rather than in operating expenditures, or OPEX (see IEA-RETD, 2011). Another way to put this is that the majority of project costs are fixed, as opposed to variable.[18] In order to illustrate this, Figure *4.1* provides an overview of the share of fixed and variable costs for a range of generation technologies:

[18] Note that CAPEX and OPEX are not the same as fixed and variable costs, as some share of OPEX is typically considered fixed.

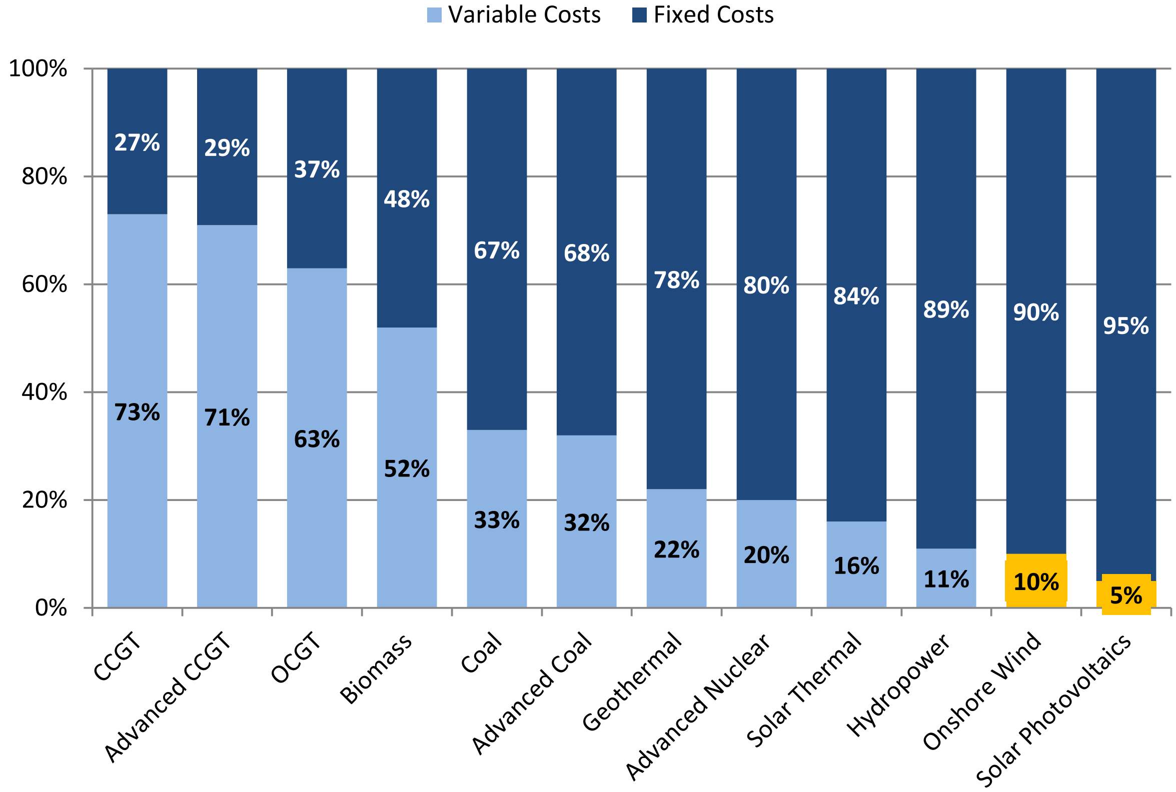

Figure 4.1. Fixed vs. Variable Costs as a Share of the Levelised Cost of Electricity in the U.S. in 2013 (Adapted from: EIA, 2013)

From a financing perspective, the implication of the above is clear: once a wind or solar project is built, lenders and investors are largely if not wholly reliant on the prevailing and future policy and regulatory environment to recover their costs, as the bulk of these costs are fixed; this **arguably makes renewable energy technologies more reliant on policy and regulatory stability than fossil-fuel based investments,** as the latter can ramp their output (and hence, their variable operating costs) up and down as market circumstances change.

In the absence of a relatively high level of certainty over future cash flows, investors in renewable energy projects, particularly traditional lenders like banks, which provide the majority of total renewable energy project financing worldwide (Frankfurt School of Finance & Management, UNEP/BNEF 2015), are much less likely to put capital at risk. Since traditional lenders are likely to continue to be needed to invest in the broader transformation of the power system in the years and decades ahead, **maintaining policy and regulatory conditions that are conducive to keeping lenders at the table is critical**. If fewer lenders are interested in allocating capital to the sector, the total investor pool shrinks and the cost of capital tends to increase as a result. As pointed out previously, higher financing costs ultimately decrease the relative cost-competitiveness of renewable energy technologies and increase the final costs to ratepayers (Fabra et al. 2014; Glemarec et al. 2012).

Since government policy in the field of renewable energy typically exerts a greater and more direct influence on a few of the key investment risks highlighted above such as offtaker risk, curtailment risk, and revenue risk, the remainder of Section 4 will focus primarily on these key risks.

4.3. BANKABILITY UNDER DIFFERENT ELECTRICITY MARKET STRUCTURES

When considering what is needed to maintain the bankability of renewable energy projects in electricity markets around the world, it is important to distinguish between different electricity market types, as what is needed to achieve bankability in each of these market types differs. While there is no universal typology for categorizing electricity markets and most markets fall somewhere along the spectrum from fully monopolized to fully liberalized, they can be broken down into three (3) broad types: single buyer markets, and markets with wholesale and/or retail competition, and fully monopolistic markets.[19] Table 4.2 provides a brief definition of each market type.

Table 4.2. Definition of Different Electricity Market Types[20]

Electricity Market Type	Brief Description
1. Single Buyer Market (e.g. South Africa, Turkey, Brazil, Nepal)	Under single buyer markets, there is competition between generators (such as during auction processes) but all generators are required to sell their power to one buyer. This single buyer is often (though not always) either government-owned or government-backed. Individual electricity consumers are typically not given the right to choose their power supplier (with the occasional exception of large power consumers), as the single buyer typically retains a monopoly over serving final customers.
2. Market with either Wholesale Competition and/or Retail Competition (e.g. Germany, Netherlands, UK, Parts of the U.S.)	Under wholesale competition, there is a competitive market framework that enables different generators to compete with one another in order to serve final electricity demand. Under this model, generators are typically private companies, rather than government-owned entities. Under full wholesale and retail competition, there is a competitive framework for both wholesale market transactions as well as a framework allowing retail customers to choose their supplier.
3. Fully Monopolized Market (e.g. Namibia, Paraguay, Libya)	Under monopolized markets, all aspects of generation, transmission, and distribution are controlled by one entity. This entity is often (though not always) government-owned or government-backed. There is no competition between generators, and customers have no choice regarding their electricity supplier. This model is sometimes referred to as “vertically integrated”. Due to the fact that investments in the first type listed above, the fully monopolized market, are by definition undertaken by the monopolist, or the vertically integrated utility, the bankability of projects in such markets is more a function of the utility’s ability to recover any additional costs from ratepayers, as well as the utility’s overall credit rating, and leverage. Since this report is focused on the Policy Frameworks governing private investment in renewable energy projects, monopolized markets will not be further considered in the following.

[19] Rather than use terms like “deregulated” or “restructured”, which may mean different things to different readers and are often imprecisely defined, this report has opted for descriptive terms instead. For more in-depth analysis of different electricity market types, see Vagliasindi and Besant-Jones, 2013.

[20] Note that these market types do not represent absolute categories and that most jurisdictions feature electricity markets that exhibit hybrid characteristics. See Gratwick and Eberhard, 2008; Vagliasindi and Besant-Jones, 2013.

One of the insights that flows from a more detailed analysis of such risks is that renewable energy policy cannot be considered in a vacuum: the surrounding economic and political environment plays a significant role, and can also directly impact the ability of renewable energy technologies to scale. This suggests that in many markets, **systematic de-risking is needed both at the individual project level as well as at the country level**, which in some cases may include a range of related economic, political and/or institutional reforms that are outside the realm of energy policy. This is especially crucial in a developing country market context.

4.3.1. The Challenge of Maintaining Bankability in Single Buyer Markets

Under single buyer markets, generators typically receive a long-term contract for their power output, one that provides sufficient revenues to recover the full costs of the project plus a return to investors. This kind of long-term, contract-based financing has been (and indeed remains in many jurisdictions) at the heart of most generation investments in the electricity sector worldwide. At its core, a **long-term contract is simply one way of bridging ratepayers' desire for long-term price stability and a utility's short- or medium-term need for electricity to serve its customers**: by doing so, the long-term contract helps make a particular generation investment bankable, while helping keep rates stable for electricity consumers in the long-term.

In single buyer markets such as Brazil, South Africa, and Nepal, independent power producers are typically not allowed to sell to any entity other than the central buyer, i.e. the utility. In such markets, **bankability is likely for the foreseeable future to continue to rely on securing long-term off-take agreements with the single buyer** either for energy, capacity, ancillary services, or for a combination of these services. As such, bankability within single buyer markets is likely to continue to rely strongly on the overall **creditworthiness of the offtaker**, including the regularity and timeliness of payment, the extent of the offtaker's leverage, its ability to service its debts, and its continued ability to cover its overall costs of service by raising rates or improving efficiencies.

Thus, even where there is a willing offtaker who is prepared to sign a long-term contract, additional policy measures may be needed, particularly if the underlying solvency of the utility or offtaker is in question. In such cases, it is common for governments to offer partial or full **credit guarantees** on loans issued to finance the project, or to provide a government guarantee on the power purchase agreement itself to protect investors against the risk that the utility or offtaker is unable to fulfil their obligations (see Section 4.4 below) (Waissbein et al. 2013). **Government guarantees on the offtaker agreements** can also be used to ensure that the various contractual agreements that have been signed are honoured in the event that there is future upheaval or disruption in the sector, the region, or in the global economy (such as significant changes to interest rates, or significant fluctuations in currency markets). Such government guarantees are already either implicitly or explicitly present in a large number of single buyer markets around the world, and are likely to remain important in many jurisdictions even if renewable energy technologies become by far the least-cost options for securing new electricity supply.

Similarly, **inflation indexation** is likely to remain important in most emerging country single buyer markets, even if renewable energy technologies like solar PV and wind power decline further in price to USD $0.02 – 0.04 cents per kWh, as any prospective project investors (whether domestic or international) are likely to continue to need protection against rapid inflation and the range of downside economic and revenue risks associated with it.[21]

In addition, the need for **concessional loans** in order to compensate for other risks that exist within the markets such as economic, regulatory, or political risks may remain. Put differently, even if electricity demand growth remains strong and renewable energy technologies remain the cheapest source of supply in single buyer markets around the world, significant regulatory, political, macro-economic, or currency instability may be sufficient to undermine bankability and prevent renewable energy deployment from scaling-up. **It is arguably these broader "systemic" risks that threaten to impede the scale-up of renewable energy technologies in such markets more than any particular gap in the policy or regulatory framework.** Despite the fact that renewables are increasingly the least-cost solution for new deployment, many of the existing framework conditions that support RE investment will likely need to remain in place in order to *further* de-risk investments.

However, while long-term contracts may remain the norm in single buyer markets, the growing need for flexibility is likely to translate into certain changes in the structure of long-term off-take agreements. **Policymakers in single buyer markets may begin to introduce PPAs with special clauses to increase flexibility, including introducing various levels of price and market risk targeted at different investor types, as well as different renewable energy technologies**. For example, developers of hydropower projects could be rewarded for increasing their ability to provide flexibility (i.e. to ramp output up and down) by introducing time-of-day or even seasonally differentiated tariff schedules within PPAs; the same could apply for PPAs offered to other dispatchable renewable energy technologies that often have a higher share of equity in the capital structure, such as biomass. Similarly, policymakers could establish different PPA types, including a standard fixed-price agreement for more risk averse investors (or less dispatchable technologies), as well as PPAs with more complex and variable pricing structures for investors willing to take on more market and revenue risk.

In order to put the various risks that projects in single buyer markets face, Table 4.3 provides an overview of the key risks in single buyer markets and provides a brief overview of how these various risks can be mitigated. Note that many of these risks apply to all electricity market types, rather than strictly to single buyer markets.

[21] In most cases (particularly in emerging markets) the price included in the contract is indexed in some way to inflation, or adjusted further to cover the currency risk, neither of which private investors or lenders can meaningfully influence. When governments included such inflation adjustment clauses or currency indexation mechanisms, they are in effect transferring the risks in such a way as to encourage investment, leaving the risks with the counterparties best able to manage them.

Table 4.3. Policy Options to Mitigate Investment Risks in Single Buyer Markets[22]

Key Investment Risks	Potential Policy Options to Mitigate these Risks in Single Buyer Markets	Potential New Features
Offtaker risk **(Counterparty risk)**	• Government guarantees on the off-take agreements (i.e. PPAs) • Partial or full credit guarantees to help secure project debt	• Offer various types of PPAs, including low risk and higher risk options for different investor types, and/or different technologies
Curtailment risk	• Clear rules governing curtailment and dispatch, including upper limits on allowable curtailment or compensation for excessive curtailed	• **Retirement of excess generation capacity** (see Section 6.2.2) • Reduction of must-run hours of conventional plants • Expand procurement of demand response to better match demand to supply
Revenue Risk	• Clear, cost-based tariffs • Robust protocols to ensure timely payment (e.g. escrow accounts)	• Move to **energy and capacity payments** (see Section 9.1.3) • Allow renewable energy producers to be remunerated for ancillary services (see Section 9.1.5)
Currency risk	• Currency indexation • Tariffs denominated in foreign rather than local currency	• Introduce PPAs denominated in both local and foreign currencies to target different investor types/preferences
Market Risk	• Provide full or partial purchase guarantees for renewable energy producers • Ensure priority dispatch for renewable energy producers	• Introduce **binding renewable energy targets** (see Section 9.3.1)
Macroeconomic Risk	• Provide government guarantees on the PPAs • Introduce full or partial inflation indexation on power purchase agreements (PPAs)	• Introduce limits on the single buyer's allowable leverage to limit its vulnerability to macroeconomic disruptions
Political / Regulatory Risk	• Avoid retroactive changes to policies and regulations that negatively impact renewable energy project bankability • Adopt long-term renewable energy targets to provide greater investment certainty (see Section 9.3.1)	• Design policies in such a way as to avoid the need for retroactive changes
Grid Access Risk	• Introduce grid priority for renewable energy producers	• Establish clear zones where grid access can be efficiently managed for new renewable energy projects

[22] In contrast to Table 4.2,
Table 4.3 does not include a row for technology, project, or social acceptance risk, as these are mostly private project management issues that the project sponsors or the Engineering, Procurement, and Construction (EPC) team normally are responsible for. This is not to suggest that policymakers have no role or influence on the ways in which these risks can be mitigated, only that their role is less direct than in the other risks listed here.

Looking ahead at what the Policy Framework Phase might look like for many of the large, single buyer markets around the world such as South Africa, Turkey, Nepal, and Brazil, the transition to a power system with a greater share of renewables may simply involve continuing or expanding upon existing policies and procedures, including providing standard long-term contracts for power output, implementing clear rules governing around curtailment, dispatch, and settlement, as well as ensuring open grid access (FERC, 2015; Bird et al., 2014). It may also involve simultaneously ensuring that measures are taken to secure adequate levels of flexibility (including flexibility from the demand side, such as via real-time demand response) and that efforts are taken to strengthen the credit-worthiness of the offtaker in order to reduce counterparty risk. In addition, it is likely to remain critical that single buyer markets adopt or strengthen their long-term renewable energy targets, in order to provide clear long-term signals to investors about the overall evolution of the sector (Kieffer and Couture 2015). This is described in greater detail in Section 6 as part of establishing a clear long-term vision.

4.3.2. The Challenges of Maintaining Bankability in Jurisdictions with Wholesale Markets

Since their rise in the 1970s, renewable energy technologies like wind and solar PV have been trying to get a foothold in electricity markets primarily designed for large, centralized fossil or nuclear plants. This history defines many of the key constraints, and shapes many of the emerging opportunities, facing renewable energy technologies. Arguably nowhere are these constraints and opportunities more forcefully present than in the liberalized electricity markets found in parts of the U.S. and the EU, as well as in other jurisdictions, such as Mexico and Chile.

The move from single buyer markets to markets based on wholesale competition has brought forth fundamental changes in electricity markets and finance. The shift toward competitive wholesale markets has meant the gradual removal of administratively set long-term contracts. Instead, electricity is traded based on anonymous bids from all power producers above a certain size operating within a given market area. This notwithstanding, market participants often have alternative ways of contracting and marketing their power, including bilateral deals (e.g. over-the-counter contracts, which enable contract terms to be customized to the needs of both parties), capacity payments, as well as alternative means of securing financing, such as hedging contracts.[23] Financing power generation projects without long-term contracts has not proved to be a simple matter.

[23] Note that in many competitive markets, utilities can still opt to sign long-term contracts for power with project developers and then sell their output either directly on the market in real-time, or via further bilateral, day-ahead, or forward contracts. See: See "Coal-Heavy Texas Merchant Generator Signs PPA with SunEdison," Katherine Tweed, Greentech Media, last modified September 09, 201, accessed February 9, 2016. http://www.greentechmedia.com/articles/read/Coal-Heavy-Texas-Merchant-Generator-Signs-PPA-With-SunEdison. In other words, a form of private "single buyer market" can co-exist inside a jurisdiction with competitive wholesale markets.

As Fitch, the global financial ratings company, noted in 1997 in relation to the risks of investing in power generation projects (both conventional and renewable) on a "merchant" basis[24] in newly liberalized markets in the U.S., "*the absence of long-term purchased power agreements, previously the norm for independent power project transactions, plus the high degree of price volatility associated with short-term energy sales, will likely result in non-investment-grade ratings for most merchant projects.*" (Fitch, 1997). While investors and project developers have found various innovative ways of adapting to the new competitive landscape, experience since the 1990s has largely confirmed that financing power generation projects (and in particular renewable energy projects) on the basis of wholesale market prices alone poses a number of critical challenges:

- Wholesale market prices are volatile, making it difficult for investors to forecast future cash flows (Rader and Short, 1998; PJM, 2015);
- In most jurisdictions with wholesale markets, prices are either flat or declining, undermining the business case for investing in new supply (Piria ed., 2013);[25]
- The growing share of near-zero marginal cost supply, notably from variable, weather-dependent renewables has helped suppress wholesale market prices. This is due in part to the merit-order effect (Sensfuß, Ragwitz et al., 2008; Bode and Groscurth, 2010; Ray, Munksgaard et al., 2010; Felder, 2011; Ciarreta, Espinosa et al., 2014), which has led to a cannibalization of revenues as wholesale market prices decline during times when variable renewable energy projects are producing the most (see IEA-RETD RES-E-MARKET);
- Without the traditional purchase guarantee often provided under long-term contracts, market participants have faced growing curtailment risk as well as the risk of negative prices during times of over-supply, which can significantly impact future cash flows and overall project viability.
- In addition, some jurisdictions levy so-called "energy imbalance payments" to penalize generators for forecasting errors (IEA-RETD 2015b); these payments tend to disproportionately penalize variable, weather-dependent generators such as solar PV and wind plants.

As these various challenges underscore, in the absence of a supportive policy environment, transitioning to electricity markets with growing shares of wind and solar power is fraught with risks (Rader and Short 1998). Although select renewable energy projects may remain bankable and continue to find backing from investors, the institutional and financing environment for investing in renewable energy technologies in jurisdictions with wholesale markets significantly increases a range of investment risks, making it difficult to achieve the kind of scale-up required to drive a sustained transformation in the overall electricity supply mix. A key part of this is related to the withdrawal of administratively set long-term contracts, which have long provided the basis for project bankability within single buyer markets.

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[24] Such projects are typically referred to as «merchant » projects, as they rely on wholesale market prices rather than long-term contracts for their power output; as a result, they face far higher risks, which translates to significantly higher costs of capital.

[25] This is due to a combination of factors including existing overcapacity in the system, a growing share of variable renewable energy supply, flat or declining electricity demand, and low (or no) carbon prices. Taken together, these factors undermine the investment case for investing in new supply.

Textbox 4.2: Pros and Cons of Withdrawing from Administratively-set Long-Term Contracts

From a financial perspective, there is a range of negative consequences associated with the withdrawal of administratively backed long-term contracts, such as feed-in tariffs and standard power purchase agreements: **first**, financing an individual project becomes considerably more complex; **second**, this financing often involves a greater number of intermediaries; it can introduce significant additional transaction costs; **third**, the higher revenue risks increase the cost of capital, which in turn makes projects costlier for ratepayers, who effectively are left to pay for the consequences of a riskier investment environment. Taken together, these various factors are likely to have a number of negative effects on the ability of projects to secure long-term debt (Piria ed., 2013). **Fourth**, if traditional lenders are less interested in investing, this leaves electricity markets with fewer banks competing to provide financing to the sector, which in turn tends to further increase the cost of capital (PJM, 2015).

Finally, another important downside of relying too heavily on wholesale electricity markets is that new capacity must often compete with already amortized assets making it difficult to build a bankable business case, a factor that can lead to underinvestment in the medium- to long-term. Left uncorrected, prolonged underinvestment can pose a threat to system reliability, while jeopardizing the ability of jurisdictions to meet both their energy and climate-related targets.

At the same time, there are clear gains that result from moving away from fixed, long-term contracts and requiring more power to be traded on wholesale markets: **first**, liquid wholesale markets can enable a greater number of generation plants to be efficiently coordinated, a benefit that is arguably even more important when integrating a large number of distributed resources, and in particular variable renewable resources. As a recent IEA report points out, agreeing on dispatch and exchange schedules that change every hour or every 15 minutes would be almost impossible without open and transparent electricity markets (IEA 2016). **Second**, allowing power to be traded dynamically in real-time as well as in other short-term markets such as day-ahead contracts can significantly reduce congestion and improve the overall efficiency of power system operations (IEA 2016).

Third, by adopting larger and more integrated balancing areas that span the territory of multiple previously vertically integrated utilities, it becomes easier for system operators to smooth the variable output of renewables, making it more cost-effective for individual jurisdictions to reach higher shares of variable renewables. For instance, larger balancing areas can help reduce the occurrence of curtailment, while reducing the overall need for storage, as well as for emergency or back-up supply. **Fourth**, having a competitive wholesale market can also lead to significant improvements in the efficiency of power plant utilization and lead to a better overall allocation of transmission investments by providing clearer locational signals regarding where new investments are needed.

Finally, under competitive wholesale markets, price signals can encourage uneconomic plants to be retired, thereby helping to reduce excess capacity in the system, as has already been occurring across the EU. An estimated 20GW of conventional fossil-fuelled capacity was retired throughout Europe in 2012/13 (Tweed, 2014), and it is estimated that the EU as a whole has a further 60GW of excess generation capacity that will need to be retired in the years ahead (BMWi, 2015a). This would be far more difficult outcome to achieve if all generation plants had long-term contracts for their output. In this way, open and competitive electricity markets can help prevent vertically integrated monopolies from shielding their assets from a more fundamental transition in the power mix, by forcing generation assets to compete in the marketplace and removing utilities' ability to pass on the costs of imprudent investments to ratepayers or taxpayers (IEA, 2016).

Thus, while the withdrawal of administratively established long-term contracts has a number of negative effects on the *financing* of new generation assets (and in particular, on technologies with high shares of fixed costs), the move toward wholesale markets for the physical trading of electricity brings a number of real and quantifiable benefits. As such, wholesale markets are likely to play an increasingly important role in many jurisdictions' ability to achieve high shares of renewables by enabling the supply of thousands if not millions of individual projects to

Textbox 4.2: Pros and Cons of Withdrawing from Administratively-set Long-Term Contracts

be coordinated efficiently, while enabling the variability of wind and solar to be better balanced and integrated. **The challenge for policymakers is therefore to find ways to harness the many benefits of wholesale markets in improving the efficiency of the *physical* side of the market without simultaneously undermining bankability on the *financial* side of the market.**

Within jurisdictions with wholesale markets, there is also less long-term certainty over what the future rules and market protocols will be, arguably resulting in higher **regulatory risk**, as these rules themselves are constantly changing, both due to the actions of policymakers, as well as due to the actions of the various electricity trading platforms that mediate wholesale market transactions. For instance, the adoption of new rules governing gate closing times, the formation of forward contracts, day-ahead contracts, as well as the introduction of any other new power market products (such as capacity markets) can have a significant impact on the ability of investors to plan future investments as well as reliably forecast their future cash flows from existing projects (Piria et al. 2013).

A further challenge is related to the cannibalization effect described earlier (see Textbox 1.1 or Section 1.2.3) whereby renewable energy technologies like wind and solar contribute to depressing wholesale market prices across a given region when the sun shines, or the wind blows. Combined with other factors such as excess capacity in the system, and low or non-existent carbon prices, the cannibalization effect creates an environment of low average wholesale market prices, which in many jurisdictions are now insufficient to finance new generation capacity. This is frequently referred to as the "Missing Money Problem" (see Textbox 4.3 below).

Textbox 4.3: What is the Missing Money Problem?

Most power generation technologies (with the exception of natural gas plants) have high fixed costs and low variable (and therefore low *marginal*) costs. And yet, in many liberalized electricity markets, current wholesale market prices are near historic lows due to a combination of factors, including overcapacity, flat or decreasing demand, and low carbon pricing. Taken together, these factors make it difficult for project owners and investors to recover their fixed and operating costs on the basis of wholesale market prices alone. In other words, **although revenues in liberalized markets are based on marginal costs, investors must recover both their *fixed* as well as their marginal costs**. This gives rise to the "Missing Money Problem", which refers to the gap in revenues between what wholesale market prices are providing and what investors in power generation need in order to make their investments bankable. As jurisdictions around the world strive to significantly increase the share of renewable energy in the electricity mix, this is likely to further increase the overall capital intensity of the system, as the share of variable (i.e. fuel) costs in total system costs continues to decline – on the basis of current trends, this is likely to make the Missing Money Problem worse.

Two main solutions have been proposed to address the Missing Money Problem: First, ensuring more robust **scarcity pricing** would see wholesale market prices spike higher and more frequently, and therefore allow power producers to bid above their marginal costs. Increasing the frequency of scarcity pricing can be achieved either by phasing out existing baseload and mid-load capacities in the system, or by removing price caps that are often in place to mitigate the potential negative effects of significant price spikes. Many European countries, including Germany, are currently implementing new market rules in order to re-finance new power generation capacity based on so-called energy-only markets.

The second potential solution is to introduce **forward capacity markets**, which would introduce capacity payments for generators in addition to the revenues they earn from per-kWh sales and the participation in ancillary services

Textbox 4.3: What is the Missing Money Problem?

markets (Milligan, 2015; Cramton et al., 2013). As pointed out above, however, capacity auctions credit wind and solar PV at a fraction of their installed capacity; this means that they are unlikely to significantly improve the bankability of variable renewables like wind and solar PV

It is unclear that either of these solutions represents an adequate solution to the Missing Money Problem: for its part, the belief that scarcity pricing will save the day underestimates at least three important factors: 1) the political challenges of phasing-out existing over-capacities (see Section 6.2.2); 2) the political challenges of lifting price caps; and, perhaps most critically, 3) how rapidly new technologies and business models are likely to respond to any future surge in wholesale market prices (which, in so doing, will tend to suppress them). As such, any high "scarcity" pricing that emerges is likely to quickly be competed away, as the market responds to the temporary surge in prices.

Second, the belief that forward capacity markets could provide adequate and tailored support (particularly for renewable energy technologies) and help them remain bankable is unclear based on their recent performance in markets such as the UK, and the U.S. It is also unclear that they could be designed to help make renewables like wind and solar bankable, as pointed out above. The Missing Money Problem therefore leaves liberalized electricity markets at a crossroads, leading some to call for a more fundamental redesign (Mitchell, 2015; Agora Energiewende, 2013).

Barring a deeper redesign, it is likely that policymakers will need to adopt a wide range of solutions and reforms in order to improve the bankability of renewable energy technologies:

- Phase out non-renewable based over-capacities (see Section 6.2.2)
- Implement more robust and effective carbon pricing (see Section 6.2.3)
- Maintain or introduce some form of floating premium, as adopted in jurisdictions like Germany
- Take measures to make the power system more flexible in order to stabilize market prices
- Improve grid expansion planning in order to avoid curtailment and negative prices
- Increase the integration of the electricity, heating and transport sectors in order to boost electricity demand growth, increase flexibility, and reduce the occurrence of negative prices
- Eliminate price caps in order to make peak pricing more effective at mobilizing new investments in related flexibility, demand response, and even potentially storage technologies.

As Textbox 4.3 illustrates, finding solutions to the "Missing Money Problem" remains a core challenge to achieving bankability for renewable energy projects in the Policy Framework Phase in jurisdictions with wholesale markets.

While renewable energy producers can now tap into additional revenues from participating in ancillary services markets, for instance, these additional revenues are comparatively small (Potomac Economics, 2015). And while there are proposals for a move to capacity-based payments rather than the current "energy-only" paradigm that prevails in the EU and in parts of the U.S. such as Texas' ERCOT[26] region, such proposals have so far yielded mixed results.

[26] ERCOT refers to the Electricity Reliability Council of Texas, the institution that acts as independent system operator for the state.

One notable challenge for variable renewable energy technologies is that capacity auctions typically credit wind and solar PV at a fraction of their installed capacity; furthermore, the capacity value for variable renewable energy generators declines at increasing penetration levels (Denholm and Katz, 2015).

Non-energy related payments rarely exceed 20-30% in liberalized U.S. markets even for highly flexible generation sources such as single cycle gas plants and combustion turbines, which can more easily tap into other revenues from ancillary services markets as well as forward capacity markets than most renewable energy projects (Potomac Economics 2015; Monitoring Analytics 2015).

Bankability for most generation technologies is therefore likely to remain largely dependent on selling electricity, though additional revenues may play a growing role in the years ahead (see below).

Consequently, **as long as project bankability remains primarily reliant on kWh sales, and as long as governments remain committed to transform the power system toward the greater use of renewable energy sources, there is likely to be a continued need to provide some level of regulatory and revenue certainty for renewable energy producers, even if they become (or remain) the least-cost supply sources in the market.**

In order to examine the various possibilities, this section is broken into two different parts: the first part focuses on the emergence of **new contractual arrangements** that are replacing (in part or in full) the traditional long-term contracts offered to renewable energy producers; the second part focuses on the potential for **new revenue streams** to help improve project bankability beyond the revenue streams earned on the wholesale market.

New Contractual Arrangements:

In order to achieve bankability for renewable energy projects within wholesale market environments, and to assure the continuous and rapid growth of renewable energy, there is likely going to be a continued need for off-take contracts of some form. However, investors and developers operating within wholesale market environments are increasingly engaging in shorter-term contractual arrangements (e.g. three to seven years rather than 10-20 years) while also entering into a greater number of contracts in order to make any individual project bankable. This includes day-ahead and forward contracts, contracts-for-differences, as well as innovations like synthetic PPAs (Baker McKenzie 2015, Labrador 2015) (see Appendix 9.1.1).

In addition, investors and project developers are responding by developing a **wider range bilateral, over-the-counter contracts**,[27] as well as a related trend toward the greater use of **innovative hedging products** which are now common in markets like Texas (see Section 9.1.1), as well as in the PJM market, which covers Pennsylvania, New Jersey, and Maryland (PJM, 2015). As recent trends across the U.S. as well as in other jurisdictions around the world such as South Africa, Morocco, and Australia are demonstrating, a growing number of RE projects are beginning to be financed by using bilateral PPAs signed directly with private companies rather than with utilities, which traditionally acted as offtakers (Baker McKenzie 2015).

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[27] "Over-the-counter" contracts refer to contracts that are customized to the unique needs of two parties. As such, they are "non-standard", and differ from the kinds of contracts traded on wholesale markets, such as day-ahead or forward contracts, which are standardized.

In the U.S. (which remains the most active market for private PPAs), an estimated 3.44GW of combined wind and solar PV capacity has been financed in this way in 2015 alone (out of a total of 15.9GW of new installed capacity), and new deals continue to be signed at a steady pace (Labrador 2016). In 2015, non-utility buyers including universities, local governments, and private companies were responsible for roughly a quarter of the 8.6GW of new wind power capacity that came online (Labrador 2016).

Broadly, these private PPAs can be divided into two different categories (Baker McKenzie 2015):

- **Standard PPAs**: typically 10 to 20-year offtake contracts signed for all of a project's output. Standard PPAs involve the actual exchange of electricity between a buyer and a seller (i.e. from a particular project in order to serve a particular load).
- **Synthetic PPAs**: financial instruments that can help create a bankable investment without relying on the actual exchange of electricity. However, like standard PPAs, synthetic PPAs involve a clear price (or price schedule) and a clear duration. There are three main types of synthetic PPAs:
    - **Contracts-for-Differences** (CfDs), which involve setting a strike price for a period of time between two actors. Both actors buy and sell their power on the wholesale market and agree to pay the difference (whether above or below the strike price) to the other counterparty. Like all synthetic PPAs, CfDs do not involve the physical exchange of electricity.
    - **Options contracts**: A "put option" gives the project owner the opportunity to purchase the right (either from a financial institution or a large power consumer) to sell electricity at a given price negotiated ahead of time. If market prices fall below this price, then the project owner can "exercise" their option to sell their electricity at this price; if prices remain higher, the project owner can continue to sell their electricity directly on the exchange.
    - **Commodity Hedges**: Large buyers of electricity may choose to hedge their exposure to fluctuating electricity prices by purchasing financing hedges linked to the price of natural gas, for instance. In this case, if the price of natural gas rises, the buyer of the hedge is protected (i.e. hedged) from the losses caused by higher electricity prices, as the contract is increasingly "in the money" (i.e. generating a positive return) as natural gas prices rise above the agreed-upon hedge price.

In the first quarter of 2015, roughly 75% of all private PPAs signed in the U.S. were synthetic (Baker McKenzie 2015). There are a number of reasons for this preference: synthetic PPAs enable a single entity (such as a large company or corporation) to virtually buy power from one project to serve loads spread across different jurisdictions, rather than signing standard PPAs with several smaller RE projects at each facility. This can save significant amounts of time as well as reduce transaction costs. Also, in some jurisdictions, such as in parts of Australia, RE project owners are required to sell their power on the exchange, making it necessary to use synthetic rather than standard PPAs (Baker McKenzie 2015).

While these innovations are not explicitly or directly the result of government policy (in the sense of being implemented by a particular government agency or ministry), they are playing an increasingly important role in some markets in helping projects achieve bankability.

In the U.S. northeast market of PJM, the share of real-time load that was served with spot market purchases during the first nine (9) months of 2015 was just 29.2%; the share served with bilateral contracts was 11.7%, and the remaining 59% was “self-supplied”, which simply means that utilities purchased their own generation (Monitoring Analytics, 2015).[28] This suggests that for most utilities within the market, it is more economic to continue to self-supply and thereby avoid the various risks of buying and selling on the wholesale market.

These shares have remained approximately the same over the last 5-7 years, and while they differ by market, the trend toward the development of a greater number and variety of contracts remains clear.

Another way in which the financing landscape for RE projects is shifting in jurisdictions with competitive wholesale markets is that new actors such as **aggregators** emerge and large companies with substantial power supply needs become increasingly important, signing off-take agreements with different renewable energy producers to meet their own internal needs as seen above (Staple and Bromaghim, 2014; Labrador, 2016). These new actors, along with large corporates, universities, and public sector institutions, could come to play a transformative role in the evolution of the electricity system, as they effectively provide an alternative pathway to achieving bankability than the one historically provided by government regulation.

As the number and complexity of private contractual arrangements grows, there is likely to be a growing need for government policymakers (particularly at the national and supra-national levels) to establish standards and protocols to ensure that the increasing counterparty complexity does not jeopardize market liquidity, or system reliability. For instance, as the number of bilateral or over-the-counter contracts grows, it will become increasingly critical to ensure that the legal basis for these transactions is sound, and that the institutional capacity to monitor and adjudicate claims resulting from their non-completion or dissolution is in place. Establishing clear rules (as well as potentially a greater number of standardized products that can be openly traded) in this and other related areas can serve as one way to improve bankability, and ensure a continued scale-up of renewable energy investments in the sector for markets that no longer have the centralized backing of a single buyer. Innovations in these and other areas are likely necessary to ensure that a greater number of both renewable generation projects and flexibility sources can maintain bankability in these rapidly changing market circumstances.

There are, however, some downsides of having more power locked away in bilateral contracts. If a significant share of total power generation is locked away in bilateral or over-the-counter contracts, driven by market actors’ desire for greater revenue certainty, this directly reduces the amount of power that is sold on the exchange. In turn, this can also reduce the depth and liquidity of wholesale markets, reducing in the process the amount of flexibility available to the market (Cochran et al., 2013). As the text above demonstrates, despite the potential benefits of private PPAs and aggregators, there are no simple answers to resolving these complex trade-offs.

[28] These shares have stayed relatively stable over the last five years, with a slight decrease in the share of self-supplied electricity and a corresponding increase in the share of spot market purchases.

New Revenue Streams:

A further feature of the Policy Framework Phase is that electricity markets are becoming increasingly complex and are beginning to give rise to new products and services. Renewable energy technologies have developed the capabilities to provide these services, such as ancillary services, active and reactive power, and the ability to ramp supply up or down in a rapid and responsive way. While these new revenue streams are likely to remain small for most RE technologies when compared to revenues from electricity sales (see below), they are likely to help some projects achieve bankability. And as the ability of renewable energy technologies to participate in the market for such services grows through technological and other improvements, these potential new revenue streams may grow further (see Section 9.1.5).

This presents a new opportunity for renewable energy producers and points to a potential future where renewable energy producers will no longer rely on only one revenue source (e.g. FIT payment or long-term PPA) – instead, **renewable energy producers (as well as other power generators in the market) may come to rely on two, three, or more revenue streams in order to create a project-specific or market-specific business model that cumulatively enables a bankable project to be realized.** As a result, a growing number of RE projects may sign partial PPAs, i.e. offtaker contracts that cover only a portion rather than 100% of their output, with the remainder being sold on the spot market, as is occurring in markets like Texas (Bailey, 2015) and Chile (The Economist, 2014), or to third party aggregators, as is starting to occur in Germany (Deign, 2015).

Different jurisdictions' regulatory frameworks will have different rules governing which combinations are allowed, and new combinations may emerge over the course of a given project's economic life as market circumstances change. Table 4.4 provides a snapshot of some of the possible configurations, and distinguishes between selling 100% of the output to a particular buyer (which is still allowed in many liberalized markets), selling a share of the total power output to a range of different offtakers as well as using a portion of the power generated directly onsite (self-use), as well as the full market option, where all power is sold directly onto the energy or ancillary services market.

Table 4.4. Principal Pathways for Marketing Generation Projects in Liberalized Market Contexts

Principal Pathways for Marketing Generation Projects in a Liberalized Market	
100% Offtaker Agreement	• Large Power Customer • Utility • Aggregator • Regulated Single Buyer (centralized offtaker)
Partial Offtaker Agreement	• Bilateral Contracts (for a portion of total power output) • Forward Contracts (for a portion of total power output) • Hedging Contracts (for a portion of total power output) • Contracts with Aggregators (for a portion of total power output) • Self-use (for a portion of total power output)
100% Market Sales	• Capacity Markets • Energy Markets • Ancillary Service Markets

While Table 4.4 shows how renewable energy producers can diversify their overall revenue streams (e.g. ancillary services markets), additional revenues for renewable energy producers from participating in these markets currently represent a small share of total revenues. Even for conventional flexible power plants such as combustion turbines, the total revenues from ancillary services rarely exceed 20% of total revenues in current markets in the U.S. such as the PJM and MISO regions (Monitoring Analytics, 2015; Potomac Economics, 2015). As such, it is unclear that providing ancillary services or even flexibility products (see Section 9.1.4) could ever play a significant role in driving renewable energy finance, though this could change with the advent of new technologies.

Another area that could provide additional revenue streams for RE producers is the introduction of locational pricing, also referred to as nodal pricing. Nodal pricing provides a means through which better locational price signals can be provided to both generation as well as demand side resources to encourage them to be sited where they can bring the most value to the system (Neuhoff and Boyd, 2011; see Section 9.1.2). The jurisdiction with perhaps the most elaborate system of nodal prices is Texas, where over 11,500 individual nodes provide direct locational pricing to better manage congestion and improve the alignment of supply and demand throughout the system (Seif and Blevins, 2016). In theory, a well-designed system of nodal prices could provide targeted, location-specific incentives for the development of new RE projects, and provide an additional source of revenues to help improve project cash flows.

Another potential solution has recently been adopted in Germany: since 2014, power producers above a certain size are required to directly market their power on the wholesale market, effectively exposing them to wholesale market prices, while awarding them a **floating premium payment**[29] to compensate for the revenue risks associated with direct wholesale market sales (BMWi, 2014; BMWi, 2015a). This premium payment may represent a good transitional (and in energy-only markets, perhaps even long-term) solution for a number of jurisdictions with competitive wholesale markets as they seek to provide a bankable basis for renewable energy investments (IEA 2016). Risk resulting from **variations in wholesale electricity prices, which are frequently beyond the control of national policymakers** (e.g. fluctuations in carbon prices, electricity demand development), can thus be effectively mitigated.

However, as the share of variable renewable energy sources in any given region grows, further increasing existing over-capacities, average wholesale market prices tend to decline, which tends to increase the required “premium” for projects to achieve bankability.[30] This so-called “Missing Money Problem” (see Textbox 4.3) for renewable energy technologies is likely to remain a key challenge for the foreseeable future, even if levelised generation costs continue to decline (Newbery, 2015; Milligan, 2015; Milligan et al., 2012; Cochran et al., 2013; Ela et al., 2014; Cramton et al., 2013; Couture and Jacobs, 2013).

Table 4.5 provides an overview of the kinds of policy solutions that are available to mitigate key investment risks in jurisdictions with competitive wholesale markets. Note that this table only includes three key risks that are most relevant when operating within wholesale market environments, but that these risks also apply to other environments.

[29] For wind and PV, this premium payment is calculated ex post, based on the actual development of wholesale market prices (Couture et al. 2015). The premium effectively covers the gap between wholesale market prices and the estimated levelised cost of generation (see Couture et al. 2011). The floating premium option has also been called the “spot market gap” model (Couture et al. 2010) as well as a “modulated premium” (IEA 2016).

[30] Note that this is compounded by other factors, such as flat or declining electricity demand, and weak carbon pricing, as highlighted previously.

Table 4.5. Policy Options to Mitigate Investment Risks in Jurisdictions with Competitive Wholesale Markets

Key Investment Risks	Potential Policy Options to Mitigate Risks in Jurisdictions with Competitive Wholesale and/or Retail Markets	Potential New Features
Offtaker risk	• Maintain a central regulated offtaker for renewable energy projects as a "last resort" option • Establish stronger legal framework for utilities and aggregators to continue to sign **private medium- to long-term bilateral contracts** (see Appendix 9.3)	• Allow the use of **synthetic power purchase agreements** (PPAs) (see Appendix 9.1.1)
Curtailment risk	• Making demand as a whole more responsive to supply conditions (e.g. via demand response, power-to-heat, power-to-gas) • Improve the overall flexibility of the power system	• Introduce **contractually bounded curtailment for variable renewable resources** (e.g. maximum allowable annual curtailment) (see Section 5.5).
Revenue Risk	• Allow renewable energy projects to seek out **partial or full offtaker agreements** (see Appendix 9.1) • Maintain or adopt a **floating premium** framework to increase revenue certainty for renewable energy producers	• **Commodity hedges** • **Synthetic PPAs** (see Appendix 9.1.1) • **Locational or nodal pricing**

4.4. MENU OF POTENTIAL POLICY SOLUTIONS

The text below provides an overview of the potential policy solutions for the bankability challenge. Some of these are described in greater detail in a series of Case Studies included in the Appendices at the end of the report. They are divided into two sections:

1: Innovative Offtaker Arrangements to Improve Revenue Certainty

- *Synthetic power purchase agreements*
    - Under a synthetic PPA, the power producer sells its electricity directly into the wholesale spot market and receives the prevailing market price; however, in order to compensate for the volatility and unpredictability of spot (or day-ahead) market prices, the power producer signs a contract for a financial product known as a "hedge" in order to provide protection against this volatility and increase the stability of future cash flows. Synthetic PPAs, in contrast with traditional PPAs, do not involve the actual physical exchange of electricity.

- *Private bilateral offtaker contracts*
    - In a growing number of markets, including Australia, South Africa, Chile, as well as the U.S., RE project owners are allowed to enter into bilateral electricity contracts. These corporate or private PPAs can be either for a share or all of a project's output and provide a potential new pathway forward to maintaining bankability for new RE projects.
- *Locational time-of-use price adjustments*
    - Mexico has recently integrated locational time-of-use energy price adjustments into their long-term (15-year) energy auctions, in order to steer prospective renewable energy projects to generate power *when* and *where* the system needs it most. This innovative approach to procurement preserves project investability while attempting to align two often disparate concepts in power system planning: project site selection that is good for the investor, and project site selection that is good for the system at-large. Case study: Locational Time-of-Use Price Adjustments: Mexico (pp. 77)
- *Hybrid energy and capacity payments*
    - Researchers in Germany have recently put forward a proposal for a hybrid energy-and-capacity payment that would supplement revenues obtained on the spot market with a fixed capacity payment per kW installed (Matthes, Graichen et al., 2014). The policy would provide an incentive for flexible power plants in particular to produce electricity when it is needed most, while providing an incentive for technologies like solar PV to adjust their output profile (e.g. by facing PV panels east and west instead of south) in order to increase output during the morning and late afternoon hours. Case study: Hybrid Capacity and Energy Payments: Not Yet Implemented (pp. 78)
- *Tapping into new carbon revenues*
    - In a number of jurisdictions around the world, including in parts of the U.S., Canada, and Europe, anaerobic digesters that capture and harness methane to produce electricity are able to tap into several different revenue streams, including electricity sales, tipping fees for accepting the delivery of municipal and other wastes, heat production, renewable energy certificates, as well as carbon revenues.
- *Public private partnerships*
    - A number of jurisdictions around the world, including Morocco and South Africa, have begun using Public Private Partnerships as a strategy to allocate the various risks and scale-up investment in the renewable energy sector (EY, 2015a). When well designed, Public Private Partnerships can appropriately allocate the risks to the individuals or actors best able to manage them and increase the overall investability of a particular project from the standpoint of international investors. This could be a viable strategy in a number of jurisdictions, notably in emerging markets.

2: Developing New Products and Opening Up New Revenue Streams for Renewable Energy Producers

- *Flexible ramping products*
    - California has recently introduced its Flexible Ramping Product, which will be procured on a competitive basis using real-time auctions. In order to qualify, the resource or technology must be able to respond to changes in net load within a 5-minute timeframe. The goal of the new policy proposal is to allow for the efficient identification and compensation of the required flexible capacity in a system with growing levels of variable renewable energy sources (CAISO, 2015). Case study: Flexible Ramping Products: California (pp. 80)

- *Participating in balancing and ancillary services markets*
    - The agency governing transmission system operators across the EU has recently put forward criteria for the kinds of ancillary services products that will be developed, some of which can be provided by renewable energy technologies (ENTSO-E, 2015a). These criteria will help further standardize and deepen the market for ancillary services and balancing products across the common market. Case study: Variable Renewable Energy Participation in Balancing and Ancillary Services Markets: EU (pp. 81)
- *Locational or nodal pricing*
    - A growing number of markets are beginning to use nodal pricing to reduce congestion on the system and improve the real-time alignment of supply and demand. A system of locational prices could provide location-specific incentives for the development of new RE projects, while providing an additional source of revenue.

5. ENHANCING THE FLEXIBILITY OF THE POWER SYSTEM

5.1. DESCRIPTION OF CHALLENGE

Electricity generated from wind and solar energy is marked by two distinguishing characteristics: variability and uncertainty.[31] Variability reflects the dependency of generation output on the availability and strength of the underlying solar and wind energy. Uncertainty reflects that the generation output cannot be perfectly predicted. Together, variable and uncertain resources on a system require a flexible power system, one that can respond to continual changes in demand and supply. As power systems seek to increase the share of variable RE, the need for flexibility from both demand and supply is likely to become increasingly important (IEA, 2015).

Flexibility is a key pillar of the Policy Framework Phase because as variable resources increase in penetration levels, the system must be sufficiently flexible to accommodate the added variability and uncertainty and still maintain reliability. An *inflexible* power system is more likely to rely on renewable energy curtailments to balance demand and supply, which in turn would limit the amount of economically desirable variable renewable energy that can be added to the grid.

All power systems possess some degree of flexibility to balance the variability and uncertainty of demand and conventional sources of energy. As this report is focused on the transitions taking place in renewable energy policy, **this section will focus on some of the ways in which renewable energy technologies can support this increased need for flexibility**.

5.2. OVERVIEW OF SYSTEM FLEXIBILITY

Numerous options for increasing power system flexibility are available in all power systems. Broadly, increases to system flexibility involve changes to two key dimensions of power system operation: physical and institutional. **Physical sources of flexibility** reflect available infrastructure such as size and strength of the transmission network and characteristics of generating plants, demand-side flexibility, and storage. **Institutional sources of flexibility** improve access to the flexible capabilities of physical sources, and refer to the underlying processes that are used to harness or increase power system flexibility. For instance, a generator is only flexible if the dispatcher has the means to access that flexibility; in turn, a flexible source of generation can only contribute to improving system flexibility if the institutional processes (including incentives, rules, and regulations) exist to bring that flexibility into the market.

In many cases, flexibility will only be offered to markets if it is sufficiently remunerated. Institutional sources of flexibility include sub-hourly scheduling and dispatch, reductions in plant minimum generational levels, and market rules that allow renewable energies to provide system flexibility (see Figure 5.1 for additional examples of both types of flexibility). The cost of increasing these sources of flexibility varies widely, but typically, improving the institutional access to existing flexibility is less expensive than adding new physical sources.

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[31] Wind and solar are sometimes referred to imprecisely as intermittent and unpredictable. Intermittent implies stop and go power, and is better reserved for unpredictable outages (including thermal). Variable describes a resource that has manageable and varying output. While wind and solar are not perfectly predictable, the resource availability can be forecasted.

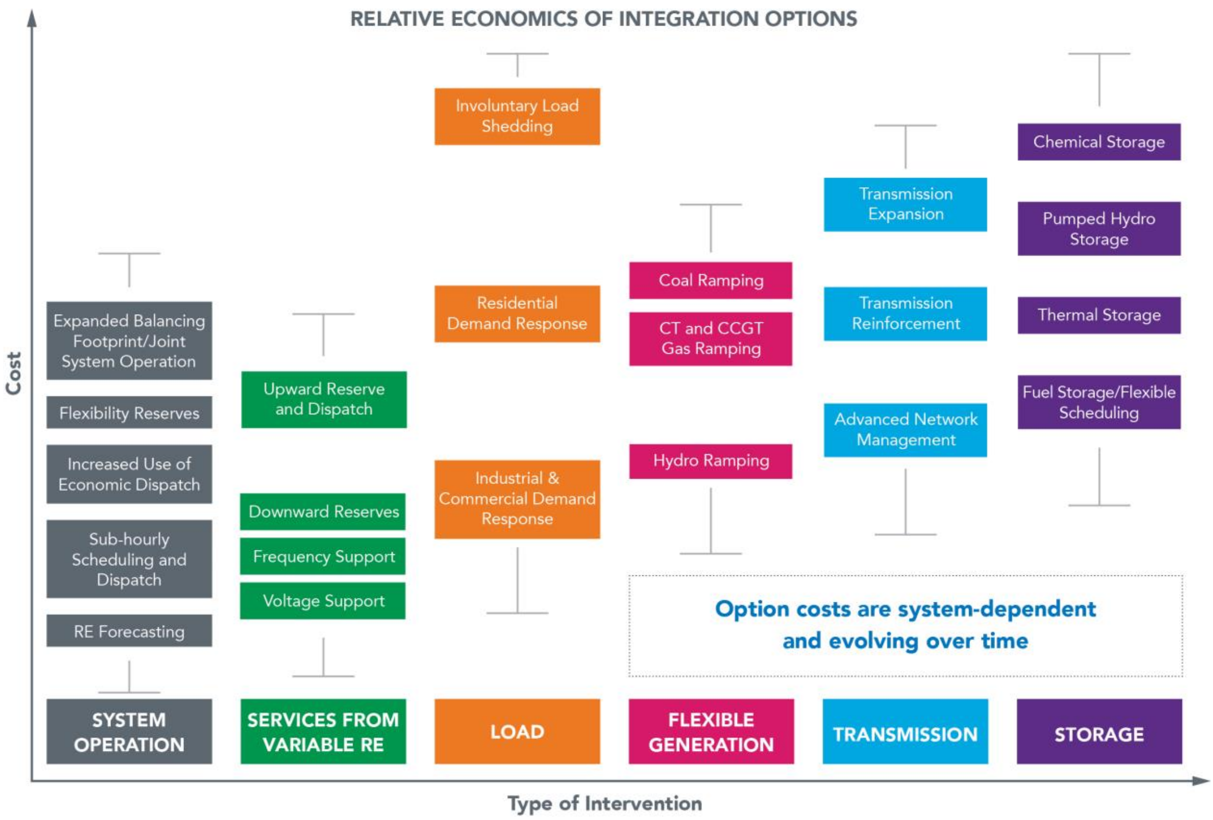

Figure 5.1. Example flexibility options. Relative costs are illustrative, as actual costs are system dependent. (Modified from Cochran et al., 2013)

Extensive analyses on best practices to evaluate and improve flexibility illustrate the broad range of actions that power system operators and planners, policymakers, and regulators can take (for recent globally-oriented studies, see, for example: IEA-RETD, 2015b; Dragoon and Papaefthymiou, 2015; IRENA, 2015; Miller, Martinot, et al., 2015; IEA, 2014a; Cochran, Miller, et al., 2014). Because this report focuses on the transitions of policies related to cost-competitive renewable energy technologies, and is not about system flexibility in general, we limit our **focus to how renewable energy policies can harness the flexibility that renewable energy generators can provide, evaluating both the physical and institutional dimensions**.

5.3. FLEXIBILITY FROM VARIABLE RENEWABLE GENERATORS

Advances in technology enable many types of variable renewable energy generators, i.e. wind and solar PV, to provide a full suite of balancing services necessary for system flexibility (see Table 5.1 for a summary of how characteristics of variable renewable energy have evolved). Flexibility is needed in both normal operations for load following and meeting daily demand peaks as well as following an outage or other disturbance. Wind and solar generators can increase the responsiveness and flexibility of the power system to help address both needs, provided the Policy Framework supports their participation.

Table 5.1. Evolving characteristics of variable renewable energy technologies (source: Milligan et al., 2015)

Characteristic	Old	New
Dispatchability	Uncontrollable, "must take"	Dispatchable through participation in economic dispatch
Forecast/uncertainty	Unpredictable	Increasingly forecastable
Variability	Highly variable over multiple timescales	Very short-term variability largely mitigated via spatial diversity
Reserve requirements	Requires dramatic increase in operating reserves from thermal units	Relatively small increase in regulation required. Can self-provide multiple reserves across multiple timescales with selective/economic curtailment
Grid support	Provides no grid support/decreases grid stability	Can provide multiple grid support services

5.3.1. Renewable Energy Support for Balancing Under Normal Conditions

The primary means of balancing the system occurs through economic-based dispatch at the minutes-to-hour timeframe. Because generators in most jurisdictions are typically dispatched at least marginal cost, wind and solar, with zero fuel costs, are dispatched ahead of thermal units. However, there are periods in which constraints on the operation of thermal units create situations in which wind and solar generation is not fully dispatched, such as when a thermal unit must be available the next day and cannot be shut-down and restarted without incurring significant wear and tear costs. In these situations the thermal generators would prefer to *pay* to generate to avoid the cost of shutting down, and the energy clearing price could be negative. Generators that can dispatch downward, including wind and solar, will reduce output to avoid paying to generate. [32]

Thus one way that variable renewable energy can contribute to system flexibility is to be available to be dispatched downward to support system balancing. This curtailed renewable energy also positions the wind or solar generators to provide upward dispatch as the economics change. In contrast to designating wind and solar as "must take," **enabling wind and solar to provide this downward and upward dispatch allows least-cost dispatch and increases system flexibility**.[33]

To access this flexibility, however, **two sets of conditions for variable renewable energy are required:**

1. **participation in the markets and/or dispatch decisions, and**
2. **full technical capabilities to participate**, such as automatic generation control necessary to provide regulation (secondary frequency reserves).

[32] Upward and downward dispatch refer to changing the assigned generation point of an individual generating unit (up or down) to effect the most economical supply of electricity to meet demand.

[33] While curtailment generates concerns about bankability of RE, increasing system flexibility overall helps minimize the need to extract flexibility from curtailment. Eliminating all curtailment is typically not a goal for planners, as building enough transmission and generation to use every kWh of wind and solar energy could impose significant costs on system. For example, ERCOT (Texas, USA) targets 2% wind curtailment rates in its optimization of transmission expansion plans (ERCOT, 2006).

Some competitive wholesale markets exclude variable renewable energy participation, either explicitly or indirectly through eligibility rules, such as (previously) Germany, which auctions frequency control reserves six days in advance, or the Alberta Electric System Operator, which procures regulation day ahead and requires the supplier to provide it for 60 minutes (Milligan et al., 2015). Areas, such as Midcontinent Independent System Operator (MISO), that have included variable renewable energy in both real-time and regulation-based economic dispatch have reduced overall curtailment levels and improved operational efficiencies and transparency (Milligan et al., 2015).

5.3.2. Renewable Energy Support Following a Grid Disturbance

The second need for system flexibility occurs following a disturbance. Here, too, variable renewable energy can provide essential services, including synthetic inertial control, governor response, voltage support, and frequency and voltage ride-through capabilities.[34] As variable renewable energy replaces conventional generation, their role in stabilizing the power system becomes increasingly important, requiring updates to interconnection and grid code requirements, as well as to overall power system operations.

Inertial control (fast frequency response) and governor response (slightly slower frequency response) have traditionally been provided by synchronous generators such as combustion turbines. But with power electronics, wind and solar generators can also provide these services synthetically. A study by NREL found that systems with high instantaneous renewable energy penetration levels can maintain frequency following a disturbance using commercially available frequency-responsive controls on wind and solar plants and storage (Miller et al., 2014). Moreover, the variable renewable energy generators with these capabilities have faster and more stable response rates and experience less wear and tear compared with conventional synchronous generators (a response time of milliseconds compared with seconds) (Milligan et al., 2015). Concerns about insufficient flexibility in high variable renewable energy grids (e.g., “duck curve” in California[35]) (St. John, 2014) can be mitigated by allowing variable renewable energy to provide grid services, thereby increasing the maximum allowable instantaneous variable renewable energy penetration and reducing variable renewable energy curtailment (Denholm et al., 2015).

Wind and solar PV can also assist by providing voltage support; smart inverters can monitor local grid conditions and autonomously provide voltage support as needed. They also can provide frequency and voltage ride-through capabilities, allowing wind and solar to remain on-line following a disturbance and help stabilize the power system (Barth et al., 2014). At the distribution level, anti-islanding technologies address safety concerns and enable PV to remain on-line.

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[34] For definitions of these and other related terms, please see “Greening the Grid Glossary,” Greening the Grid, accessed February 9, 2016, http://greeningthegrid.org/resources/glossary.

[35] The “duck curve” describes steep ramping requirements (in CAISO, up to 13,000 MW in three hours) in the period around sunset, when the high-penetration PV systems stop generating at the same time that evening load increases. See http://www.caiso.com/Documents/FlexibleResourcesHelpRenewables_FastFacts.pdf.

Variable renewable energies reflects one of many types of connections to the power grid through power electronic converters, including electronic loads and high-voltage DC transmission, that are increasing on the power system (Milligan et al., 2015). These changes are creating the need for new sources of physical flexibility, and critically, institutional structures that allow the power system to harness this flexibility. In many settings, as highlighted previously, **new RE actors may be able to provide this flexibility at lower economic cost than conventional providers if the Policy Framework enables their participation.**

Table 5.2. Flexibility from variable renewable energy can occur at many timescales

Timescale of Flexibility	Type of Flexibility	How variable renewable energy provides this
Sub-second	Autonomously generated: Synthetic inertia	Fast frequency response with a power electronic converter
Seconds	Autonomously generated: Synthetic governor response	Slower frequency response through electronic governor
Minutes	Remotely operated: Automatic generation control	Market or system operator inclusion in ancillary services
Minutes to hour	Economic dispatch	Market or system operator inclusion in dispatch
Day	Scheduling (unit commitment)	Market or system operator inclusion in day-ahead scheduling

5.4. FLEXIBILITY FROM NON-VARIABLE RENEWABLE GENERATORS

Although this section has focused on the role of flexibility from variable generators, which is a relatively recent technological innovation, power systems have long extracted flexibility from non-variable RE, such as hydropower. Yet, even with these technologies, opportunities exist to extract additional flexibility compared to current practice. For example, hydropower generation might be dispatched in a context of agricultural or environmental schedules, which could be modified to support flexibility during critical periods. In some areas, inflexibility of hydropower has increased the amount of wind curtailment. For example, during spring run-off months when river levels are high, Bonneville Power Administration, in the Northwest United States, must run water through its generators to avoid excess use of spillways, which can increase total dissolved gases and harm fish. As a result, excess generation supply during these periods has been the cause for wind curtailments, a sign of an inflexible power system (Bird et al., 2014). To increase system flexibility, market signals, such as negative prices, can be used to help increase load or decrease supply during these periods, and also encourage the use of more hydro storage, if feasible, to improve flexibility.

Extracting additional flexibility from biofuel-based generators could be hindered by institutional constraints, such as contract designs in which feed-in tariffs discourage reducing supply during periods of oversupply. In this case, extracting additional flexibility can focus on designing policies and contracts to be inclusive of the value of its flexibility offerings.

5.5. MENU OF POTENTIAL POLICY SOLUTIONS

To access flexibility from renewable energy sources, policy makers and regulators have been revising interconnection standards, grid codes, policy incentives, and market participation rules. The menu of policy solutions described in the report to support flexibility from variable renewable energy adhere to the following broad principles:

- Design planning and operations in order to harness flexibility at the system level (rather than the individual plant level). In other words, each wind turbine does not need "backup" generation or storage to balance its variability; the system as a whole must be balanced, and some of this flexibility can come from vRE.
- Encourage more energy to be dispatched on a least-cost basis, as opposed to contracts that require generation to be "must-take" and thereby limit system flexibility
- Create institutional platforms, such as competitive procurement and wholesale market rules, to allow different technologies to compete to provide flexibility, including new suppliers of flexibility services
  - Value energy and flexibility based on objective, verifiable criteria such as service quality and performance
  - Regulatory and/or legal changes may be required to support technology neutrality and/or new market entrants
- Value the flexibility from variable renewable energy, including compensating variable renewable energy for the provision of grid services if conventional technologies are being compensated
- Provide clear guidance on cost allocation for the procurement of flexibility (i.e., who pays and how).

The following policy solutions to procure flexibility from renewable energy generators are organized by the two interrelated goals to:

1. Increase the physical supply of flexibility from renewable energy, and
2. Increase institutional access to flexibility resources by economically integrating renewable energy into market and system operations.

1: Increase the Physical Supply of Flexibility from Renewable Energy

- *Require variable renewable energy to provide grid services*

The capability for wind and solar generators to provide grid services is enable through widely available technologies such as smart inverters, automatic generation control, reactive power provision capabilities, and frequency and voltage fault ride through functionalities. These capabilities can be required through grid codes, market participation rules, and eligibility criteria associated with renewable policy support mechanisms (e.g., feed-in-tariffs), among other options Even if those capabilities remain dormant in the immediate-term, retaining the option to utilize flexibility capabilities in variable renewable energy will be critical as renewable energy penetration levels increase in the longer term. Case studies: Utilize Variable Renewable Resources to Provide Grid Services: Colorado, USA (pp. 82) and Requiring Wind to Provide Reactive Power: United States (pp. 84)

- *Support pilot studies to explore vRE flexibility services*
  - As a first step toward utilizing variable renewable energy resources to provide grid services, utilities and original equipment manufacturers can partner to gain familiar with this set of activities by designing and implementing pilot projects. Case study: Support Pilot Study for Wind Providing Secondary Reserves: Belgium (pp. 83)

2: Increase Institutional Access to Flexibility Resources by Economically Integrating Renewable Energy into Market and System Operations

- *Allow or require vRE to participate in wholesale power markets*
  - Enabling variable renewable resources to provide energy, capacity and ancillary services within wholesale market framework helps to promote efficient system outcomes and the overall economic integration of renewable resources.
- *Encourage more accurate variable renewable energy bids*
  - Through the use of intra-day markets, shorter gate-closure times, and centralized forecasting, variable renewable resources will be able to provide more accurate information on their expected contribution to the system and market, and system operators will have the means to make least-cost scheduling and dispatch decisions based on those bids. This will promote an overall more cost-efficient market.
- *Change dispatch practices of non-variable renewable energy*
  - Resources such as hydropower (both large- and small-scale) and biopower, if available within a system, can be highly effective contributors to grid flexibility. Augmenting dispatch practices and the financial arrangements associated with them can help to enable a more flexible and economic power system. Case studies: Incentivizing Flexibility from Biogas: Germany (pp. 84) and Extracting Additional Flexibility From Large-scale Hydropower: India (pp. 85) and Extracting Additional Flexibility From Small-scale Hydropower: France (pp. 86)
- *Adopt contractually protected curtailment rules*
  - Curtailment of variable renewable generation may be economic for the system at-large, e.g., due to transmission constraints or when conventional flexibility is exhausted. Utilities and system operators can promote market and administrative changes that allow for future renewable projects to be curtailed in such cases, while at the same time providing investor certainty, for example, by bounding curtailments on an annual basis, and providing clarity on how cash flows will be impacted during times of curtailment (e.g., whether a wind farm will be compensated for curtailing energy production). Such an administrative change might occur through specification in new power purchase agreements or by modifying eligibility criteria for policy incentives to allow for curtailments. Curtailment can also be addressed through market designs, such as requirements for vRE to be economically dispatched and use of negative energy pricing.

6. ESTABLISHING A LONG-TERM VISION FOR A CLEAN AND SUSTAINABLE POWER SYSTEM

6.1. DESCRIPTION OF CHALLENGE

Many countries around the world have started their transition towards cleaner and more sustainable power systems. Decarbonizing the power sector is one of the primary drivers for this transformation. With the recent Paris Agreement (UNFCCC 2015), nearly 200 countries have committed to substantially reduce their greenhouse gas emissions, a trend that is likely to continue as the effects of climate change continue to be more widely felt. A desire to reduce carbon emissions is therefore becoming an important driver (and in some jurisdictions, the most important one) behind the push for energy system transformation.

According to the latest Intergovernmental Panel on Climate Change (IPCC) report, decarbonizing electricity systems is an important component of cost-effective mitigation strategies for keeping global temperature increase below 2 degrees. To meet this goal, global greenhouse gas emissions will have to be reduced by at least 50% (and up to even 85%) by 2050, compared to the level in 2000. For developed countries as a group, this translates to a required carbon reduction of 80-95% compared to 1990 levels (Bruckner et al., 2014). The European Commission, for instance, set the target of reducing greenhouse gas emission by 80-95% by 2050 compared to 1990 levels (EU Commission, 2011a; EU Commission, 2011b). As a result, a **near zero-carbon power sector may become a common target among countries striving to significantly reduce their carbon emissions**, given the current landscape of costs and challenges of decarbonisation across other sectors (Jones and Glachant, 2010). At the latest G7 meeting, the largest economies of the world have agreed to strive for the “decarbonisation of the global economy over the course of this century” (G7 Germany, 2015).[36]

The increase of renewables and the vision for a cleaner and more sustainable energy system is also driven by other policy objectives, inter alia the push to simultaneously diversify the economy and the overall energy mix, the desire to increase electric vehicle use, security of supply, resilience, hedging against fossil fuels price volatility, job creation and local value creation, and the reduction of air pollution (IPCC, 2014).37 Frequently, policy programs are driven by a number of interrelated policy objectives, as the example of New York shows below.

[36] Transitioning towards cleaner and more sustainable power systems is a challenge for policymakers in many jurisdictions regardless of the structure of the electricity market. Jurisdictions with abundant hydropower resources, such as several Canadian provinces and Norway, or jurisdictions with abundant geothermal resources such as Iceland represent notable exceptions. However, in those jurisdictions other environmental concerns.

[37] The latest IPCC report stated 17 co-benefits of climate mitigation action of which many are related to the deployment of renewable energies. See IPCC, 2014.

Textbox 6.1: Reforming the Energy Vision, New York, U.S.A

The state of New York is facing a series of challenges driving power sector transformation: a mandate to reduce carbon emissions, upward pressure on pricing due to aging infrastructure, electric price volatility driven by greater utilization of natural gas, distributed energy resources challenging legacy utility and regulatory models, an outlook of continued extreme weather events, and a variety of other challenges. The state regulator, the New York Public Service Commission, has opened a series of regulatory proceedings which intend to re-conceptualize the role of distribution utilities and other market actors, and create an environment that aligns utility interests with stated energy policy objectives, with a particular focus on maximizing system-wide efficiency by incorporating distributed energy resources. This overall effort is called "Reforming the Energy Vision" (State of New York, 2016).

Through an expansive, structured stakeholder engagement process and a series of technical meetings, the effort has set out to identify what types of changes might be made to regulatory paradigms and market design structures to accomplish a range of goals. This includes efforts to create a distribution-level market that enables distributed energy resources to actively participate, the development of new technology and cyber security standards, a re-examination of ratemaking and the regulatory paradigms, and many other items. The process has been driven largely by the regulator, which is tasked with balancing a multitude of objectives and putting forth an iteratively approached, multi-phase implementation plan.

Policies for a cleaner and more sustainable power system can help establish long-term objectives for change, provide a coherent vision for sectoral transformation, and provide a framework for future energy policy decisions. In many liberalized markets, for instance in Germany, newly constructed renewable projects must compete against fully amortized fossil fuel power plants that do not face substantial pricing for carbon-related externalities. These conditions can be problematic at a time during which policymakers are trying to steer markets towards decarbonisation. Introducing more robust pricing for environmental externalities like carbon can help to create a level playing field for renewable energy technologies. With respect to renewable energy competitiveness, this can further reduce the cost-gap between fossil and renewable generators, create upward pressure on wholesale electricity markets and thus increase the market-related revenue streams for renewables. It should also be recognized that these challenges are especially pronounced in markets with flat or decreasing electricity demand, or with significant excess generation capacity.

6.2. CATEGORIZING VISION POLICIES FOR CLEAN AND SUSTAINABLE POWER SYSTEMS

In order to direct investment into low-carbon and sustainable energy technologies, policymakers should provide a clear long-term vision of where the future power market (and the electricity mix) is heading. A long-term vision for the direction of the market, and the implementing policies to get there, can help to promote investment security in the sector. At the same time, these types of policies can also have an effect on the merit order in liberalized power markets and therefore also influence the potential revenues for renewable energy producers in competitive wholesale markets. The implementation and potential combination of these policy solutions will depend on national regulatory traditions, priorities of policy objectives and the anticipated ease of political implementation. These can be established by:

1. Setting binding renewable energy targets
2. Phasing-out non-renewable technologies
3. Implementing carbon pricing (such as carbon taxes, cap-and-trade systems, or other similar means of putting a price on carbon emissions).
4. Formulating emission standards for existing and-or new power plants

Table 6.1. Categories, policy objectives and effects on renewable energy competitiveness of vision policies

Categories	Policy Objective	Effect on RE Competitiveness	Examples
1.Binding Renewable Energy Targets	• Reserve market share for renewable energies • Long-term certainty for investors	• Lower capital costs due to lower investment risk • Potentially reduction of wholesale market prices (decreasing market-based revenues for renewable energy sources)	• Long-term renewable energy targets in Denmark
2. Phase Out Policies for Non-renewable Technologies	• Rapidly reduce carbon emissions in the short-term • Phase out the oldest (and frequently least efficient and highest emitting) power plants	• Increase wholesale market prices due to modification of merit order • Reduction of (over-)capacity	• Coal phase out in Ontario, Canada • Climate contribution, Germany
3.Carbon Pricing Policies	• Price in the negative externalities • Fuel switch from carbon intensive technologies to low-carbon technologies	• (Slightly) increase the market clearing price and therefore increase the market-based revenues for renewable energy producers	• European emissions trading system • Carbon floor price, UK • Carbon tax in Alberta, Canada.
4. Emission Standards for Power Plants (Existing or New)	• Phase out existing power plant from carbon-intensive technologies • Prevent the construction of new carbon-intensive power plants	• Increase the available market for low-carbon technologies • Increased market clearing price in case of regulation for existing power plants (phase out)	• Clean Energy Standards in British Columbia, Canada • emission standards, USA

Source: Authors

6.2.1. Binding Renewable Energy Targets

Over 160 countries around the world have established targets for renewable energy deployment (Kieffer and Couture, 2015). **The primary objective of these policies is to reserve a certain market share for renewable energies** (or other zero-emission power generation technologies). This will give potential investors more long-term certainty regarding the future development of the electricity mix. This will remain critical in the coming decades, since changes to other framework conditions (e.g. market design) are more challenging to predict and thus are likely to introduce additional risks for investors.

Recently, renewable energy targets have also been implemented or adjusted to control the growth of renewable energy. The reasons for implementing targets for renewables are manifold. Even though climate policies and carbon reduction target play an important role, other policy objectives (e.g. diversification of energy mix, reducing import dependency, macro-economic benefits, rural electrification) are frequently equally important.

The direct effects on renewable energy deployment of adopting long-term targets are broadly positive, since a long-term vision is provided to investors and a defined market share is dedicated to renewable energy producers. Renewable energy targets are frequently set in terms of short-, mid- and long-term targets, as this provides a clearer development trajectory and provides regular opportunities to revise progress and introduce new measures to ensure that the jurisdictions is on track toward achieving its objectives (Kieffer and Couture, 2015).

However, due to the merit order effect the deployment of new (variable) renewable capacity in markets with established generation asset bases and flat or declining demand leads to an over-supplied market, as has already begun to happen in certain parts of the EU.[38] As depicted in Figure 6.1 below, in settings with wholesale electricity markets in particular, this may lead to lower market clearing prices and revenue erosion for all producers, including renewable energy generators. The merit order effect depends primarily on the electricity mix, the flexibility within the system and the actual share of variable renewables (Ray, Munksgaard et al., 2010; Cludius, Hermann et al., 2014).

[38] An over-supplied market might be avoided by utilizing phase out policies (see subsequent sub-section).

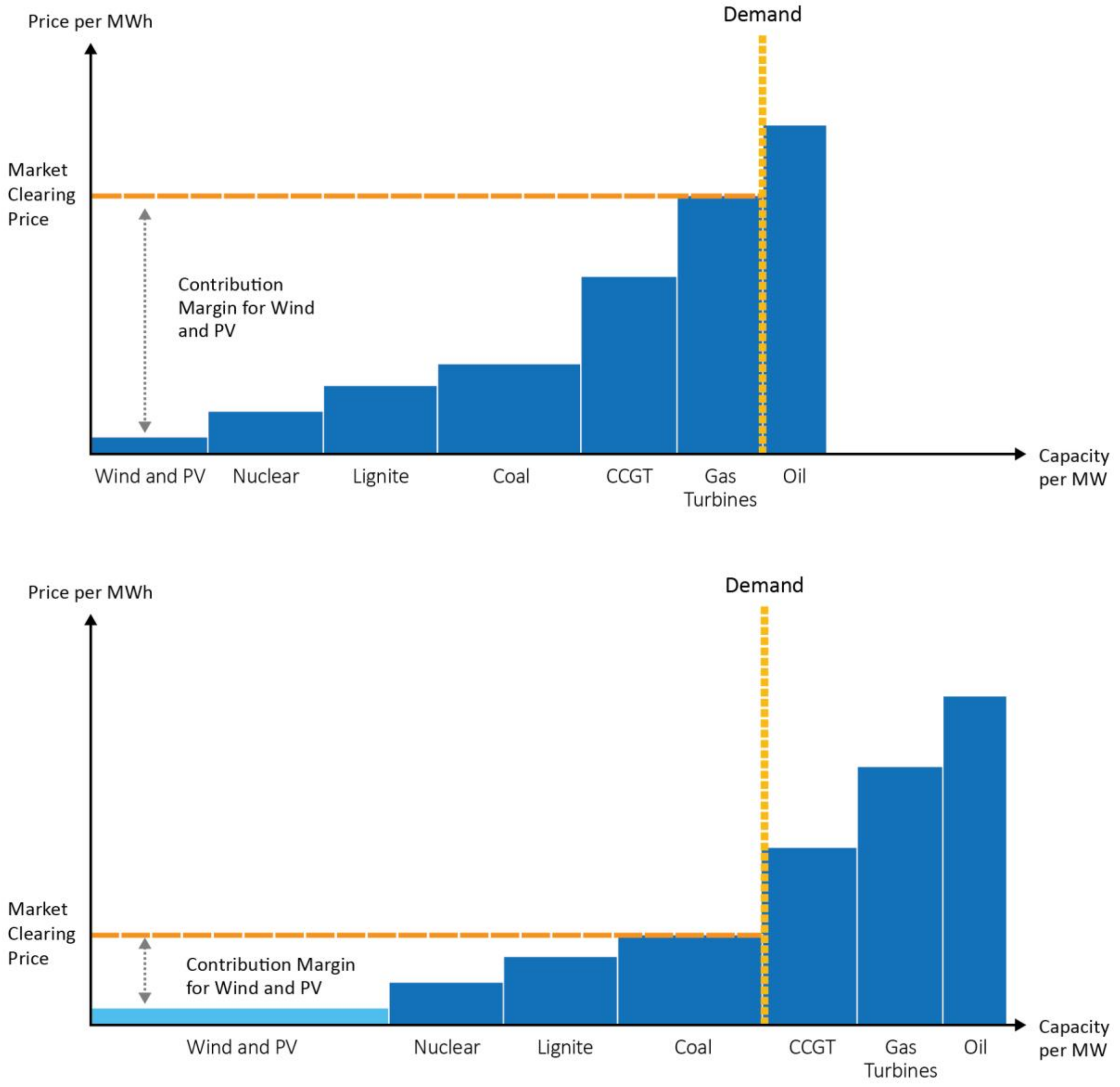

Figure 6.1. Typical Merit Order with low and high shares of variable renewables (Source: Authors)

When designing such policies, policymaker can benefit from following these key principles (see also Kieffer & Couture, 2015):

- Support analysis of the available renewable energy potential to determine regionally-appropriate targets;
- Engage with stakeholders to discuss feasibility of various targets, seeking context-appropriate balance of ambition and achievability;
- Ensure that an appropriate verification and compliance framework is in place, potentially including penalties for non-compliance;
- Ensure that the targets are backed by specific policies and measures to support goal attainment.

6.2.2. Phase Out Policies for Non-Renewable Technologies

As was highlighted in a recent IEA report, the biggest challenge in the transformation phase of electricity system “may be managing the costs associated with scaling down the old system” rather than building up the new one (IEA, 2014a). Over the next 25 years, it is estimated that a total of 610 GW of coal capacity worldwide will need to be phased-out for environmental reasons (IEA, 2016).

This challenge applies to across all electricity markets, but most notably to jurisdictions with flat or declining electricity demand, as additions of new renewable capacity tend to shrink the market share available to other technologies, often putting downward pressure on the revenues and therefore the profit forecasts of incumbent actors.[39] However, in order to transition to a cleaner power system, it is likely that most jurisdictions around the world will have to undertake concerted measures in order to phase out existing fossil (or nuclear) capacity, while constraining the development of new fossil-fuel based power plants.

Indeed, several jurisdictions around the world have implemented policies that directly target the phase out of non-renewable generation assets. Some have targeted the phase out of nuclear power, since using and deploying this technology was no longer in line with their long-term visions of a sustainable power system or with the growing need for flexibility (e.g., Germany, Philippines, Switzerland). And recently, more and more jurisdictions have adopted plans to strategically phase out carbon-intensive generation, namely coal and lignite. These policies are under discussion in wide range of countries including Denmark, Germany, and the UK (Agora Energiewende, 2016; UK Government, 2015), and it has already been done at the sub-national level in jurisdictions like Ontario in Canada. In some parts of the United States Independent System Operators have already identified need for new capacity additions due to retirements coal-fired capacity in relation to stricter environmental regulation (MISO, 2015).

The primary objective of phase out policies for carbon intensive technologies is to rapidly reduce emissions in the short-term and to phase out the oldest (and frequently least efficient and highest emitting) power plants. This is often introduced because existing carbon pricing schemes alone have been deemed insufficient to drive the phase out at the scale and pace desired. In Germany, for instance, it was calculated that for moving out lignite power plants out of the merit order via market based carbon price signals, a European carbon price 40-60 €/tCO_2 would be required (Götz and Huschke, 2013, Hermann and Harthan, 2014) – almost ten times higher than current prices in the European emissions trading scheme.

While phase out policies have no *direct* effect on the deployment of renewables, they have a number of indirect effects, including creating demand for new generation, and augmenting the revenues that power producers receive in competitive wholesale markets. By reducing the overall available generating capacity, phase out policies tend to increase wholesale market prices, ceteris paribus. This increases revenues of renewable energy (and gas) power producers, especially in markets with substantial over-capacity. Figure 6.2 below indicates the effects on the merit order, including market clearing prices and higher contribution margins for wind and PV.

[39] This can be seen clearly in the case of Germany, where the two largest utilities E.ON and RWE have seen their share prices tumble and an estimated EUR 19Bn wiped off their market value over the last year (2015) alone. See: http://www.reuters.com/article/germany-utilities-idUSL8N14Y2EO

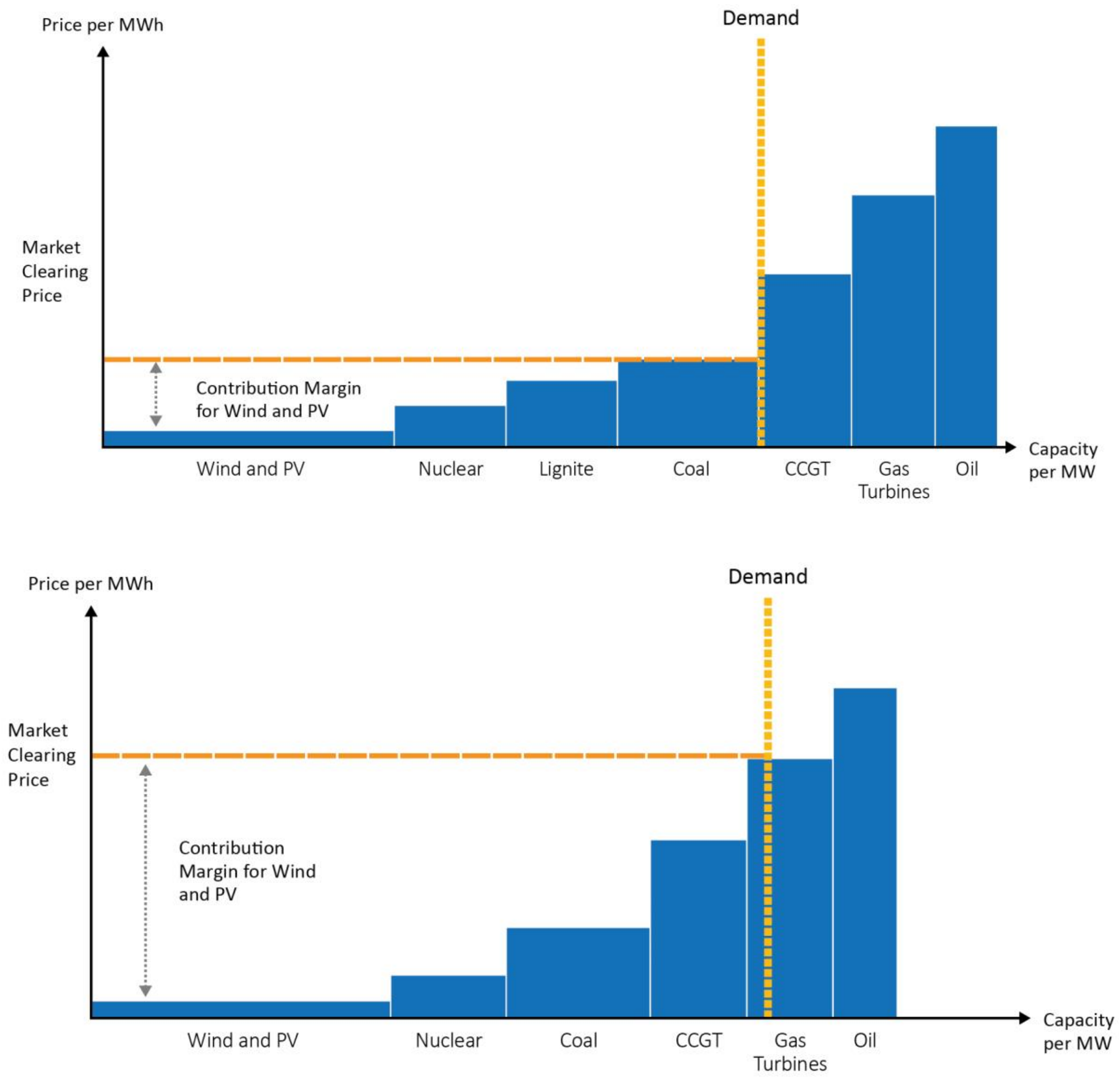

Figure 6.2. Effects of phase out policies (e.g. lignite) on merit order in competitive wholesale markets (Source: Authors)

When designing phase out policies, policymaker should adopt the following **key principles** (see also Harris et al., 2015):

- Gather data and publish estimates on the various costs and benefits (including the health, environmental, and water-related benefits) of a phase out strategy;
- Undertake detailed stakeholder consultations to develop realistic phase out timelines and objectives with power plant operators;
- Establish a clear and transparent trajectory for phasing out power plants, including a detailed phase out plan with timelines and a compliance schedule, potentially including penalties for non-compliance;
- The funding of retraining programs, pension and healthcare assurances, financial support for industry restructuring, and other similar measures should be considered to mitigate the negative economic and social impacts of plant retirements, as well as for elements of the fuel supply chain.

6.2.3. Carbon Pricing Policies

Carbon pricing policies are increasingly being utilized throughout the world – in 2014, more than 40 national and 20 sub-national jurisdictions were pricing carbon (World Bank, 2014). The primary objective of these types of policy interventions is to price in the negative externalities of carbon intensive power generation technologies, and to induce a shift to lower carbon technologies.

These policies can have direct effects on the deployment levels and overall cost-competitiveness of renewables. Internalizing the negative external costs of fossil fuels will further reduce the cost-gap between fossil-fuel based power generation and renewable energy power generators. At the same time, carbon pricing has an important effect on the merit order in liberalized power markets. Since the market clearing price is usually determined by fossil-fuel based power plants, carbon pricing will tend to increase the market clearing price and therefore increase the revenues for renewable power producers (and all others) in competitive wholesale markets. Figure 6.3 below indicates the effects on the merit order, including market clearing prices and higher contribution margins for wind and PV. Note that higher carbon prices can also significantly increase the revenue base of renewable energy power producers in wholesale markets.

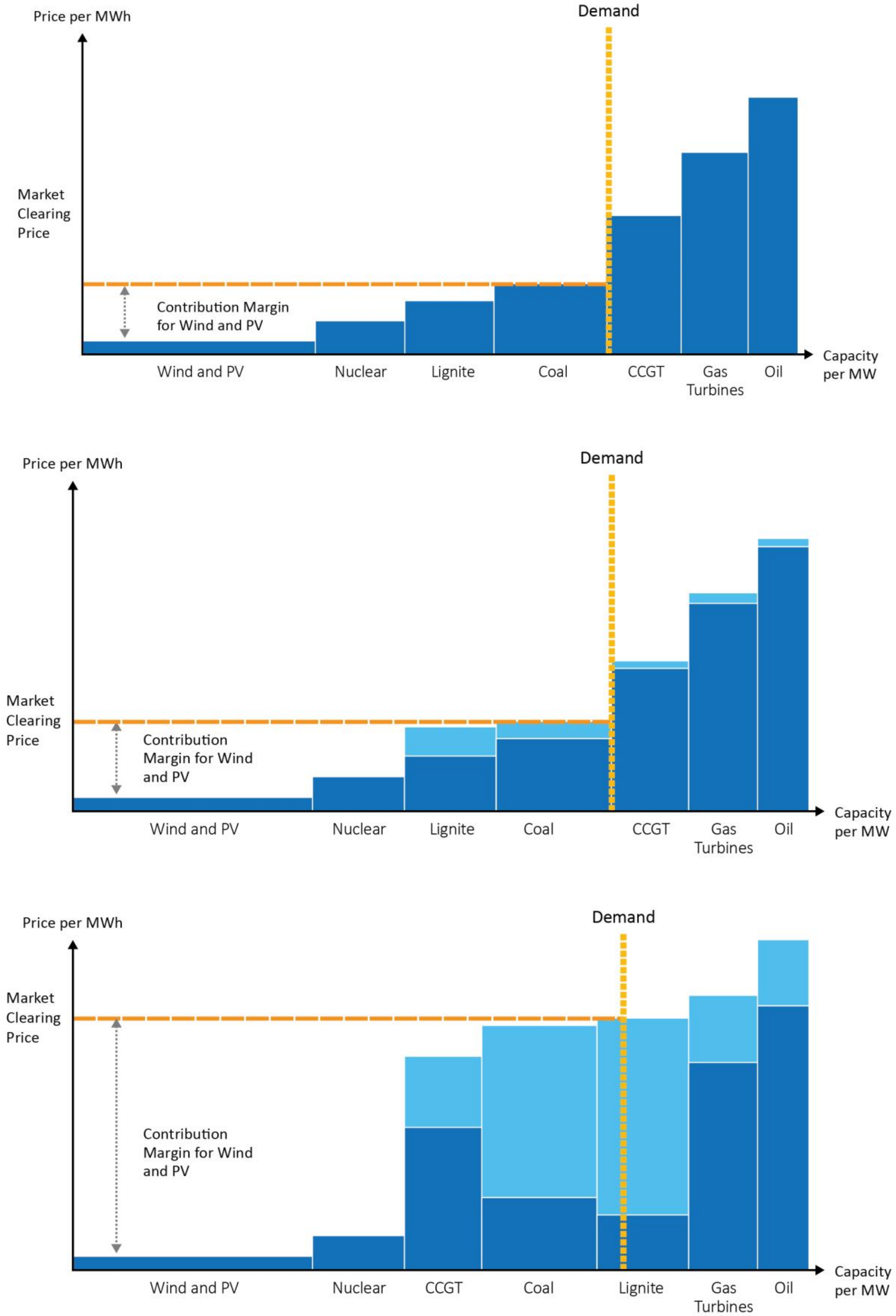

Figure 6.3. Effects of carbon pricing on merit order in competitive wholesale markets (Source: Authors)

When designing carbon pricing mechanisms, policymaker should adopt the following key principles (see also World Bank, 2015):

- Promote frameworks for accurate and transparent carbon accounting across all technologies;
- Establish transparent design process of setting relevant design metrics (e.g., cap, tax level);
- Establish long-term trajectory for pricing scheme to inform investors;
- Facilitate open stakeholder process and public communication plan to ensure an open and balanced debate on the merits and downsides of the policy.

6.2.4. Emission Standards for Power Plants (Existing or New)

As highlighted above, an increasing number of jurisdictions are implementing carbon or other environmental regulation for new or existing power plants, in order to to either gradually phase out existing carbon-intensive power plants or to prevent the construction of new carbon-intensive power plants. At the same time, policymakers are also regulating other environmentally harmful emissions from power plants, including SOx, NOx, and water pollution, etc.

In the case of emission standards for *existing* power plants, the effects are very similar to those of phase out policies as discussed above (larger market share for renewables, less over-capacity in markets with stable or shrinking electricity demand, and potentially higher wholesale market prices). In the case of emission standards for *new* power plants, the effects on the merit order and therefore the competitiveness of renewable energy technologies is less clear. Other low carbon technologies (e.g. nuclear) might also have relatively low marginal costs and therefore have a dampening effect on the market clearing price. However, strict emission standards can be an important driver for renewable energy deployment and other zero-carbon technologies.

When designing emission standards for existing or new power plants, policymakers should adopt the following **key principles** (see also Schäuble et al., 2014):

- Assess the technology-specific emissions and the impact on overall emissions
- Support transparent analysis on the effects of potential regulations on existing power plants and security of supply
- Increase the stringency of carbon and other pollutants related requirement over time
- Engage all relevant actors in a transparent dialogue on potential policy implications

6.3. MENU OF POTENTIAL POLICY SOLUTIONS

The menu of policy solutions to manage the transition towards cleaner and more sustainable power systems is organized in accordance with the four categories developed above :

1. Setting binding renewable energy targets
2. Phasing-out non-renewable technologies
3. Implementing carbon pricing (such as, cap-and-trade systems, or other similar means of putting a price on carbon emissions).
4. Formulating emission standards for existing nor new power plants

1: Setting Binding Renewable Energy Targets

- *Binding long-term renewable energy targets*
    - The primary objective of these policies is to reserve a certain market share for renewable energies (or other zero-emission power generation technologies). This will give potential investors more long-term certainty regarding the future development of the electricity mix. This will remain critical in the coming decades, since other framework conditions (e.g. market design) are more difficult to predict and thus introduce additional risks for investors. Case study: Binding Renewable Energy Target Setting: Denmark & Sweden (pp. 87)

2: Phase Out Policies for Non-Renewable Technologies

- *Phase out policies for carbon intensive technologies*
    - This challenge primarily relates to electricity markets with stable or declining electricity demand, since additions of new renewable capacity will shrink the remaining market share for incumbent actors. Case study: Managing the Phase Out of Fossil Fuel Plants: Ontario, Canada (pp. 88)
- *Phase out policies for nuclear power*
    - Some countries have implemented phase out policies for nuclear power, since using this technology was no longer consistent with their visions of a sustainable power system. Even though nuclear phase out policies have no positive effect on carbon emissions, this policy can be beneficial for renewable energy deployment since excess inflexible generation capacity can be reduced.

3: Implementing Carbon Pricing

- *Establish a cap-and-trade mechanism*
    - Cap-and-trade mechanisms set caps for overall emissions in given jurisdictions (or industries) and enable emissions allowances to be traded. Carbon prices, however, can be volatile and can therefore fail to provide a sufficient investment signal for low-carbon technologies. Therefore carbon floor prices can be implemented additionally.
- *Establish a carbon floor price*
    - In order to provide investors with the adequate price signal for low-carbon technologies, policymakers can implement complimentary minimum carbon prices (i.e. floor prices) in addition to existing emissions trading mechanisms. Case study: Establish a Carbon Price Floor: United Kingdom (pp. 88)
- *Establish a carbon tax*
    - Carbon taxes are a frequently used alternative policy solution to cap-and-trade mechanisms. The carbon content of the burned fossil fuels is taxed. The tax level can be increased over time.
- *Climate contribution for carbon intensive technologies*
    - The climate contribution can be implemented in addition to existing cap-and-trade mechanisms. Power plants will have to pay an additional financial fee per unit of carbon. Certain free allowances per power plant can be used to only target the most carbon intensive technologies. Case study: Climate Contribution for Carbon Intensive Technologies: Not Yet Implemented (pp. 89)

4: Formulating Emissions Standards for Existing or New Power Plants

- *Zero or low emissions standards for all new capacity*
  - Policymakers can regulate that all new power generation units should be zero carbon emitters or simply renewable energy producers. This policy can be interpreted as a more aggressive renewable portfolio standard. Case study: Zero-Emission Standards for All New Capacity Additions: Not Yet Implemented (pp. 90)
- *Zero or low emissions standards for existing power plants*
  - Policymakers can formulate emission standards for existing power plants in order to drive the decarbonisation of power systems. The primary objective of introducing more stringent regulatory or performance standards is to phase out existing carbon-intensive power plants. By formulating increasingly stringent emission standards for existing power plants, policymakers can manage a gradual phase out of carbon-intensive generation. However, other pollutants from fossil fuel based power plants can also be regulated. Case study: Plant-level Emissions Intensity Limits for New and Existing Power Generators: U.S.A (pp. 90)

The implementation and potential combination of these policy solutions will depend on national regulatory traditions, priorities of policy objectives and anticipated ease of political implementation. The next section provides case studies to illustrate policy approaches for sustainable power system transformations.

7. DISCUSSION OF POTENTIAL POLICY FRAMEWORKS

Section 7 presents the full menu of potential policy solutions outlined in this report, and applies this menu to discuss what the Policy Framework Phase could look like for a set of illustrative contexts for contrasting countries where renewable energy technologies have become cost-competitive with conventional new-build generation.

The primary function of this section is to clarify for policymakers what the Policy Framework Phase will look like in practice, and how it may differ based on their unique national context. In order to do so, this section will sketch a set of hypothetical policy combinations in different illustrative example cases, including elements to support **Bankability**, **Flexibility**, and **Vision**.[40]

Table 7.1 shows the full list of potential policy solutions discussed in the previous three (3) sections.

Table 7.1. Full Menu of Potential Policy Solutions

Potential Policy Solutions	Market Structure	Variable RE Share	Governance Level
Maintaining the Bankability of Renewable Energy Projects (from Section 4)			
*Synthetic power purchase agreements**	Wholesale Energy Market	All	NA
Private bilateral offtaker contracts	All	All	NA
*Locational time-of-use price adjustments**	All	Low	All
*Hybrid energy and capacity payments**	Wholesale Energy Market	Medium	National, Regional
Tapping into new carbon revenues	All	All	All
Public private partnerships	Single Buyer Markets	All	National, Regional
*Flexible ramping products**	Wholesale Energy Market	Medium	All
*Participating in balancing and ancillary services markets**	Wholesale Energy Market	Medium	All
Locational or nodal pricing	Wholesale Energy Market	Medium	National, Regional
Enhancing the Flexibility of the Power System (from Section 5)			
*Require variable renewable energy to provide grid services**	All	Medium	Utility
*Support pilot studies to explore variable renewable energy flexibility services**	All	Low	Utility
Allow or require variable renewable resources to participate in wholesale power markets	Wholesale Energy Market	Low	National, Regional

[40] As highlighted previously, a key question in the Policy Framework Phase is whether the policy combination will enable projects to be bankable.

Potential Policy Solutions	Market Structure	Variable RE Share	Governance Level
Encourage more accurate variable renewable energy bids	Wholesale Energy Market	Low	National, Regional
*Change dispatch practices of non-variable renewable energy**	All	Low	National, Regional
Add contractually protected curtailment rules	Single Buyer Markets	Medium	All
Establishing a Long-term Vision for a Sustainable Power System (from Section 6)			
*Binding long-term renewable energy targets**	All	All	National, regional, utility
*Phase out policies for carbon intensive technologies**	All	All	National, regional
Phase out policies for nuclear power	All	All	National, regional
Establish a cap-and-trade mechanism	All	All	National, regional
*Establish a carbon floor price**	All	All	National, regional
Establish a carbon tax	All	All	National, regional
*Climate contribution for carbon intensive technologies**	All	All	National, regional
*Zero or low emissions standards for all new capacity **	All	All	National, regional
*Zero or low emissions standards for existing power plants**	All	All	National, regional

*explored in Case Study (see annexes)
Market Structures: monopolistic, single buyer, wholesale competition, or all of those
Variable RE Shares: low, medium, high, or all of those
Governance Levels: National, regional, utility

7.1. ILLUSTRATIVE CONTEXTS

Table 7.2 describes the three (3) illustrative country contexts

Table 7.2. Key Characteristics of Illustrative Country Contexts

Emerging Single Buyer Market	Wholesale Energy Market with a Low Carbon Strategy	Wholesale Energy Market Targeting High Shares of Renewables
• Emerging economy • Single buyer market • Targeting high (50%+) shares of variable renewables • Limited neighbouring interconnections • Low CO2 price • Increasing power demand	• Developed economy • Competitive wholesale market • Technology-neutral low carbon strategy • Medium CO2 price • Limited interconnections • Stagnating power demand	• Developed economy • Competitive wholesale market • 100% target for renewable generation • Low CO2 price • Good interconnection • Decreasing power demand

7.1.1. Illustrative Policy Framework for Country A: Emerging Single Buyer Market

'Country A' is an emerging economy with a single buyer market targeting high shares of variable renewable energy. Its power sector is also characterized by quickly growing demand, a long-established low CO_2 price, and limited interconnection with neighbouring nations. The grid is largely reliable and well-managed by a state-owned vertically integrated electric utility. The Policy Framework for Country A might consist of the following building blocks:

Table 7.3. Aspects of the Policy Framework for Country A

Policy Solutions for Country A
Maintaining the Bankability of Renewable Energy Projects
Hybrid energy and capacity payments
Locational time-of-use price adjustments
Private bilateral offtaker contracts
Enhancing the Flexibility of the Power System
Support pilot studies to explore variable renewable energy flexibility services
Add contractually protected curtailment rules
Require variable renewable energy to provide grid services
Establishing a Vision for a Sustainable Power System
Binding long-term renewable energy targets
Phase out policies for carbon intensive technologies
Zero or low emissions standards for all new capacity
Zero or low emissions standards for existing power plants
Establish a carbon tax

Potential Effects on Renewable Energy Deployment:

In Country A, the Integrated Resource Planning (IRP) creates binding capacity targets for all technologies, including renewable energy – due to the policy-driven emissions constraints considered in the planning exercise, high shares of renewable energy are targeted. Also resulting from the IRP process is a long-term plan for phasing out coal-fired power generators, which focuses on phasing out the oldest and least efficient power plants first. Strict carbon intensity limits are imposed for new power generators, assuring that new capacity consists of low- and zero-carbon technologies. With higher shares of renewables on the grid, dispatchable low-carbon power generators such as biomass are rewarded for both their energy and capacity contributions in competitive procurement processes. Wind and solar continue to sign long-term competitively procured energy contracts with the single buyer, but with *ex ante* hourly price adjustments that steer project developers toward high system value project locations. With limited interconnections available and a shrinking baseload fleet, the single buyer's System Operator identifies renewable energy development zones for the Procurement Office to ensure a favorable geographic dispersion of wind and solar that, in aggregate, contributes substantially to system reliability.

The power sector regulator, in collaboration with the single buyer utility and local standards boards, modifies the grid code and interconnection requirements, mandating that new variable renewable IPPs be technically capable of providing a range of grid services – to the extent that these grid services require curtailment, the single buyer retains a contractually defined right to do so in the long-term PPA. The single buyer also runs a pilot study in collaboration with an existing IPP to better understand how renewables might reliably provide frequency regulation.

7.1.2. Illustrative Policy Framework for Country B: Wholesale Energy Market with Low Carbon Strategy

Country B is a developed economy with a competitive wholesale market and a technology-neutral low-carbon strategy, specifically targeting an 80% reduction in power sector emissions by 2050 compared to 1990 levels. The Policy Framework for Country B might consist of the following key building blocks:

Table 7.4. Aspects of the Policy Framework for Country B

Policy Solutions for Country B
Maintaining the Bankability of Renewable Energy Projects
Synthetic power purchase agreements
Private bilateral offtaker contracts
Participating in balancing and ancillary services markets
Hybrid energy and capacity payments
Enhancing the Flexibility of the Power System
Allow or require variable renewable resources to participate in wholesale power markets
Encourage more accurate variable renewable energy bids
Require variable renewable energy to provide grid services
Establishing a Vision for a Sustainable Power System
Establish a carbon tax
Establish a carbon floor price
Phase out policies for carbon intensive technologies
Zero or low emissions standards for all new capacity

Potential Effects on Renewable Energy Deployment:

In Country B, the government is keen on establishing a low-emission standard for all new power plants and to phase out its existing coal-fired plants. While it has no legally binding renewable energy target, it plans to achieve a low-carbon power system by mid-century. One of the main policy instruments to achieve this objective is a cap and trade system accompanied by increasingly stringent environmental standards on air pollutants (mainly NOx, SOx and mercury). In order to ensure that the jurisdiction avoids one of the pitfalls that have plagued other carbon trading mechanisms around the world, it has introduced a price floor that will ratchet up over time.

In order to improve the bankability of future projects, it has loosened the rules governing private and bilateral power purchase agreements, enabling project developers to sign full or partial off-taker contracts with a range of new actors, including aggregators as well as the main utilities operating within the market, who are required to meet the increasingly stringent low-carbon standards. This will be instrumental to ensure that projects continue to be able to access financing. It has also phase out excess capacity, which, due to its flat electricity demand growth, has been instrumental in stabilizing wholesale prices at more attractive levels.

Due to its limited interconnections, flexibility is becoming a growing priority and it is responding to this need by adapting its dispatching protocols and beginning to require more flexibility from all generators within the system.

7.1.3. Illustrative Policy Framework for Country C: Wholesale Energy Market Targeting High Shares of Renewables

Country C is a developed economy with a competitive wholesale market targeting 100% renewable generation by 2050. The Policy Framework for Country C might consist of the following key building blocks:

Table 7.5. Aspects of the Policy Framework for Country C

Policy Solutions for Country C
Maintaining the Bankability of Renewable Energy Projects
Private bilateral offtaker contracts
Locational or nodal pricing
Participating in balancing and ancillary services markets
Enhancing the Flexibility of the Power System
Require variable renewable energy to provide grid services
Change dispatch practices of non-variable renewable energy
Encourage more accurate variable renewable energy bids
Establishing a Vision for a Sustainable Power System
Binding long-term renewable energy targets
Phase out policies for carbon intensive technologies
Establish a carbon tax

Potential Effects on Renewable Energy Deployment:

In Country C, the government has adopted an ambitious and legally binding long-term renewable energy target, including a clear phase out strategy for all non-renewable generation, including nuclear power. This overarching renewable energy target provides the strategic direction for the sector as a whole and has played an important part in giving investors, manufacturers, as well as other stakeholders the certainty they need to make long-term investments in the jurisdiction.

In order to support project bankability, it has opened up the legal and regulatory framework to greater private PPAs as well as aggregators, who are busy locking in supply primarily from the hundreds of thousands of small and medium power producers, effectively fulfilling the role that used to be filled by the government-backed single buyer. The long-term targets help ensure that there is sufficient market demand for new renewable energy projects, while the overall policy and regulatory stability help keep the costs of finance low. Renewable energy producers are also able to tap into new revenue streams by providing ancillary services as well as flexibility-related products.

While the jurisdiction has strong and deep interconnections with its neighbours, one of the main priorities remains enhancing the overall flexibility of the power system to respond to rapid changes in output from weather-dependent renewable energy projects such as solar PV and wind power. In response, it has developed advanced dispatching practices to extract more flexibility out of non-variable renewables like hydropower, bio-energy, as well as pumped-hydro systems, and it has adopted incentives to encourage producers (or the aggregators who purchase their power) to produce more accurate output forecasts and to coordinate in shorter intervals with the responsible system operator.

8. SYNTHESIS AND POLICY PRINCIPLES

This report offers a range of potential policy solutions for supporting renewable energy sources in the light of their increasing cost-competitiveness with conventional technologies. In short, we attempt to shed light on two important aspects that policymakers face:

1. **RE cost-competiveness**: Which benchmarks are crucial for understanding renewable energy cost-competitiveness?
2. **The future of renewable energy policy**: What kind of Policy Framework can be established once renewable energy technologies have become the least-cost source for new power generation?

This section summarizes the most important findings and related policy recommendations.

8.1. RENEWABLE ENERGY COST-COMPETITIVENESS

To understand renewable energy cost-competitiveness, policymakers need to understand and clearly differentiate the role of the most important cost-competitiveness benchmarks:

- Retail competitiveness, which is relevant primarily to distributed renewable energy technologies such as roof-top PV.
- LCOE competitiveness, which is relevant primarily for renewable energy technologies being developed in traditionally regulated electricity markets or markets with centralized procurement processes.
- Wholesale competitiveness, which is relevant for all renewable energy technologies that are operating in competitive electricity markets.

Neither of these competitiveness benchmarks is fixed; policymakers can influence the cost-competitiveness of renewable sources of electricity generation by modifying the broader energy policy framework, including changes to taxation, market rules, as well as other regulations.

8.2. POLICY FRAMEWORK PHASE

The primary focus on the “policy support” phase is to scale-up deployment, reduce the costs of RE, and cover the remaining cost-gap with conventional alternatives. Once renewables become the least-cost technologies for new power generation (LCOE Competitiveness), policy may begin shifting from the Policy Support Phase to the Policy Framework Phase.

According to the analysis set out in this report, the Policy Framework for a cost-competitive renewable energy technology consists of a context-appropriate combination of policies spanning the three pillars of the Framework Phase:

- **Maintain the bankability** of new investments in renewable energy technologies
- **Enhance the overall flexibility** of the power system, specifically in order to adapt to growing shares of variable renewables
- **Establish a long-term vision** for a clean, sustainable power sector

Implementing policies for enhanced flexibility and long-term visions for cleaner and more sustainable power system will also increase the bankability of new renewable energy projects. More flexibility will result in less curtailment and the avoidance of negative or very low wholesale market prices. The implementation renewable energy targets, phase out policies, carbon pricing or emission standards can reduce over-capacities and thus have an thus increase contribution margins for renewable energy producers in competitive wholesale markets.

8.2.1. Maintaining the Bankability of Renewable Energy Projects

Maintaining the bankability of investments in renewable energy is vital to ensuring a continued scale-up in renewable energy investment. **The issue of bankability can therefore be thought of as something of a "litmus test" for the overall Policy Framework**: Are renewable energy projects in my jurisdiction bankable? Can investors expect to recover their high upfront costs within a reasonable timeframe based on their current as well as any foreseeable future revenue streams (e.g. PPAs, wholesale markets, ancillary services, reactive power)? If renewable energy projects (of certain types, or in general) are not bankable, what can be done to improve bankability? And finally, even if one or a few projects can achieve bankability, is the overall policy and regulatory environment sufficient to support a significant scale-up of investment in the market?

This report has broken down the various policies for maintaining bankability into two basic categories:

1. **New contractual arrangements** governing the sale of electricity: In certain markets, new financial innovations such as hedging products and so-called "virtual PPAs" can help individual projects achieve bankability even in the absence of administratively-set long-term contracts or PPAs. Policymakers could seek to mobilize these innovations by introducing clear rules governing the design and settlement of these new arrangements, while ensuring that all new arrangements are consistent with the broader objectives of maintaining power system flexibility and reliability.

   Similarly, in markets where large electricity consumers have expressed a desire to participate more actively in the electricity market either directly by developing and owning renewable energy projects or by purchasing the output from such projects, the existing market rules could be designed to allow such bilateral power sales either for a part or all of a given project's output. Allowing private bilateral power sales can help increase the flow of capital to the renewable energy sector while increase the diversity of actors contributing to the transformation of the power system – it can also help unlock other parallel business models that would not otherwise be possible, such as dedicated electric recharging facilities purchasing renewable power.

   As the share of renewable energy grows, the number of actors involved in a given market also tends to grow. This includes both a greater number of generators, as well as a greater number of intermediaries such as aggregators. Policymakers could seek to develop new rules to allow new business models and actors to participate in the electricity system, and aid in its transition to higher shares of renewables by providing both supply and demand-side solutions. In some cases, this will simply involve eliminating restrictions; in others, it will involve actively encouraging the rise of new actors in a more pro-active way, such as through restructuring, unbundling, or the simple removal of an existing actor's monopolistic or single buyer status.

2. **New products or services that can provide additional revenue streams**: In the Policy Framework Phase, policymakers could seek to develop new products or platforms (e.g. ancillary services markets) that can help diversify the revenue streams of RE producers while encouraging them to participate in providing balancing, ramping, frequency regulation, and other valuable system services. While such requirements have been seen negatively by some in the renewable energy industry, a greater level of market integration, service provision, and responsiveness by renewable energy producers is likely necessary for all power systems with high and growing shares of variable renewable energy.[41]

   Another option that policymakers could adopt is a form on the floating premium model, which provides a fluctuating premium for renewable energy producers on top of wholesale market prices. This can help directly address the "missing money problem" (see Text Box 4.3) reduce the risks associated with financing high fixed cost technologies in environments with low wholesale market prices, while improving overall project bankability.

8.2.2. Enhancing the Flexibility of the Power System

Flexibility is a key pillar of the Policy Framework Phase because as variable renewable energy resources increase in penetration levels, the system must be sufficiently flexible to accommodate the added variability and uncertainty and still maintain reliability. Yet, variable renewable energy sources can also *supply* flexibility.

Advances in technology enable many types of variable renewable energy generators to provide a full suite of balancing services necessary for system flexibility. As variable renewable energy displaces conventional generation, it becomes a critical source for flexibility.

For variable renewable energy to supply flexibility, the power system operator must have *access* to this flexibility. A variable generator is only flexible if the dispatcher has the means to access that flexibility.

Thus, policies to procure flexibility from renewable energy address two goals, creating our two categories of policy solutions:

1. **Increase the physical supply of flexibility from RE:** These policies (e.g., grid codes) incentivize or require variable renewable energy generators to offer the full range of technical capabilities to provide system flexibility, such as automatic generation control.

2. **Increase institutional access to this flexibility:** These policies (e.g., market rules) incentivize or require variable renewable energy generators to be available to supply this flexibility, and include variable renewable energy as eligible providers for grid services.

In addition to flexibility from variable generators, opportunities exist to extract additional flexibility from non-variable generators, such as hydropower, a traditional source for flexibility. Market signals, such as negative prices, can be used to help increase load or decrease supply during periods of oversupply. Also, renewable energy policies and contracts can be designed to reflect the value of non-variable RE's flexibility offerings, such as that from biogas plants.

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[41] Naturally, policymakers may choose to exempt power producers below a certain size from these requirements (e.g. 100kW), as the transaction and other costs may not be worthwhile.

A system with flexible operations positively impacts bankability. A more flexible power system will be more sustainable and therefore more bankable for variable renewable energy.

8.2.3. Establishing a Long-term Vision for a Clean and Sustainable Power System

Power sectors are quickly evolving – by establishing a coherent vision or roadmap for sectoral transformation, policymakers can help increase investor certainty for all generation technologies, including renewable energy technologies. These vision policies may be considered an indirect policy in the broader framework for renewable energy technologies.

Policies for low-carbon transitions can be grouped into four categories:

1. Setting binding renewable energy targets: The primary objective of binding renewable energy targets is to reserve a certain and increasing market share for renewables. This will give potential investors more long-term certainty regarding the future development of the electricity mix. This will remain critical in the coming decades, since other framework conditions (e.g. market design) is likely going to chance and thus induce additional risks for investors.

2. Phasing-out non-renewable technologies: Fossil and nuclear phase out policies can lead to carbon and other emission reductions and create space within the market for additional capacity additions from renewable energy technologies. This challenge primarily relates to electricity markets with stable or declining electricity demand, where overcapacities are an increasing structural problem, although in the long-run, all jurisdictions will need to deal with issues relating to phasing-out existing or aging generation capacity.

3. Implementing carbon pricing: Pricing carbon can help to create a level playing field for RE technologies. Carbon policies can also increase market-based revenues for renewable energy producers, since decarbonisation policies lead to the internationalization of negative external effect and thus can increase the market clearing price in competitive wholesale market. Currently, new renewable energy plants often compete against old, amortized, carbon intensive power generation technologies. A large set of policy options exists for policymakers, including cap-and-trade mechanisms, carbon taxes, carbon floor price, and others.

4. Formulating emission standards for existing or new power plants: By formulating environmentally sound emission standards for existing or new power plants, policymakers can foster the deployment of renewable energy technologies. Next to carbon, the emission standards for other pollutants (SOx, NOx, water consumption levels, radioactive particles), are an important intervention point.

9. APPENDIX – CASE STUDIES

In order to highlight for policymakers the various policy solutions that are the most relevant or applicable to their jurisdictions, the individual solutions include a brief “**applicability filter**” featuring three different aspects:

- the **market context** (whether single buyer or jurisdictions with competitive wholesale markets);
- the **share of variable renewable energy** at which the policy solution becomes relevant (low, medium, high);
- and finally, the **level of governance** at which the various solutions apply most directly (national governments, regional or state-level governments, or at the utility-level).[42]

The function of this filter is to help policymakers orient themselves, and identify policy solutions that may be relevant to their particular market context.

9.1. BANKABILITY CASE STUDIES

9.1.1. Synthetic Power Purchase Agreements: U.S.A.

Context:

In the United States, low natural gas prices, the anticipated expiry of the U.S. Production Tax Credit (which has been renewed recently) (Sweet, 2015), combined with the fact that many utilities have already surpassed or are near reaching their Renewable Portfolio Standard (RPS) obligations has left a number of renewable energy producers (onshore wind power producers in particular) seeking alternative ways of structuring off-take agreements that do not rely on securing PPAs from traditional electric utilities (Marks and Rasel, 2014). In recent years, this has given rise to what has been called the “Synthetic PPA”, particularly in liberalized markets like Texas, PJM, and the NYISO region (Chadbourne, 2013).

In Texas, prices for wind PPAs in Texas have declined to the USD $20/MWh range, due in large part to a combination of a $23/MWh federal tax incentive and an excellent wind resource (Bailey, 2015). Texas also has a highly competitive and liquid wholesale spot market, a well-developed market in financial products and services, as well as a sophisticated system of nodal prices and regional trading hubs to reduce congestion, all of which increases transparency for both new and existing actors. In addition, wind power developers have been able to profit from a well-designed land-use planning and zoning regime to develop their projects. Taken together, these factors have helped make Texas, which now has over 16GW of installed capacity, the leading state in terms of installed wind capacity in the U.S. (AWEA, 2015). As the availability of PPAs begin to dry up, however, wind developers in Texas have begun to seek out new ways of financing wind power without relying on traditional PPAs.

[42] Utility level solutions refer to policies implemented at the utility level rather than at the regional, national, or supra-national level. While this is uncommon in the EU, where even highly technical regulatory and policy issues are typically governed by national or supra-national policymakers (e.g. the European Commission), utility-level policy-making is quite common in the U.S., Canada, as well as in other markets around the world such as South Africa, and Japan.

Policy Solution:

Under many of the hedging contracts that are being signed in Texas at the moment, project developers are effectively signing contracts with financial institutions that guarantee a certain revenue (the "strike price") for a portion of their power output. Under a synthetic PPA, the power producer sells its electricity directly into the wholesale spot market and receives the prevailing market price; however, in order to compensate for the volatility and unpredictability of spot (or day-ahead) market prices, the power producer signs a contract for a financial product known as a "hedge" in order to provide protection against this volatility and increase the stability of future cash flows.

Due to the obligations imposed by the hedge provider (usually a bank or large trading house), wind producers need to guarantee a certain minimum level of production – due to forecast uncertainties, and the desire to avoid having to buy power during times of high prices to supply their agreed-upon volumes, wind producers typically opt to contract only a portion of their output (e.g. 70%), and sell the remainder directly on the wholesale market. In contrast to a standard 20-year PPA, however, most of these contracts range from 10-13 years. Approximately 1/3 of the 4.8GW of wind power installed in Texas in 2014 was financed using hedges in the form of partial offtaker contracts (Bailey, 2015).

In this way, the Synthetic PPA effectively enables project developers (in combination with federal tax incentives) to secure debt and equity financing required to finance their projects. In some cases, the counterparty signing the Synthetic PPA is a power marketer (or aggregator), while in others it is a financial institution, one that seeks to benefit from providing a hedging product on the expectation that power prices will be higher than the price signed as part of the Synthetic PPA. If the price agreed in the Synthetic PPA (the so-called "strike price") is lower than spot market (or day-ahead) price, the provider of the hedge (i.e., the offtaker) pays the difference to the producer; if it is higher, the project developer or owner pays the difference to the provider of the hedge contract.

This kind of solution underscores how actors in the liberalized markets are responding to the reduced availability of long-term offtaker contracts. While Synthetic PPAs are not a "policy solution" in the sense of having been developed and implemented by the regulator or a government ministry, they highlight how actors are taking steps to achieve bankability for technologies that have entered what this study has called the Policy Framework Phase. This also highlights how some of the roles previously fulfilled by government can be fulfilled by the private sector (e.g. establishing PPAs in the open market).

Applicability:

Market Context	Variable RE Share	Governance Level
Liberalized	All	All

9.1.2. Locational Time-of-Use Price Adjustments: Mexico

National Context:

The Government of Mexico has recently introduced a range of far-reaching power sector reforms, including the creation of an independently operated wholesale electricity market operator (CENACE) and efforts to encourage the emergence of a greater number of independent power producers (IPPs). This signals a significant shift away from the previously dominant role of the Federal Electricity Commission (CFE), which owned approximately 85% of generation and was responsible for power sector planning (Save et al., 2014).

Policy Solution:

Under the new electricity sector law, project developers, distributors, and other offtakers will be allowed to sign long-term (15-year) contracts for clean energy through auctions organized and administrated by CENACE. These same generators can participate in auctions for capacity (15-year terms) and clean energy certificates (20-year terms).

The Mexican government has set out to provide long-term certainty to renewable energy developers and financiers, while at the same time encouraging the development of variable renewable energy projects that generate power when and where the system needs it most. To accomplish this, CENACE and the Ministry of Energy (SENER) developed a methodology which calculates an effective ex ante "benchmark" price adjustment (based in Mexican pesos or USD per MWh) that is calculated on an hourly basis for each generation zone – in the process, CENACE produces hourly price benchmarks for an average 24-hour period of each month of each year of the 15-year contract, effectively setting out a detailed schedule of anticipated prices, as the benchmark price adjustment is then added to each generator's contract price. When the benchmark is positive in a given location and hour, this reflects an ex ante expectation that power generation will be of a higher value to the system, and additional compensation above and beyond the contract price is provided to the generator. When the benchmark is negative, compensation is adjusted downward below the contract price, reflecting the projected lower value of that generation to the system.

The entirety of the location-specific 15-year benchmark trajectory is published in advance of a given long-term energy contract auction, and is intended to steer project developers toward selecting more "system-friendly" project locations. Project developers who are confident that their project can maximize the upside of the benchmark mechanism may be able to offer a lower contract price, and thus have a higher likelihood of securing a long-term contract in the auction. Generally speaking, this innovative approach to procurement attempts to align two often disparate concepts in power system planning: project site selection that is good for the investor, and project site selection that is good for the system at-large. In doing so, this approach exposes the variable renewable energy project developers to a quantifiable and predictable amount of upside and downside risk, helping to preserve overall project investability.

Applicability:

Market Context	Variable RE Share	Governance Level
All	Low	All

9.1.3. Hybrid Capacity and Energy Payments: Not Yet Implemented

National Context:

Since 2014, due to a change in market rules, renewable energy producers above a certain size in Germany are obliged to sell their power either onto the wholesale market or to a third-party rather than to the government-backed single buyer as was the case in the past. However, despite significant cost reductions over the last decades, renewable energy technologies like solar and wind still cannot be financed based on wholesale market prices alone. Currently, the feed-in tariff mechanism is offering a so-called "floating premium" on top of wholesale market prices. The premium payment is determined ex-post at the end of each month, based on the monthly average wholesale market price for PV and wind energy (Couture, Jacobs et al., 2015).

To a certain extent, the producers of wind and solar electricity can increase their revenues by selling their electricity in hours when other wind and PV producers are not. However, this potential for revenue optimization is rather limited, and the costs of shifting their output from one time of the day to another are comparatively high.

However, in order to meet Germany's ambitious renewable energy targets of 80% by 2050, a number of proposals have been advanced to attempt to incentivize renewable energy producers to adjust their output to make it more responsive to overall system needs while simultaneously providing sufficient revenues to make projects bankable.

Policy Solution:

Instead of granting renewable energy producers a per-kilowatt-hour payment on the wholesale market prices, the think tank Agora Energiewende has put forward a proposal for a **hybrid energy-and-capacity payment** that would supplement revenues obtained on the spot market with a fixed capacity payment per kW installed (Matthes, Graichen, et al., 2014). Under this proposal (which was not implemented but may be of interest to other policymakers elsewhere), the policy would involve setting the capacity payment according to how well the individual power plant is able to respond to the needs of the overall power system. In other words, the power plant should receive an incentive to produce electricity at times and in the location when and where electricity is needed (e.g. by facing solar PV systems east and west instead of south as most solar PV systems in Germany today).

As the proposal is structured, renewable energy producers would face greater exposure to actual wholesale market prices and would therefore have a greater incentive to modulate their output to support more system-optimal operation where and when possible. This could involve consuming or storing more power onsite on a flexible basis, or finding an alternative third-party buyer (e.g. an aggregator) to purchase any excess power that could be sold at a higher price than the prices available on the wholesale market. One of the main objectives of the proposal is to make the combination of capacity payments and revenues from wholesale electricity markets sufficient to finance future renewable energy projects in Germany without any further policy support.

The main challenges under this proposed approach is determining the appropriate level of capacity payments, as there is insecurity about the future development of wholesale market prices (the other main source of income under this approach), and how often the capacity payments themselves are revised. However, if well-designed, this combination of energy and capacity payments could help support bankability and provide an alternative to traditional energy-only markets and traditional capacity markets.

Applicability:

This policy solution is primarily applicable for liberalized power markets with high shares of variable RE sources, i.e. when other flexibility options are no longer sufficient to match supply and demand.

Market Context	Variable RE Share	Governance Level
All	Medium	National or State Level

9.1.4. Flexible Ramping Products: California

National Context:

California has been developing significant volumes of variable renewables like wind and solar to meet its 33% Renewable Portfolio Standard (RPS) target by 2020, with 13TWh of wind power and 10.5TWh of solar PV as of 2014 (California Energy Commission, 2014). While this remains an important achievement, it has also led to a unique set of challenges. In particular, California regularly faces a steep generation requirement in the early evening as the solar power across the state ramps down – this has been referred to as the “duck curve” (Crawford, 2015).

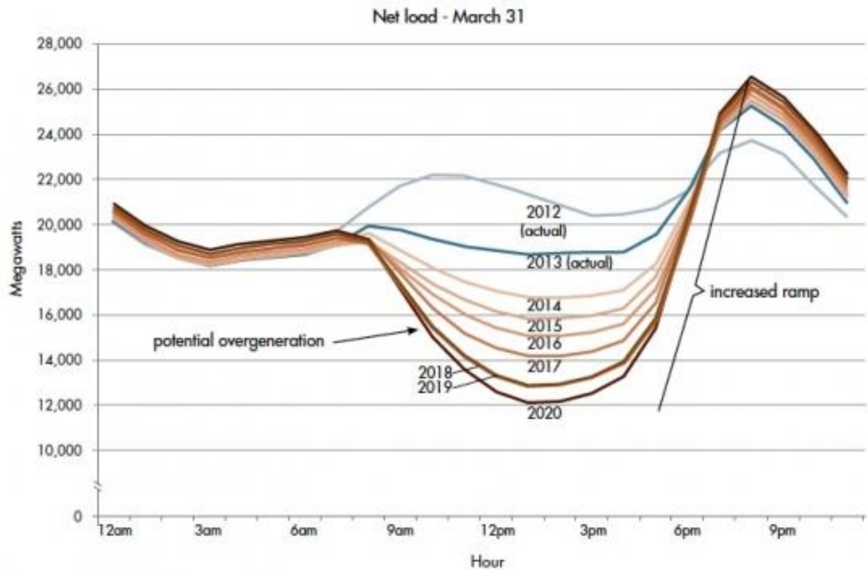

Figure 9.1. California Duck Curve (California Independent System Operator; CAISO)

The duck curve underscores the need for resources (or institutional processes) that can rapidly respond to rapid changes in net load, a key requirement for power systems with growing shares of variable renewable energy (Denholm et al. 2015). In response to this growing demand to secure the bankability of flexible sources of generation, in particularly in the locations required, California has developed a set of products to target this particular need (CAISO, 2013). Since the focus is on making flexible resources bankable, this short case study is included here rather than in Appendix 9.2.

Policy Solution:

In order to respond to this unique operational requirement, the California Independent System Operator (CaISO) has outlined a set of key operating capabilities that flexible resources must be able to provide, including:

- Sustained upward or downward ramp;
- Change ramp directions quickly;
- Respond rapidly within a defined period of time to sudden changes in operation requirements;
- Store electricity or rapidly modify onsite demand;
- Ability to start and stop several times over the course of a day;
- Ability to accurately forecast available operating capabilities;

The Flexible Ramping Product that is now being finalized will be bid on a competitive basis in real-time, and will be continuously procured and dispatched within California's real-time dispatch operations. In order to qualify, the resource or technology must be able to respond to changes in net load within a 5-minute timeframe. The "Real Ramping Need" that is required reflects the actual, real-time system need for flexibility at that moment.

The stated goal of the new policy proposal in California is to allow for the "*identification, commoditization, and compensation*" of the required flexible capacity in a system with growing levels of variable renewable energy (CAISO, 2015). The continuous competitive bidding will result in clear, market-based pricing for flexibility, which renewable energy producers will potentially be able to tap into for additional revenues. This mechanism could therefore help improve the overall bankability of new flexible resources.

It is unclear at this stage; the bidding has not yet been launched.

Applicability:

Market Context	Variable RE Share	Governance Level
Liberalized	Medium to High	All

9.1.5. Variable Renewable Energy Participation in Balancing and Ancillary Services Markets: EU

National Context:

In the EU, a number of stakeholder consultations have been held to discuss the various rules and regulations that will govern the future structure of bidding for the provision of balancing and ancillary services (ENTSO-E, 2015a). The development of markets for ancillary services is in direct response to the growing share of variable renewable energy sources and the increasing need to ensure that a range of ancillary services in the European electricity sector are provided and remain bankable, including frequency response, rapid reserve, black start capabilities, and reactive power (ENTSO-E, 2015b). The goal of these consultations, which are underway between the various transmission system operators (TSOs) across the EU, is to arrive at a common set of rules and products that will govern the future provision of these services. There are also parallel consultations underway on the provision of other complex products such as "automatic Frequency Restoration Reserves" (aFRR) as well as "Frequency Containment Reserves" (FCR) as well as a range of other innovative products in the ancillary services market.

Policy Solution:

In the most recent stakeholder consultation documents available for the structure of balancing and ancillary services markets (October 2015), a number of different criteria are set out for the kinds of products for which different bidding platforms will be developed (ENTSO-E, 2015a). These criteria include the minimum and maximum delivery time, the means by which the ancillary service is activated (continuously or via a clearing process) as well as the eligible bid size (which has been decreased in the most recent consultation documents from 5MW down to 1MW in order to recognize the role that smaller loads and generators can play in ancillary services provision).

At the moment it is unclear what the bid prices will be and whether they will be sufficient to incentivize renewable energy producers to begin participating in ancillary services and balancing markets more actively. If they begin to participate and can provide competitive bids, these various ancillary services could provide an additional source of revenues that could improve the overall bankability of certain renewable energy projects, or certain technologies. It could also provide additional incentives for more location-sensitive renewable energy project siting, in the event that location-specific pricing signals are introduced in the future. While participating in ancillary services markets is unlikely to be decisive in determining a renewable energy project's bankability in today's electricity markets, it could well become decisive in the years ahead as products grow in number and complexity, and as the value of the services grows.

Applicability:

Market Context	Variable RE Share	Governance Level
Liberalized	Medium	All

9.2. FLEXIBILITY CASE STUDIES

9.2.1. Utilize Variable Renewable Resources to Provide Grid Services: Colorado, USA

National Context

Xcel Energy is a vertically integrated investor owned utility in Colorado, USA with a peak load around 7 GW. Although currently over half of its energy coming from coal-fired power stations, it is on track to comply with a 30% renewable portfolio standard by 2020. Xcel is a relatively isolated system, with limited transmission ties to other systems, and therefore must maintain balance primarily within its jurisdiction. Already Xcel has experienced large instantaneous penetrations of energy, including several times over 60% (Goggin, 2013). The utility has plans for continued expansion of their wind power fleet, and has been highly motivated and proactive in studying and addressing a range of wind integration issues (Xcel and EnerNex, 2011).

Policy Solution

Beginning in 2011, Xcel began utilizing Automatic Generation Control (AGC) capabilities at many of its wind facilities – today, over two-thirds of its wind facilities have AGC, allowing for the central grid operator to have direct control over wind turbines to provide regulation and load following services. If the flexibility in the conventional fleet is exhausted (e.g., due to minimum turn-down limits), Xcel employs its wind plants with AGC capabilities. Xcel also uses curtailed wind to provide both positive and negative reserves, and retains the right in its power purchase agreements with wind generators to curtail wind generation as the system deems necessary (Bird et al., 2014; Weiss and Tsuchida, 2015). Wind-provided AGC can help provide a cost-efficient source of regulation, and adds to the flexibility available to the power system operator. By providing wind plants a setpoint via its economic dispatch process, Xcel's average annual wind energy curtailments have gravitated near 2% of wind energy production in recent years. Xcel has also made use of more advanced power electronics to allow their wind generators to provide automated frequency response services. Wind turbines have a faster response time in the first ~15 seconds following large drops in frequency than conventional generators, which can help to improve overall system reliability and performance after contingency events.

Applicability

Market Context	Variable RE Share	Governance Level
All	Medium	Utility

9.2.2. Support Pilot Study for Wind Providing Secondary Reserves: Belgium

National Context:

Secondary (spinning) reserves are frequently procured from gas-fired units in Belgium, leading to higher must-run costs for the system. The Belgian system operator Elia has identified the need to diversify spinning reserves resources, and recognizes that variable renewable resources could become a significant contributor given their increasing role in the market. However, there has been a minimal amount of institutional experience to-date with utilizing variable renewable resources for secondary reserves.

Policy Solution:

A technical pilot project was assembled to explore the feasibility of wind turbines providing secondary reserves to the Belgian system, and for stakeholders to gain and share relevant experiences publicly. The pilot study occurred on the Estinnes Wind Farm, and involved the project owner, the wind turbine manufacturer, the offtaker utility, and the system operator.

Specifically, the study explored over a 2-month period the provision of *downward* secondary reserves, as providing upward secondary reserves requires withholding energy production, which would result in the loss of green certificates for the wind farm. The study found that wind farms can likely exhibit a high level of performance for providing secondary reserves, and highlighted a series of technical considerations related to forecasting and dispatch practices that could be improved to ensure reliable delivery of secondary reserve products. On top of exploring the technical feasibility, the pilot study highlighted that energy production based support schemes for wind might act as a barrier for future participation of wind generators, despite their technical capability to do so (Voet, 2015).

By exploring both technical and market aspects to be investigated further, this pilot project represents an important first step towards greater utilization of variable renewables for meeting system flexibility and reliability needs.

Applicability:

Market Context	Variable RE Share	Governance Level
All	Low	Utility

9.2.3. Requiring Wind to Provide Reactive Power: United States

National Context:

System operators control voltage and maintain reliability by requiring generators to produce or consume reactive power. Historically, wind generators, which lacked inverters, could not produce and control reactive power. The equipment necessary to provide this power was deemed too expensive.

However, equipment to provide this service is now commercially available, and prices for inverters have since fallen. Costs to wind generators are now comparable to that of a synchronous generator.

Policy Solution:

In November 2014, the U.S. Federal Energy Regulatory Commission (FERC) proposed that it revises its 2005 interconnection requirements for wind generation, and stop exempting wind facilities from providing reactive power (FERC, 2015). This proposal follows on a recent decision to accept a similar proposal by the Pennsylvania-New Jersey-Maryland (PJM) Interconnection. The ruling also requires that this supply of reactive power be dynamic, which characterizes the speed and ability to continuously respond to changing system conditions.

If the proposal is accepted and published, the requirement to supply reactive power would apply to all plant upgrades and new generation (synchronous and non-synchronous). Due to potential cost barriers, the exemption would be maintained on existing wind generators. Wind plants generating less than 10% of nameplate capacity would also be exempt from supplying reactive power.

Applicability:

Market Context	Variable RE Share	Governance Level
All	Medium	National, Regional

9.2.4. Incentivizing Flexibility from Biogas: Germany

National Context:

Germany has ambitious long-term targets for renewable energy sources in the electricity sector (at least 80% by 2050). Dispatchable renewable energy technologies such as biogas will provide a critical role in maintaining system balance as wind and PV comprise more than 50% of the electricity mix.

From 2000 until 2012, biogas producers in Germany benefited from a national feed-in tariff mechanism. Since every kilowatt hour was remunerated equally, there was no incentive to follow wholesale power market signals. Instead, biogas power producers tried to maximize feed-in tariff revenue by operating continuously at maximum power, even when market did not value this generation (Bofinger et al., 2010).

Policy Solution:

In 2012 and again in 2014, Germany amended the support framework for biogas in order to take better advantage of the dispatchability of this technology. Producers of biogas power plants larger than 100 kW can now opt for a combined payment for the installed capacity and the kilowatt-hours produced and sold on the spot market plus a premium payment (BGBl, 2014). This "flexibility premium" consist of a fixed capacity payment of in order to finance the high installed costs of the biogas plant. The payment levels vary for existing and new plants. The biogas producer no longer receives a fixed FIT payment for each kilowatt-hour produced. Instead, the power has to be sold directly on the volatile spot market where prices reflect supply and demand. In addition, the new regulation states that the biogas operator is not allowed to run the plant at maximum power all the time. In order to benefit from this flexibility payment, biogas plants need to be remote-controllable. It should be noted that with the 2012 and 2014 policy amendment, the growth of the biogas sector in Germany was significantly slowed down. However, this was not due to the implementation of the flexibility premium but instead to reduced tariff payment levels.

Applicability:

Market Context	Variable RE Share	Governance Level
All	High	National, Regional

9.2.5. Extracting Additional Flexibility From Large-scale Hydropower: India

National Context:

India has approximately 40 GW of installed hydropower, which serves an important role for both agricultural water supply and electricity supply. Hydropower schedules are typically based on daily requirements for water releases to serve agriculture. But even under scheduling constraints to serve agriculture, hydropower can contribute to system flexibility on a minute-to-minute basis if incentivized.

Policy Solution:

The Central Electricity Regulatory Commission (CERC) has required hydropower plants under its jurisdiction to meet a "normative annual plant availability factor" (NAPAF) of approximately 80%, which roughly translates to requiring that the average daily available capacity of the hydropower plant, when inflow is available, must be equal to 80% of the installed capacity in MW. The purpose of this is to ensure that hydropower plants are available to operate close to installed capacity for at least three hours of every day, as opposed to operating at lower capacities for longer (ICRA, 2009). This better enables the hydropower plant to serve as a peaking unit. If plants are available to operate above NAPAF for 3 hours, they are eligible for financial incentives.

The Power System Corporation of India (POSOCO) has evaluated the availability of hydropower to contribute to system flexibility and has compared power plants under CERC regulation with plants under various state regulatory bodies that do not require this availability factor (POSOCO, 2015). POSOCO determined that a key policy to improve system flexibility would be for state regulatory bodies to extend this requirement to hydropower plants under their jurisdiction.

This regulatory model is not limited to hydro's role as a peaking unit, but could be broadened to provide financial or regulatory incentives to have hydropower plants be available for other grid services, for example, to be available to provide threshold ramping rates.

Applicability:

Market Context	Variable RE Share	Governance Level
All	Low	National, Regional

9.2.6. Extracting Additional Flexibility From Small-scale Hydropower: France

National Context:

For many decades, France has been making use of its hydropower capacity to balance supply and demand. Previously, hydropower was used to back up nuclear power plants in times of high electricity demand. Since the 2000s, the share of variable renewable energies increased considerably, with now about 9 GW of installed wind capacity and 5.6 GW installed PV capacity in 2014. In 2030, the share of non-dispatchable renewables (wind power, PV, run-of-river hydro and inflexible biomass) is planned to contribute 25-33% of total electricity generation (Fraunhofer IWES, 2015).

Policy Solution:

Since 2001, small-scale hydro power projects (up to 3 MW) have been compensated via a feed-in tariff. In order to encourage these projects to operate flexibly, a payment regime based both on the time of year and the time of day was established (J.O., 2001; J.O., 2007)[43]. From November until April, the period of the year with the highest power demand, hydropower producers receive an increased tariff. Likewise, the tariff is slightly lower from 10 p.m. to 6 a.m. year round during off-peak periods. From December to March, two peak demand hours in the morning and in the evening are remunerated with a higher tariff payment.

Hydropower producers can and do opt into these time-differentiated tariffs. Alternatively, they can receive one single tariff (no differentiation), remuneration based on two components (summer and winter), four components (summer, winter, off-peak and normal demand) or five components (summer, winter, off-peak, normal demand and peak-demand periods).

Applicability:

Market Context	Variable RE Share	Governance Level
All	Low	National, Regional

[43] Time-differentiated tariffs apply to installations on the French mainland, not to those in the overseas territories.

9.3. VISION CASE STUDIES

9.3.1. Binding Renewable Energy Target Setting: Denmark & Sweden

National context:

As of mid-2015, there are 164 national governments around the world that have adopted renewable energy targets, making them a defining feature of the global energy landscape (Kieffer and Couture, 2015). This number includes jurisdictions that have relatively modest targets of 10% strictly of renewable sources of electricity (RES-E) by 2030 to highly ambitious targets to reach 100% of total energy consumption by 2050. Renewable energy targets are not innovative perse but will likely play an important role in the future for countries which target very high share of renewables, since they give a clear indication of how the electricity market will develop.

Binding renewable energy targets[44] can play an important role in creating investor certainty and in mobilizing capital. While renewable energy targets have occasionally been criticized as a form of "demand pull" (the artificial creation of demand for renewable energies, in a situation in which the market itself would not be investing in renewables), the case of island regions (e.g. Haiwaii) as well as the EU more broadly demonstrates that cost-competitiveness alone is often insufficient to drive a significant and sustained transformation of the generation mix due to a host of market, technological, infrastructural, as well as cognitive barriers (Rader and Norgaard, 1996; Kieffer and Couture, 2015). As such, binding renewable energy targets may still be necessary in many jurisdictions, even if renewable electricity technologies are fully competitive (and even significantly cheaper) than existing conventional generation.

Policy solution:

As the above suggests, renewable energy targets help and are even crucial to govern the transition of the energy and electricity system in the decades ahead, even if renewable energy technologies are cheaper than conventional alternatives. In this sense, binding renewables targets (binding targets in particular) can be seen as a way of ensuring that the market and supporting supply chain develop in a certain way (such as toward full decarbonization, as has been adopted in Sweden). In the case of Denmark, which has adopted a 100% renewables target by 2030 for its electricity system, the target has played a significant role in mobilizing both citizens and power utilities to take measures to achieve it (Couture and Leidreiter, 2014). In addition, the renewable target is supported by a wide range of other complementary policies, including a high carbon price, as well as a clear strategy to phase out coal use for power generation. This underscores how specific policies like renewable energy targets can be used synergistically in order to encourage the development of a successful energy system transition.

Applicability:

Market Context	Variable RE Share	Governance Level
All	All	National, regional

[44] Experience from around the world indicates that the structure and design of renewable energy targets varies widely, from purely aspirational targets to legally binding renewable energy targets with clear penalties and compliance schedules. Clearly, binding targets send the strongest signal to the investment and project developer community.

9.3.2. Managing the Phase Out of Fossil Fuel Plants: Ontario, Canada

National Context:

Policymakers from several jurisdictions around the world have announced plans to phase out coal or lignite power plants in the coming years, e.g. Alberta (Canada) (Government of Alberta, 2016) and the U.K. (The Economist, 2015). In other jurisdictions such as Germany, NGOs and think tanks are calling for a coal phase out in order to reach mid-term carbon reduction targets (Agora Energiewende, 2015b), while in the U.S., an estimated 51GW of aging coal capacity is scheduled to be retired in the coming years (Dimsdale et al. 2015). However, Ontario in Canada is one of the few jurisdictions worldwide that has actually implemented and finalized the phase out of all of its coal-fired power plants between 2004 and 2014. In 2007, coal still accounted for approximately one fourth of the provinces' electricity generation, produced by five coal-fired power plants. However, all power plants relatively old and owned by the government, while most of the coal used for power generation was imported. The campaign for the phase out of coal started in the late 1990s and primarily focused on the negative health impact of coal-fired power plants. In the early 2000s, all political parties committed to the coal phase out, however with different timelines (Harris et al., 2015).

Policy Solution:

Implementing the phase out policy in Ontario was relatively straight forward, since the Ontario government owned all power plants and absorbed all costs related to the coal phase out. First, an aggressive phase out until 2007 was implemented by the government in 2004. However, the timeline was changed in order to reduce hardship and other negative impacts and the last power plant was eventually disconnected from the grid in 2014. The Ontario government also combined the coal phase out with several other energy policies, such as a support program for renewables. At the same time, it was shown that the available renewable energy potential from biomass, wind and PV could readily replace the existing coal capacity (Harris et al. 2015).

Applicability:

Market Context	Variable RE Share	Governance Level
All	All	National, regional

9.3.3. Establish a Carbon Price Floor: United Kingdom

National Context:

The U.K. is pursuing a low-carbon strategy for the electricity sector. In 2008, the government passed the Climate Change Act including emission reduction targets of 34% by 2020 and at least 80% by 2050. The U.K. wants to reach this target by investing in a range of low carbon technologies, including energy efficiency, renewables, nuclear and carbon capture and storage (UK Government, 2008).

However, the European Emissions Trading scheme did not deliver the initially expected carbon prices of about 30 €/tonneCO_2. Instead, EU ETS carbon prices fell below 20€/tCO_2 in 2009 and below 10€/tCO_2 in 2011. In 2013, prices gravitated below 5 €/tCO_2 for several months.

Policy Solution:

In order to provide investors with the adequate price signal for low-carbon technologies, the UK decided to implement an additional and complimentary minimum carbon price in 2012 to bolster the existing EU carbon price. This is important since most low-carbon technologies are highly capital intensive and therefore investors require knowledge about long-term price trends which cannot be provided by volatile carbon market prices.

If the price of the European emissions trading scheme drops below a certain level, electricity producers have to pay the difference to the UK Treasury. Initially, the carbon floor price was scheduled to increase to £30/tCO_2 by 2020. However, due to continuously low European carbon prices, policymakers in the UK feared that a significantly higher national carbon price would put its industry at a competitive disadvantage (HM Revenue & Customs, 2014). Therefore, the carbon price floor is capped at £18/tCO_2 from 2016 to 2020.

Applicability:

Market Context	Variable RE Share	Governance Level
All	All	National, regional

9.3.4. Climate Contribution for Carbon Intensive Technologies: Not Yet Implemented

National Context:

In 2014 it became apparent that Germany would fall short in meeting its 2020 carbon reduction targets (40% reduction compared to 2050 levels) without additional policies in the power sector. Emissions were 26 percent below 1990 levels (BMUB, 2014). Despite the rapid roll-out of renewables, the German energy sector is still dominated by coal contributing with 48% to the national electricity mix (AGEB, 2015). The instrument for additional CO_2 reductions in the electricity sector needed to be compatible with the European Emissions Trading System.

Policy Solution:

Instead of phasing out lignite power plants immediately, German policymakers were looking for a transitional approach in order to minimize the hardship for the remaining workers in the historically important coal industry. Each power plant operating in Germany would receive a certain allowance of free emissions. For additional emissions, a financial climate contribution would need to be paid. The free allowances were calculated in a way that only the most carbon-intensive power plants (old lignite plants) would have to pay the financial contribution which would increase for older power plants (BMWi, 2015b). At the same time, lignite power plants would have also had the option to only reduce their power generation instead of shutting down the power plants completely in order to avoid lay-offs. This policy has not yet been implemented anywhere. It was debated in Germany in 2015 as an instrument to change the power generation mix towards less-carbon intensive technologies, however, not implemented due to political pressure from the lignite industry.

Applicability:

Market Context	Variable RE Share	Governance Level
All	All	National, regional

9.3.5. Zero-Emission Standards for All New Capacity Additions: Not Yet Implemented

National Context:

In order to manage the transition towards very high shares of renewable energy sources, policymakers can clearly regulate emissions from new capacity additions, keeping in mind that conventional power plants frequently have a lifetime of 40 years or more. If a given country sets a 100% percent renewable energy target for 2050, for instance, there is close to no room for new fossil fuel based capacity additions. Zero emission standards for all new power generators can help to achieve these long-term targets.

Policy Solution:

Clean Electricity Standards are very similar to Renewable Portfolio Standards which are implemented in more than 30 U.S. states. However, they are not targeting a cumulative share of clean energy technologies in the total power generation mix. Instead, they regulate all new deployment in the electricity market. Clean Electricity Standards require that a certain percentage of new electricity power generation relies on zero-emission sources. Zero-emission standards are the most radical form of clean emission standards, regulating that all new power plants should have zero emissions. The types of technologies eligible for deployment can be further specified by policymakers. Policymakers can also regulate that only capacity additions from renewable energy sources are allowed.

Applicability:

Market Context	Variable RE Share	Governance Level
All	All	National, regional

9.3.6. Plant-level Emissions Intensity Limits for New and Existing Power Generators: U.S.A

National Context:

The United States Environmental Protection Agency (US EPA) is legally empowered under the Clean Air Act (CAA) of 1963 to establish emissions standards for any stationary source of air pollution that is anticipated to endanger public health or welfare.[45] Deeming CO_2 as such a pollutant, the Agency began exploring approaches to limit carbon emissions from the power generation fleet at a national level[46].

[45] See: http://www.epa.gov/clean-air-act-overview/clean-air-act-requirements-and-history. Accessed on 8 February 2016.

[46] The U.S. power fleet is responsible for approximately 31% of national greenhouse gas emissions. See: http://www3.epa.gov/climatechange/ghgemissions/sources.html. Accessed on 8 February 2016

Policy Solution:

The US EPA first began exploring the prospect of regulating carbon emissions for new power generators. After conducting a review of available technologies and analyzing the costs and benefits of imposing various carbon intensity limits, the EPA in March 2012 proposed a single carbon intensity limit (specified in lbs CO_2/MWh) for all newly constructed fossil fuelled power plants. The Agency modified the rule to specify distinct limits for natural gas and coal-fired power plants in response to a public consultation process. However, the performance-based metrics leaves the door open for utilizing any technology or approach that enables natural gas or coal-fired power stations to meet the emissions standard. At 0.64 Mt CO_2/MWh for new coal-fired plant, the standard ostensibly requires that any newly constructed coal-fired plant utilize carbon capture and sequestration technology, unless other compliance options become available.

Backed by extensive analysis and years of stakeholder engagement, the US EPA also promulgated the "Clean Power Plan" for the existing power generation fleet. The Plan created customized targets for each of the 50 U.S. states, based on the current resource mix of each state, and an analysis of the various compliance mechanisms each state has at its disposal to reduce carbon emissions. A signature design element of this policy solution is flexibility of compliance with emissions targets. Compliance mechanisms binned into four (4) "building blocks," including: energy efficiency, renewable energy, coal-to-gas fuel switching, and efficiency upgrades to fossil fuel power plants. The Clean Power Plan allows states the flexibility to drive the process of compliance, based on their assessment of how best to do so while respecting other local policy objectives. Furthermore, states are encouraged to collaborate with one another to develop more efficient compliance plans on a multi-state basis. (EPA, 2016b)

At a higher level, these standards provide not only flexibility for compliance, but clear long-term guidance to power sector investors about the nature of new generation investments. The Clean Power Plan is currently on hold for implementation, pending legal challenges being considered in the U.S. Supreme Court.

Applicability:

Market Context	Variable RE Share	Governance Level
All	All	National, regional

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