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How to use PPAs for cost-efficient extension of renewable energies

Experiences with Power Purchase Agreements from Europe and the U.S. / Lessons learned for China

Imprint

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Executive Summary

A power purchase agreement (PPA) is a financial mechanism that allows utilities and corporations to procure renewable energy (RE) from producers with minimal to no upfront capital cost in order to meet their RE goals. While the United States (U.S.) leads the PPA growth globally, the adoption of PPAs in Europe is on the rise and new activities started to take place in the emerging markets. This is thanks in large part to the rapidly falling cost of wind and solar energy and the desire to mitigate adverse environmental impacts of electricity generation. This report comprises a literature review on the evolving practices in PPA implementation in the U.S. and Europe, including PPA types, key factors enabling PPAs, as well as challenges and limitations associated with PPA applications.

Built on the experience and lessons learned from the U.S. and Europe, this report sheds light onto feasible options that could be adopted by China to enable the implementation of PPAs for RE investments. In addition, the report discusses the recent policy and market developments in China that could expedite PPA implementation and help China's power market transformation toward more affordable, reliable and clean energy.

1 Introduction

The landscape of today's renewable energy (RE) market has changed dramatically over the last decade because of the rising demand for RE and steep decline of solar and wind cost. As the RE market has evolved, so have the financing mechanisms associated with it. Power purchase agreements (PPAs) in various forms are one of the financing options most widely adopted in many countries around the world.

In this report, we aim to provide an overview of PPAs and their most common types, both in the U.S. and in European countries. We then review why PPAs were established in the U.S. and why they are emerging in Europe as a viable financing option, what key elements enabled PPAs in the U.S. and Europe, and what these developments mean for China.

PPAs differ from administrative policy mechanisms for RE. A PPA is a private-law contractual approach that does not rely on direct subsidies from governments. However, depending on the market regulation, it may be possible for RE producers that receive for example feed-in premium (FIP) to enter into PPAs (see section 4.1.1 and 4.2.3). In addition, regulatory frameworks like tax rules may have a relevant impact on the adoption of PPAs in a national market. Generally, a PPA refers to an electricity delivery contract between an electricity seller and a buyer. A PPA provides the electricity generators with a bilateral sales mechanism which guarantees revenues and thus investment returns for the contract duration period.

The period of the contract is pre-agreed and the analysis of examples has shown that it can range between three and 25 years. A PPA may provide an important element of the overall financial feasibility for the construction of a capital-intensive RE power plant. Power plants require significant upfront costs which lead to long-term lock-in of capital cost obligations as well as a high perception of risk by financing banks and investors.

Depending on the potential contract partners that buy the renewable electricity, PPAs can be categorized into two main groups: **utility PPAs** or **corporate PPAs**. In Europe, there is a third category, **community PPAs**, in which the contract parties are the energy communities, e. g. cooperatives. Both in the U.S. and Europe, the major buyers are utilities (**utility PPA**).

PPAs can be triggered by different regulatory obligations: Utilities in the U.S. use PPAs to meet their renewable portfolio standard (RPS) requirements[1], utilities and companies in Sweden to meet their quota obligation[2]. Other reasons for utilities to purchase RE via PPAs include improving corporate image and expanding retail marketing options, such as enabling customers to purchase green electricity at a special tariff. With increasing RE penetration and increasing desire of corporations to thrive for sustainability, PPAs have become a popular financing mechanism also for commercial and industrial (C&I) enterprises and corporations to source renewable electricity (**corporate PPA**). PPAs become a viable source of electricity from a managerial perspective because they start to get competitive in direct comparison with conventional power plants due to the steep cost decline of RE technologies and the increasing risk perception by financiers of conventional power plants.

PPAs can have different contractual forms depending on the regulatory design of the relevant electricity market, the capability of the buyers, and the business models behind them. In the U.S. and Europe, two main PPA structures exist: **physical** and **financial PPAs**. A detailed explanation of main characteristics and differences between those two main forms of PPA will be provided in section 2.

Compared to the structure of often highly regulated incentive policies, PPAs provide very flexible financing mechanisms and can therefore be easily adapted by different parties and actor constellations. As RE grows rapidly in various markets, innovative structures and features of PPAs continue to emerge. For example, the so-called **multi-buyer structures** involve more than one corporate buyer to support a project, e. g. by concluding parallel PPAs with different corporate buyers where each buyer only commits to buying a portion of the produced electricity.[3] Besides, there are also **aggregating buyer groups/consortia,** where companies of the same industry or government entities aggregate their power demand and jointly negotiate a PPA[4] (see also section 3.2.3).

In addition, strategies of **portfolio structuring** are also gaining more interest, where **smaller-scale RE projects are being pooled** within a fund or other investment structure that may be more attractive to lenders to reduce and optimize the transactional administrative cost of a PPA.[5]

In the U.S., various formats of PPAs have been legalized and regulated at the federal level by the Federal Energy Regulatory Commission (FERC). However, states are also involved in the regulatory process through agency rule-making as well as legislative action[6]; a number of states have enacted legislations to authorize and regulate the PPAs directly while a majority of states have statues defining PPAs[7]. The state-level policies vary to align the PPA mechanism with other policies such as net metering, RPS, third-party financing and energy efficiency resource standards. For example, to help meet a state's RPS goals, most legislations give the public utility commission power to either direct or allow local utility companies to sign PPAs with qualified independent RE generators.

PPAs contributed significantly to the successful development of RE in the U.S. in the past decade. For example, 7.6 gigawatt (GW) of wind capacity was deployed in 2018 in the U.S., 50.1 % of that was attributable to utility wind PPAs.[8]

Corporate PPAs have been on the rise due to corporations' desire to meet their RE and financial goals. By the end of 2018, developers signed 3.4 GW of wind PPAs and 2.5 GW of solar PPAs with C&I customers; regarding the cumulative capacity in operation, the C&I wind and solar capacity reached 7.6 GW and 1.2 GW, respectively.[9] Facebook, Google, Amazon, AT&T, Walmart, Apple, Microsoft, and ExxonMobil are leading the corporate renewable procurements in the U.S. with a combined market share accounting for 58% of PPA volume by contracted capacity in 2018.

In Europe, the PPA market is still relatively new, small in size and currently limited to the following countries in decreasing amounts: Spain, Sweden, UK, Norway, Netherlands, Ireland, Denmark, Belgium, Germany, Italy, Finland, Portugal, France and Poland[10]. The situation in those countries is quite heterogeneous. PPAs have always been used in many European states by utilities to procure RE, especially in those which have always had quota system for RE in place, such as Sweden, UK and Poland. But PPAs have been also used in states without a quota system, such as Germany, due to the increasing demand for green electricity among German consumers as well as the favorable regulation in the past which provided RE surcharge reductions for buyers procuring RE directly from producers (so-called "green electricity privilege"). As a result, some German utilities have specialized in procuring and offering electricity generated by RE power plants. Due to the policy changes and elimination of the green electricity privilege, these players mainly invest directly in RE power plants and may enter into PPAs with operators, whose RE power plants will exit the 20-years support period soon.

Corporate PPAs were almost non-existent in Europe until 2013[11], with the exception of Sweden, which has a quota system in place under which car manufacturers and energy-intensive industries and electricity suppliers are required to acquire and cancel RE certificates. This encouraged also corporations in Sweden to procure RE. Since 2013, the market volume for corporate PPA increased rapidly in Europe[12] due to favorable market conditions that arose in the context of favorable RE policy structures. They have enabled RE to become competitive and more independent from support policy mechanisms. The reasons for this situation will be explained in more detail in section 4.2.

Currently corporate PPAs in Europe have a cumulative volume of approximately 9.4 GW of either already installed or contracted generation capacity. [13] The majority of the contracts have been signed in 2017 and 2018. The largest part of the contract volume was attributable to wind energy projects in Scandinavia, including Norway, Sweden, Finland and Denmark (4,7 GW), the UK (1,5 GW) and PV projects in Spain (1.6 GW) (see figure 1).[14] The PPA buyers with the largest contract volume of around 700 MW each were in 2017 the Norwegian aluminum producer Norsk Hydro and the Internet company Google.[15] In the same year the first utility PPAs were signed in Portugal and Spain without any RE subsidies from their governments. In the UK, first corporate PPAs without subsidies were announced for 2018 for both wind and PV[16]. It shows that RE have become competitive with non-RE power plants and that financing mechanisms such as PPAs may provide a viable alternative to the regulatory RE financial support mechanisms provided there exist suitable market structures.

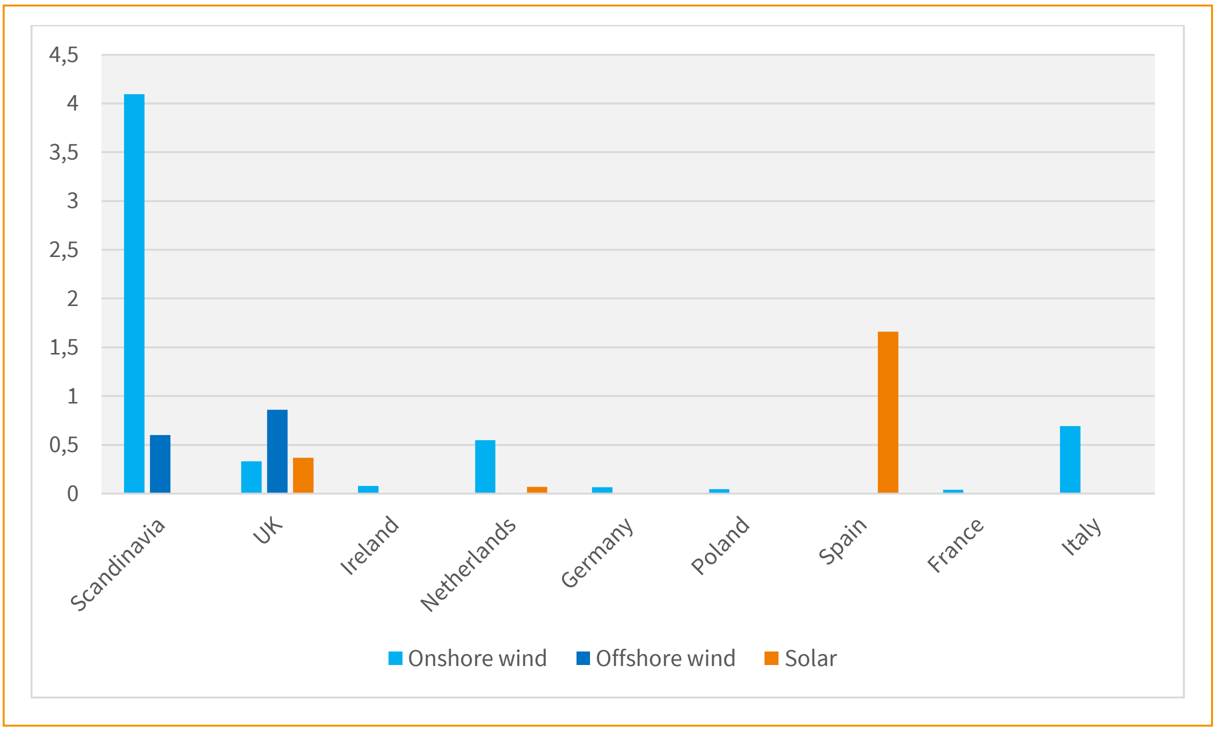

Figure 1 **Capacity of PPAs in different European countries in the end of 2018 in GW.[17]**

China's policy makers have made tremendous effort to promote RE system integration. Recently China decided to gradually move from a highly regulated feed-in tariff (FIT) system to a FIT-system that determines the price per RE project by auctions. China is also developing provincial pilot spot markets, introduced mandatory provincial or regional renewable quota standards and aims to reduce RE curtailment to about 5 % of total RE generation in 2020. The energy market reform is evolving, as well as the RE incentive policy approaches. In 2019, the National Development and Reform Commission (NDRC) issued a policy promoting subsidy-free wind and solar projects and established rules obligating the two large state-owned grid companies to purchase power from approved subsidy-free projects under 20-year contracts. However, China has also encountered barriers when implementing PPAs, which have been used only for a small number of projects so far[18]. Because PPA is a new and emerging financing model for China, the lessons learned and best practices from the U.S. and Europe could benefit its more targeted implementation in this country.

This report is structured into the following sections:

- **Section 2** presents the main PPA variants on the U.S. and European electricity markets.
- **Section 3** discusses the elements that support PPAs in the U.S. It illustrates the trends of utility and corporate RE procurement through PPAs, and discusses traditional PPA approaches and innovative business models.
- **Section 4** discusses different models for variable RE participation in electricity trading in the European Union (EU)and explains developments in regulation and electricity markets that facilitate PPAs in the EU. It introduces two country examples: Germany and Sweden.
- **Section 5** summarizes success factors and limitations of PPAs.
- **Section 6** provides insights and options for China regarding the transition from FIT to market-based RE incentive mechanisms. It covers approaches of integrating PPAs into the Chinese market, the possible role of PPAs in the further development and action options that could enable better and quicker implementation of PPAs in China and support market-based RE penetration, including spot markets.
- **Section 7** highlights the key findings from this analysis.

2 Types of PPAs in Europe and the U.S.

2.1 General definition

Depending on the electricity market regulation in a certain country, there can be two basic PPA variants: **physical PPAs** and **financial PPAs** (also called synthetic or virtual PPAs (VPPAs)). The following two sections are dealing with the main characteristics, design options and legal framework with regard to those two PPA variants.

PPAs are long-term delivery contracts between electricity generators and buyers, which may include **utilities, corporations and energy communities**. Therefore, in view of the potential contract partners it can be differentiated between utility, corporate and community PPAs.

2.2 Physical PPAs

In a physical PPA, an RE producer (seller) sells its electricity to a buyer at a long-term fixed price. The energy output will be delivered to buyers physically. The scope and forms of physical PPAs vary by country. For example, in Europe, there are two main forms of physical PPAs: direct PPAs (or on-site PPA or near-site generation/PPA or behind-the-meter PPA) and a sleeved PPAs (or off-site generation/PPA). In the U.S., direct PPAs can be either on-site or off-site, and the sleeved PPA is also known as “utility green tariff” or “back to back PPA”.

2.2.1 Direct PPAs

In the definition of a direct PPAs model that can be found in European studies, the delivery of electricity takes place behind the meter on the buyer’s property, not on the side of the electric grid/utility and therefore without use of the grid [19] and involving of a **balance responsible party (BRP)**. By that, grid fees and other feeds associated with the BRP role can be avoided. Direct PPAs are particularly challenging because they require close proximity of the RE power plants to the consuming facility (e. g. a factory) to enable a direct electrical wiring of seller and buyer. This type of PPAs provides the most direct link between RE generation and site consumption.[20] Typically, a direct PPA is an option to purchase electricity from RE power plant which is designed in collaboration with the PPA buyer who agrees to site the RE system on its property and purchases the generated electricity exclusively over the entire project lifetime. Therefore, direct PPA contracts are more likely to be concluded for smaller plants, e. g. PV systems installed on rooftops.[21] Those RE power plants are owned, operated, and maintained by a third-party developer, which minimizes the complexity for the buyer. Depending on the electricity market regulations, it is also possible to involve a **BRP** in order to enable the RE generator to feed any electricity surplus which is not being consumed directly by the seller into the grid.[22]

In the U.S, an on-site PPA often involves a third-party developer, who owns, operates, and maintains the RE system whereas a buyer agrees to site the RE system on its property and purchases the system's output. On the other hand, for buyers who have limited on-site space to install RE facility direct PPA can be also off-site, which means the RE power will be delivered to buyer via grid. For example, a corporate facility contracts a PPA with off-site generator, and the final price for delivered RE output will be the combination of contracted PPA price plus transmission and distribution expenses[23]. It should be noticed that although the produced energy is delivered off-site, there is a difference between off-site direct PPA and off-site sleeved PPA, which will be described in section 2.2.2. It should also be noticed that off-site PPA can be financially settled, which will be described in section 2.3.

2.2.2 Sleeved PPA

In current European practice, direct PPAs are quite uncommon, because usually large wind and solar parks are not located close to major consumption centers (e. g. industrial parks or cities) and it does not make financial or organizational sense to build direct connections over long distances. Usually, regulation is also structured in such way to avoid that kind of evasive behavior from the use of common infrastructures. Hence the most common form of PPAs are sleeved PPAs. In sleeved PPAs, the buyer purchases the RE electricity from the RE producer by involving a **BRP**.[24] The BRP has to act as the buyer's agent in managing the offtake which leads to management fees associated with the intermittent nature of RE generation output – **"sleeves" or "sleeved fees"**.[25]

The delivery of electricity happens on the base of volume balance; the BRP manages the exactly timed matching of generation and consumption volume at any given point of time. Although the green electricity is not delivered physically to the buyer, it does obtain the contracted amount from the grid at the time it is fed-in by the seller. Therefore, PPA contracting parties do not have to be located in the same grid area. In case of the EU, they can be even situated in different member states.[26]

In the U.S., although the direct PPA has been widely used for utility RE procurement, corporations often find it difficult to contract with a proper RE producer (seller) due to lack of market information and low-risk tolerance. A sleeved PPA can be a solution to that problem. It is designed as a three-way contract among RE producer, utility (or electricity service provider), and end-user (corporate for example) to manage RE development. First, RE producer and utility contract a PPA. Second, the end-user contracts another matching PPA with the utility to purchase those RE outputs. In addition, utility will charge fees on providing such services. In this model, both utility and end-user are RE buyers, so it is also known as "back-to-back PPA."[27] Thus the main difference between direct off-site PPA and sleeved PPA in the U.S. is that the sleeved PPA is a three-way-contract involving besides RE seller and buyer also an utility, whereas the direct off-site PPA is a two-way-contract between RE seller and buyer.

Sleeved PPAs avoid site-level constraints such as available land and resource potential. They provide the opportunity to reduce RE generation cost per kWh through economies of scale of larger plants and site selection focused on the best natural resources. Connection of the RE power plant to the grid incur grid charges, but it may make it also less reliant on only one buyer, as in case of a direct PPA.[28] It is important to note, that long-term fixed prices are an important **risk hedge** in case wholesale market prices rise. But they also bear risks if market price decrease.[29] For a discussion on hedging strategies in the U.S., please refer to section 3.2.6.

The sleeved PPA structure is currently the most commonly used corporate PPA model in Europe and in the U.S.[30]

2.3 Financial (virtual) PPA (VPPA)

Financial PPA (or virtual PPA (VPPA)) includes an agreement between RE producer and electricity buyer about a hedging for a contractually defined amount of electricity or green certificates.[31] In this PPA structure the RE power plant does not have to be spatially related to the location of the purchaser, similarly to a sleeved PPA.[32] The RE producer sells its electricity on the wholesale market, usually with the help of a direct marketer to a buyer of its choice (not identical with the PPA buyer) and the buyer procures electricity on the wholesale market from a supplier of its choice (not identical with the RE producer in the PPA). This mechanism does not cause any “sleeving fees”. [33] The long-term price fixation means that the PPA contract parties are required to make differential payments depending on the electricity price development on the wholesale market as well as on the agreed fixed price. The contractual relation between RE producer and buyer relates to the obligation of making the differential payments depending on the electricity price on the wholesale market. Specifically, if the wholesale price is below the agreed fixed price, the buyer pays the price difference to the RE producer for the contracted amount of electricity, and vice versa. Basically, a VPPA works similar to a sliding FIP or a CfD, but is based on a bilateral mutual obligation structure between private market players instead of involving a public entity in the allocation of money.[34]

There exists a variety of possibilities of how to design the contract structure and manage the risk distribution between the parties. In particular, it is necessary to define how the compensation payment is calculated. [35] In addition to the fixed price, the following elements should be set in the contract:

- **calculation modalities for the reference price** (e. g. base load vs. peak load, time window length, mode of average calculation, how to deal with negative electricity prices etc.);
- **amount of electricity delivered** (total production vs. interval, minimum or maximum amount; how to deal with redispatch and feed-in measures of the grid operator as well as force majeure cases etc.);
- **inflation indexing**.[36]

It is important to note that in a VPPA, it is possible that the buyer is opening himself up to the “basis risk” in the wholesale price volatility when both buyer and seller are making their electricity sales and purchases on different wholesale markets (e. g. in different countries). If the prices in the buyer’s and producer’s markets do not move in tandem this would lead to an imperfect hedge. Therefore, it is essential to evaluate the price correlations between the two markets in order to design the PPA in a way that maximize the price stability as much as possible.[37]

Options are another possible structure of VPPAs[38]**.** Options set a cap-and-floor mechanism instead of fixing a single price or price table per MWh. If the reference price (e. g. at the intraday market) is lower than the floor price, the generator exercises its option to sell the power at the floor price. If the reference price is higher than the ceiling price, the buyer exercises its option to purchase the power at the ceiling price.

<table>
<tr><th colspan="3">Power Purchase Agreements (PPAs) – Europe</th></tr>
<tr><td colspan="2">Physical PPA
(bilateral OTC)</td><td>Virtual PPA (VPPA)
(bilateral or organized OTC/ hedging arrangement)
or
Synthetic PPA
Financial PPA</td></tr>
<tr><td>Direct PPA
or
On-site PPA
Near-site generation/PPA
Behind-the-meter PPA</td><td>Sleeved PPA
or
Off-site generation PPA</td><td>Contracts for Difference (CfD)
Futures
Options</td></tr>
</table>

Table 1 **Most common PPA structures in Europe.**

<table>
<tr><th colspan="4">Power Purchase Agreements (PPAs) – US</th></tr>
<tr><td colspan="3">Physical PPA
(bilateral OTC)</td><td>Virtual PPA
(bilateral or organized OTC/ hedging arrangement)
or
Synthetic PPA
Financial PPA</td></tr>
<tr><td colspan="2">Direct PPA</td><td rowspan="2">Sleeved PPA
or
Back-to-back PPA
Utility green tariff</td><td rowspan="2">Contracts for Difference (CfD)
fixed for floating swaps</td></tr>
<tr><td>On-site PPA</td><td>Off-site PPA</td></tr>
</table>

Table 2 **Most common PPA structures in the U.S.**

3 PPAs in the U.S.

3.1 Contractual elements

A PPA establishes all the contractual aspects of the sale of electricity. Typically, a buyer seeks solicitations of interest and outlines criteria for a PPA through a competitive solicitation, or a request for proposals (RFP).[39] The RFP is an important step in the process. The RFP terms must represent the buyer's minimum requirements, establish the baseline for suppliers to respond to, and be the starting point for project negotiations. RFPs must be descriptive of the requirements while retaining sufficient flexibility to ensure a successful RFP process. [40]

Negotiating complex PPA contracts poses a significant challenge even when all parties follow the legal best practices. The need for balanced and clear contracts is particularly important because PPA contracts often cover decades-long projects, which could involve multiple developers, financiers and buyers. PPAs must be carefully drafted to ensure 1) the parties' rights and obligations are clearly set out, 2) the project's risks are properly allocated between the parties, and 3) the terms and conditions of the sale of electricity (including pricing and delivery) are clearly stated. The table below summarizes the key contractual aspects typically included in a PPA.

PPA: key components and terms	
Buyer	The purchaser of power and/or renewable attributes of the system.
Liabilities	The contract defines the legal obligations of the buyer and the system owner for system maintenance, repair, or other liabilities arising from unforeseen events.
Contract Term	The period during which the buyer agrees to purchase power from the system owner.
PPA price	The contract specifies the rate ($/kWh) at which the buyer will pay the project developer for the system's output. Determining a PPA pricing structure is a crucial step. A fixed price and an escalator (see below) are commonly-used pricing structures.
Escalator	Contract clause under which the PPA price increases over time at a pre-determined rate, generally less than 3%.
Expiration	Conditions defining the buyer's options at the end of the contract term, including whether the buyer will have the option to purchase the system.
Environmental attributes	Contractual instruments representing the environmental attributes of the system's output such as the ownership of the environmental incentives and attributes of the project embodied in renewable energy certificates (RECs).
Assignability	The ability of the project developer to transfer site rights to another party.
Credit support	Corporate buyers may need to provide credit support to backstop their payment obligations. That credit support may take the form of a payment guaranty by a creditworthy entity, a letter of credit, cash collateral or a combination of these.
Performance terms	The PPA specifies the obligations of both the buyer and system owner concerning the system's performance, including any exclusions under which either party is exempt from compliance with contract terms (e. g. force majeure events).

PPA: key components and terms	
Site right agreement	Agreement defining the developer's rights to access and use the buyer's property for project development, operation, maintenance, and decommissioning.
Tax equity	Capital raised from a taxable entity in return for the receipt of tax incentives.

Table 3 Key components and terms in a PPA.

A well-designed PPA can include various financial remuneration parameters to incentivize RE generators to provide a broad spectrum of flexibility and reliability services to the grid[41]. For example, to enable RE generators to contribute to grid reliability, PPAs may include requirements (e. g., specified by the utility, which is the RE buyer) such as power factor, which can enable RE generators to operate in various modes (power factor, reactive power, voltage control). That can influence the overall system efficiency or voltage ride-through, which can prevent a cascading failure of electricity supply by enabling RE generators to remain connected and operational during periods of severe under- or over-voltage. Similarly, PPAs can incorporate flexibility considerations such as automatic generation control to allow system operators to utilize RE generators for load following.

3.2 Elements supporting PPAs

Regulatory framework and market infrastructure are two important pillars enabling renewable PPAs in the U.S. An effective regulatory framework provides planning certainty which is needed to stimulate stakeholder (RE producers and buyers) response regarding RE deployment and the market functionality plays a key role to ensure open and fair competition. This section reviews the regulatory aspects and market factors, which support the growth of PPAs for RE in the U.S.

3.2.1 Federal regulation

Because electricity is a commodity, it is important for the buyers and sellers to understand how the electricity markets are regulated in the U.S. at the federal and state levels (3.2.1 and 3.2.2, respectively), when it comes to choosing RE. In the U.S., the sale of electricity is subject to federal and state regulations (depending on the nature of the sale), the identity of the buyer and seller and the market structure (e. g., wholesale, retail, deregulated, regulated) in which the sale takes place.[42]

Under the Federal Power Act (FPA), the Federal Energy Regulatory Commission (FERC) regulates rates and interstate transmission and wholesale sales of electricity. The FERC is an independent federal agency and has jurisdiction over: 1) public utilities including private companies that either sell power for resale or own/operate transmission facilities in interstate commerce (which covers most of the Continental United States), and 2) cooperative utilities (though this jurisdiction is pre-empted if the cooperative has loans guaranteed by the Rural Utilities Service of the US Department of Agriculture). However, the FERC does not have jurisdiction over 1) state or municipal entities that sell electricity, and 2) sales of electricity in Texas (though the FERC has certain reliability-related jurisdiction even within the Electric Reliability Council of Texas - ERCOT).

The FERC must ensure that the rates, terms and conditions under which an entity proposes to sell its electricity are **just and reasonable**. While no fixed definitions on "just and reasonable" exist, the courts and FERC developed a doctrine that rates, which have been approved by FERC under FPA (the filed rates) and are effective (actually in effect), are presumed just and reasonable. The “filed rate doctrine” protects purchasers from unilateral price increases initiated by the seller unless expressly contemplated by the contract (for example, a PPA). This doctrine has also been applied to protect sellers from regulatory revisions, unless such revisions are enacted by FERC to protect the public interest. Thus the **“filed rate doctrine” mitigates the regulatory risks for PPAs**, and enables FERC-regulated PPAs and their associated rates to be a **more dependable source of revenues for the seller**. Another risk mitigation option is provided by the Cost of Service Standard, which requires the FERC to set rates at levels that allow a prudently managed company to recover its expenses and attract capital. Because price is usually the most important part of the PPA, which influences the economic viability of an RE project, the rate regulation provides certainty to RE investments under FERC-regulated PPAs.

3.2.2 State regulation: wholesale and retail markets

Whether and which types of PPAs are allowed in a given state is highly dependent on state regulations. Prior to the 1970’s, all electricity markets in the U.S. were part of a regulated monopoly controlled by utilities and overseen by each state’s public utility commission (PUC) or public service commission (PSC), or utility board (referred to as PUCs thereafter). The Public Utilities Regulatory Policies Act (PURPA) enacted in 1973 allowed 17 states **to restructure their wholesale electricity markets** with further legislation in the 1990s allowing **retail competition** in individual states. The restructured **wholesale electricity markets** created a market-based, competitive system that allowed independent generators such as RE producers to participate in electricity markets.[43] On the other hand, in fully integrated states (e. g., the Southeast, Southwest), utilities generally own and operate all of the generators, transmission lines and distribution networks. Therefore, these markets have little or no competition for the supply of electricity, which means independent RE producers cannot sell electricity to the grid via a non-utility PPA.

State PUCs generally have jurisdiction over retail sales of electricity and local distribution within a state, although some municipalities and electric cooperatives self-regulate their own retail activities. As mentioned in section 1, most state legislation authorizes the PUC to direct or allow local utility companies to enter into PPAs with qualifying generators in order to help meet state’s Renewable Portfolio Standard. The second type of state legislation addresses the length of PPAs; states such as Michigan and Washington passed legislation requiring commission approval for utilities entering into PPAs longer than a designated length of time (for example, six years or longer in Michigan[44]). The third type of legislation addresses the interconnection issues by directing utilities to facilitate the transmission of electricity from third-party generators directly to individual customers.[45]

With market deregulations, three types of electricity markets exist in the U.S.: 1) traditional regulated markets, where both wholesale and retail markets are regulated and operated by vertically integrated utilities; 2) competitive wholesale markets with a traditional regulated retail markets, which maintain the vertically integrated utility structure for the retail markets while unbundling generation assets and allowing generators to participate in an Independent System Operator (ISO) or regional transmission organization (RTO), which are organizations that operate the multistate or regional transmission system and wholesale markets. The transfer of electricity between states is facilitated by regional transmission organizations (RTOs) and independent system operators (ISOs), and 3) competitive wholesale and retail markets.

Wholesale and retail market structures dictate the PPA options available to RE producers and buyers. As discussed in 2.3, **VPPAs** do not require physical delivery of electricity from the producer to the buyer; the producer sells the electricity on the wholesale market[46]. In other words, RE producers can be in any locations, which have a competitive wholesale market whereas there is no location restriction for buyers as long as they are in the contiguous U.S. As a result, VPPAs are widely adopted in the U.S. **Physical PPAs** have more constraints on market structure; non-utility buyers must be located in the retail electricity choice territory (i. e., competitive retail market) and the RE project must be located in a deregulated wholesale market that is interconnected with customer's ISO/RTO[47]. **Sleeved PPAs** can be used in some regulated electricity markets as an option under green energy tariff.[48] Figure 2 shows the market requirements for implementation of certain forms of PPAs in the U.S.

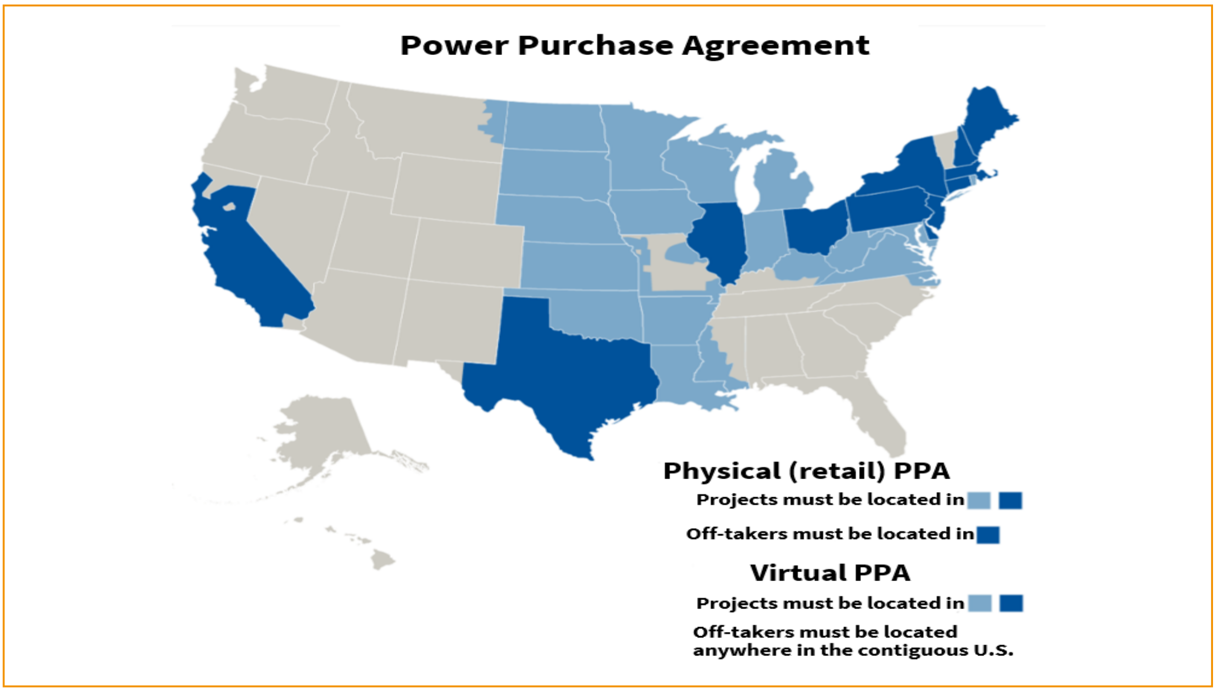

Figure 2 **Available PPA types under different market structures** [49]

3.2.3 Net metering

Net metering is a billing mechanism that enables grid-connected RE owners to be credited for the electricity that they provide to the grid. Common examples of net metering installations are PV panels on the roof of a commercial/residential building or a small wind turbine at a school, which are connected to meters measuring the **net quantity** of electricity that the customer uses. The customers pay the electricity purchased from the grid, and are credited for the excess electricity (i. e., when feeding electricity to the grid). With limited exceptions, most states in the U.S. have mandatory state-wide net metering policies whereas a small number of states have a voluntary net metering policy. Allowing net metering played an important role in promoting investment in distributed installations and PPA adoption because it made variable RE economically viable, especially during the earlier time when RE was not cost competitive compared to conventional generations.

Recently, there has been considerable interest in seeking **alternatives to net metering** because utilities and grid companies complain that RE generators selling electricity back to the grid do not pay their fair share of distribution costs. Some utilities have requested regulatory reviews through proposals to replace net-metering. In addition, the regulatory reviews arise from pre-existing legislative or regulatory requirements when the total installed net metering capacity reaches the threshold[50]. A number of states have or are in the process of making decisions about replacements for net metering or phasing out net metering. For example, regulators in Hawaii replaced net metering in 2015 with options for customers to utilize energy storage or to be compensated at a reduced rate when feeding electricity into the grid. In 2017, Indiana passed a bill to phase out net metering; systems installed prior to the end of 2017 will be grandfathered for 30 years while customers who install systems after 2017 will receive compensation at the utility's marginal cost, plus 25 %, beginning in 2022. How these post-net metering policies will affect the adoptions of PPAs at different scales (except PPAs with utilities) is unclear.

3.2.4 Tax incentives

Tax incentives have been an important driver of RE deployment in the U.S.; the two key corporate tax benefits, i. e., the **production tax credit** (PTC) and the **business energy investment tax credit** (ITC), have helped make RE cost-competitive with conventional electricity. However, with these tax credits being reduced or phased out, the renewable PPA price could be negatively affected. Moreover, the U.S. has implemented a new solar import duties ("Section 201 Solar Tariff") on imported solar cells and modules, which could increase the costs of solar cell and module[51]. Despite the changes in tax credits and newly imposed import duties, some recent studies indicate the falling cost of RE could offset these negative effects[52].

3.2.5 Falling cost of RE

Falling costs of RE generation and innovations in energy service solutions are changing the way utilities and corporations procure and use electricity. The falling levelized cost of energy (LCOE) provides an incentive to corporate buyers to procure RE because it could lower their operation costs. Although **technology improvements** remain the vital driver of cost reduction, **competitive procurement** and **experienced project developers** are also recognized as key factors driving down the installation cost[53]. In 2018, utility-scale PV LCOE in the U.S. was around $40/MWh and the best-of-class wind LCOE was less than $30/MWh; these LCOEs were at or below the marginal cost of common conventional generation technologies[54].

Driven by the sharp drop in installed cost and enabled by improved capacity factor, low interest rate, production tax credits, and competition among developers, wind and solar PPA prices have fallen dramatically over time. The market analysis by LBNL finds that the average price of wind PPAs has dropped to or even below $20/MWh in 2017 from between $55 and $70/MWh in PPAs executed in 2009[55]. A similar downward trend generally holds true for utility-scale PV PPAs, whose average prices have dropped to or even below $40/MWh from 2011, when the prices were above $100/MWh[56]. In some sun-rich states such as Colorado, Nevada, Arizona, Texas, and New Mexico[57], PV PPAs have been priced at below $30/MWh. The falling cost of RE will make RE competitive with conventional energy fuels and benefit PPA growth, even after tax credits for RE are phased out.

3.2.6 Hedging strategies and energy management

With a **well-designed pricing structure**, PPAs can be used to hedge against the long-term electricity price risk, mitigate both investment and operation risks, and attract financing. Traditionally, physical PPAs with long-term contracts were used as a **risk mitigation tool** against uncertain but often rising energy prices. On the other hand, cheap natural gas and falling RE costs are likely to **depress prices and sustain downward pressure on wholesale electricity prices**,[58] which have slowed down the growth of physical PPAs in some markets. For instance, physical PPAs contributed to over 80% of U.S. wind capacity installations in 2000 and decreased to less than 50% in 2018.[59] With changing market dynamics, VPPAs started emerging as an innovative hedging structure for wind developers to stabilize their revenues and attract long-term financing[60]. VPPAs came into the market in 2015 and accounted for over 25 % of U.S. wind capacity installations in 2018[61]. Using VPPAs as hedging strategy for PV deployment is less common than for wind in the U.S. because of different tax incentives and profile of energy generation (e. g. solar energy is mostly generated during the day and around noon when the risk of wholesale power price fluctuation is higher than at night)[62]. More innovative approaches are designed to hedge against the uncertainty and variability of wind and solar generations and to provide benefits to both the buyers and sellers (see next section).

3.3 Innovative PPAs in the U.S.

The increasing penetration of variable RE poses new challenges to power system flexibility and stability as well as brings new risks and opportunities to both RE producers and buyers. The traditional PPAs are often inadequate in addressing these emerging issues. For instance, with higher share of RE, curtailment may happen more often than originally expected. If not considered in the PPA contract, **unexpected or higher-than-expected** curtailment could create financial losses for the developers and buyers. As a wider range of corporations from different sectors with varying sizes and patterns of electricity demands are entering the PPA market in the U.S., **PPA structures have been evolving to address new challenges and re-balance risks** by leveraging recent technological advances (e. g. energy storage), developing creative ways to improve grid planning and adapting to changing policies and market dynamics. Below we discuss the driving forces of PPA evolution, as well as innovative business models that are being enabled with the help of PPAs.

3.3.1 Risk re-allocation and mitigation

RE places planning risks to both RE producer and buyer due to the fluctuation of generation. The risk is increasing due to contractual complexity when engaging with more stakeholders such as financier, insurer, and other counterparties. Depending on PPA structures, table 4 summarizes the different types of risks and how they are allocated traditionally in a PPA.

Core risk	Primary risk sources	Traditional risk allocation
Fuel risk	Wind speed, solar irradiation, and other RE resource performance, depending on natural resource conditions (physical PPA & VPPA)	RE producer & buyer
Shape risk	The buyer's demand is not simultaneous with producer's output (physical PPA & VPPA)	RE producer & buyer
Operational risk	Underperformance of a generation system (physical PPA & VPPA)	RE producer & buyer
Price risk	The difference between the wholesale price and the contracted price (VPPA)	Buyer
Basis risk	The difference between the buyer's retail price and the wholesale price (VPPA)	Buyer

Table 4 **PPA risks allocation.**

Innovative PPA models intend to mitigate risks from both the RE producer and buyer perspectives. One of the common issues that arose with increasing RE penetration is curtailment, which refers to the energy output reduction of a plant from what could otherwise be produced due to limited grid transport capacities or system stability issues. If a PPA allocates all risks to the RE producer, the buyer (typically utility buyer) will be able to reduce its RE procurement with no penalty. If a PPA allocates all risks to the buyer, the buyer has to pay all energy output, sometimes including curtailed output, generated by the RE producer. Both approaches make the PPA contracting process difficult because the risk is perceived to be too high either way.

Capacity & Energy PPA and Time-of-Day price caps

The **Capacity & Energy PPA** is therefore introduced as an innovative risk-sharing approach in which the pricing consists of two components, a fixed capacity price ($/MW-month) and an energy charge ($/MWh).This limits the curtailment risk for the seller to the energy charge only.[63] Another new contract structure to mitigate curtailment risk is the **Time-of-Day (ToD) price caps**, in which PPA prices vary in each hour of the day by using a price multiplier. The buyer can, therefore, set low prices during the likely oversupply hour and high prices during the peak hour. This approach will encourage the RE producer to shift its energy output to hours with higher prices and to reduce curtailment by incorporating storage system.

Proxy Generation PPA

With rapidly increasing corporate RE procurement in the U.S., corporations are seeking more flexible and low-risk procurement approaches. The **Proxy Generation PPA** is one of the new models for corporate buyers that wish to minimize risks they are unable or unwilling to absorb[64]. For example, operational risk is often shared by buyers and seller under current PPA models (table 4), but is beyond the control of the buyer. In addition, traditional VPPA contracts, which are typically designed at "as generated"-quantities, have proven untenable for corporate buyers[65]. Unlike traditional PPAs measured by actual energy output, the Proxy Generation PPA is settled based on the measured fuel and the expected generation[66]. The operational risk is therefore reallocated to RE producer and the corporate buyer bears no risk. The box below provides an example of Microsoft's Proxy Generation PPA implementation[67].

Mircosoft Procured 178 MW of wind through Proxy Generation PPA

In 2016, Microsoft procured 178 MW wind from the Bloom Wind Project in Kansas through Allianz Risk Transfer (ART) to power the data center in Cheyenne, Wyoming, and this was the first Proxy Generation PPA.

In this model, Microsoft has contracted a 10-year Proxy Revenue Swap agreement with ART, which serves as an insurance and reinsurance company (hedge provider). The project receives merchant revenue (revenue received through the market during operation) through the market. The swap provider pays the project a fixed price for a "settlement period". In return, if the proxy revenue is higher than the fixed payment during the settlement period based on the project's calculated proxy generation, the payment difference goes to the swap provider and vice versa.

3.3.2 Technology advance - dispatchable RE

Technology advances are a key driver of PPA innovations in the U.S. Due to variable output, wind and solar used to be treated as non-dispatchable resources and required conventional power plants and other dispatchable renewable to maintain flexibility[68]. The increasing RE penetration challenges the energy system to balance demand and supply.

A well-designed PPA can include **incentives to compensate the ancillary services/grid support functions** of variable wind and solar[69]. One of these innovative PPA models may schedule the percentage of solar or wind potential production while the RE buyer (e. g., a utility) controls the output of electricity[70]. Any unscheduled energy production can provide ancillary services such as spinning reserves and frequency response instead of posing an integration challenge to the grid. In this way, variable RE are treated as dispatchable resources in order to provide ancillary services, which are paid for.

Another approach is to **incorporate backup conventional generators and battery storage** into wind and solar generation sites to make them dispatchable. The decreasing cost of battery storage makes **RE-plus-storage** a viable option. In the combination, wind and solar can charge the battery during off-peak hours and discharge electricity when load demand is high, thus achieving some energy shifting. However, storage also brings a new challenge in terms of allocating control rights, that is, whether the RE producer or buyer has the right to decide about the storage performance[71]. Adding storage as a technological element will certainly change the overall PPA structure. The box below provides an example of how solar/wind-plus-storage PPA works in Nevada[72].

NV Energy proposed Renewable-Plus-Storage PPA

In 2018, NV Energy filed a Request for Proposals (RFP) including dispatchable energy. Battery energy storage system (BESS) associated with RE resource has been considered to support RE deployment.

In the BESS-based PPA model, two-tiered pricing is proposed to promote battery deployment. Buyer shall receive all energy produced during the Full Requirements Period, which is the period consisting of June through August, hours ending 17 through 21 (5pm-9pm). In addition, the electricity rate during this period is equivalent to 6.5 times the electricity rate applicable during the non-Full Requirements Period.

Only very few PPAs to date have combined conventional resources and RE to implement a dispatchable/semi-dispatchable PPA. For example, a concentrating solar thermal plant could be combined with a natural gas-fired combustion system to mitigate intermittency issues. The Box below provides an example[73].

Xcel Energy Semi-Dispatchable Renewable PPA

Xcel Energy is an electric services company with four utility subsidiaries serving 3.6 million electric customers across eight states of the U.S. In 2018, Xcel Energy has released their new Model PPA for Wind and Solar Generators, as well as new Model PPA for semi-dispatchable Generators.

The Semi-Dispatchable PPA enables power providers with a solar thermal generator that incorporates a natural gas-fired combustion system to contract a PPA with Xcel Energy. The conventional plant is designed to supplement the generation of solar thermal energy, thus mitigating intermittency issues and making the generation fleet "semi-dispatchable". Power provider shall make available to Xcel Energy all ancillary services associated with the power plants, at no additional charge.

For energy generated by the solar thermal plant, Xcel Energy will pay a contracted solar energy rate. For natural gas generated energy, a monthly tolling payment, based on mutual agreement, will be applied.

3.3.3 Options for small market participants – energy aggregation, joint tenancy and reseller contracting

With increasing interest in RE procurement from small corporations with relatively low energy demand, PPA models are evolving to meet increasing demand for RE from smaller companies with lower energy demand. Unlike large buyers such as utilities and large corporations, smaller buyers have difficulty reaping the full benefits of a PPA. The size requirements for buyers to sign PPAs, the inability to pursue economies of scale and the high transaction cost limit the use of PPAs for small buyers[74]. Three innovative approaches are therefore created to involve small market participants.

Energy aggregation refers to a group of companies (energy buyers) who together purchase energy from a single or multiple RE producers[75]. Although the energy consumption for an individual is small, energy aggregation can achieve the economies of scale and retain the economic advantages of a high-volume purchase. The Box below provides an example of implementing renewable VPPA through energy aggregation in Massachusetts[76].

Three corporates buyers implemented solar VPPA through energy aggregation

In 2016, three corporations – the Massachusetts Institute of Technology, the Boston Medical Center, and the Post Office Square Redevelopment Corporation entered into a fixed 25-year VPPA with a 60 MW solar farm located in North Carolina. While North Carolina disallows competitive market access, this solar farm is located in PJM interconnection territory and therefore could sell into PJM Interconnection and facilitate a VPPA.

Dominion Energy, an energy service company is the developer and owner of the solar farm while Customer Energy Solutions is a trading company that serves as an agent that sells the power on the wholesale market (Mid-Atlantic Wholesale Electricity Market). The generated electricity will not be physically delivered to the three buyers, but the RECs help them to identify their energy attributes and to claim RE procurement activities.

Joint tenancy is another approach that enables small customers to sign PPAs with RE producer. In this PPA model, corporate buyers contract a small portion of the expected generation of an RE project that has an anchor tenant – —a buyer that contracts a large percentage of the projects' generation[77]. This approach suits small buyers with lower credit ratings and lower risk-tolerance because the anchor tenant finances the majority of the project[78]. Recently, an unprecedented model has been initiated by allowing multiple small corporations to aggregate and to act as the anchor tenant collectively, and the Box below illustrates this innovative joint tenancy PPA example[79].

Five corporations forming an aggregation group to act as the anchor and contracted solar VPPA

In 2019, five corporations – Bloomberg, Cox Enterprises, Gap Inc, Salesforce, and Workday have formed an energy aggregation group, which served as the anchor tenant to contract 42.5 MW of a 100 MW North Carolina solar project through VPPA. Other corporations can now procure the remaining RE cooperatively with lower risks.

Lastly, small buyers can engage in pre-contracted, resold tranches of a larger PPA, which refers to the **reseller contracting model**[80]. In this model, a large buyer may purchase the entire energy output from a project and then resale a portion of that purchased energy to other smaller buyers. Small buyers, as the second counterparty, have more flexibility in terms of financing and risk control. On the other hand, similar to a joint tenancy model, since the PPA was signed by the large-scale buyer, small buyers have fewer PPA options, and the project price and term may be unfavourable in the end.

4 PPAs in EU member states – different incentive policy backgrounds, similar emerging business models

Before going into detail about different possibilities of implementing PPAs on the European market, the differences between trading models for variable RE will be shortly explained. Especially the difference between PPAs and direct trading/marketing in the wholesale market will be discussed in more detail in order to provide suitable background information regarding the heterogeneous situation for PPAs in Europe. Direct marketing occurs in different forms: The German cases of direct marketing and mandatory acquisition will be covered as well as the trading mechanism "contracts for difference" (CfD) used in the UK.

The analysis focuses on the different mechanisms form the perspective of the RE producer.

Generally, the main differences between PPAs and other marketing models are:

- the place where the trading takes place: usually on the organized multilateral wholesale market (stock exchange) (**direct marketing in Germany**), on the long-term bilateral wholesale market (**over the counter, OTC, in form of PPAs)** or outside the wholesale market, directly to the grid operator (**mandatory acquisition in Germany**).
- contract parties: RE producer on the one hand and company, utility or energy community on the other hand (**PPAs**), RE producer/direct marketer and electricity buyer on the spot market (**direct marketing**), RE producer and grid operator **(mandatory acquisition in Germany**) or RE producer and private consumer (**tenant electricity model in Germany**).

PPAs can be a part of a RE support policy scheme, such as in case of **direct marketing (CfD) in the UK**. More often they do exist independently from the state support structure.

In the next section the main models for variable RE participation in electricity trading will be presented:

- direct marketing/trading on the wholesale market in Germany,
- direct marketing (CfD) in the UK and
- mandatory acquisition (guaranteed acquisition) in Germany.

4.1 Other models for variable RE participation in electricity trading in the EU

4.1.1 Direct marketing in Germany

Direct marketing for RE was introduced in **Germany** in 2014 in order to incentivize a better integration of RE in the electricity market as well as sensitize RE producers for the patterns and specifics of the demand side. It differentiates between mandatory direct marketing of new plants commissioned after 1 January 2016 and with installed capacity above 100 kW and the optional direct marketing of existing plants.[81]

In this model, the RE producer receives the so-called market premium for selling electricity on the wholesale market in addition to the market price. In practice, most RE producers sell their electricity through direct traders on the wholesale intraday stock exchange. PPAs in the market premium model are possible, but not frequently used in practice. It may happen in the form of a bilateral PPA instead of real-time offering on the stock market (see also section 4.2.3). The market premium is paid by the distribution system operator (DSO) on a monthly and retroactive basis for a 20-year period. Altogether the sum of the stock exchange remuneration and the market premium corresponds at least to the amount of the fixed FIT for installations, who are lower than 750 kW and therefore not obliged to take parts in the auctions. For them, the amount of the market premium is calculated as the difference between the FIT for the respective RE technology (EEG remuneration) and the average market price of electricity calculated on a monthly basis – average price monthly (APM). In case of wind and PV, the amount is corrected by a weighting factor that reflects the market value on the spot market. In addition, a management premium (MP) shall offset the costs of offsetting the forecasting errors and constitutes a part of the calculation of the reference value based on APM (see below).[82]

The market premium is calculated as follows:

market premium = EEG remuneration – reference value*

*reference value = APM – MP

For those installations that are obliged to take part in the auctions, the level of the market premium is determined in the auction. Since the portion between market price and market premium is highly variable, the mechanism of market premium is defined as a **sliding feed-in premium (FIP)**[83].

RE producers can also sell their electricity on the spot market or directly to the buyer with a PPA without receiving the market premium and without being subject to all other regulatory conditions of the EEG. This so-called “other direct marketing” is almost never used because the financial disadvantages due to the lost FIP are quite high and the trading on the spot market currently provides not enough financial securities for RE to enable a sufficiently reliable refinance security. [84] However, PPAs as a form of the “other direct marketing”, are increasingly gaining importance in Germany (see section 4.2.3). The “other direct marketing” have an important advantage over the direct marketing model: the green characteristic of RE electricity can be sold and certified as such, because the proof of origin can be conveyed or sold to the purchase entity.[85] This is a potential additional source of revenues, but current extremely low prices for green electricity certificates prevent a further utilization. This conveying or selling of the green electricity certificates is not allowed for RE plants that receive FiT or FiP.

RE that receive FITs can easily switch to direct marketing and back to the FIP model on a monthly basis while retaining the right to the previous fixed FIT. The benefit of direct marketing is the possibility to earn more profits than the fixed FIT when selling electricity during peak demand times at peak prices above the average monthly market price. Additional revenue opportunities can be explored by the sale of balancing energy. Biogas plants can also benefit from the so-called flexibility bonus rewarding their demand-oriented generation.[86]

4.1.2 Direct marketing (CfD) in the UK

In the UK the so-called **contracts for difference (CfD)** were introduced in 2017 as the government’s main mechanism for supporting low-carbon electricity generation.[87] A CfD is a long-term contract between an electricity generator and Low Carbon Contracts Company (LCCC)[88], which is a private company fully owned by the Secretary of State for Business, Energy and Industrial Strategy (BEIS). For the duration of the contract (15 years) the RE producer receives a remuneration per produced kWh at the awarded level (the “**strike price**”) that should reflect the cost of investing in a particular low carbon technology[89]. So the producer does not have to sell the electricity in the wholesale market at market price. In this design form, CfD is a mix of a **sliding FIP scheme**[90] (state support) and a synthetic PPA in the form of **hedging** (see section 2.3). It can be therefore described as an element of a state support policy structure. When the market price for electricity (the reference price) is below the "strike price", LCCC pays the RE producer the difference. When the reference price is above the strike price, the RE producer pays LCCC the difference[91] (see figure 3).

Figure 3 **Schematic illustration of the contract for difference (CfD) mechanism in the UK.**[92]

The CfD scheme shall encourage RE producers to participate directly in medium- and long-term electricity trading, spot-market trading or balancing power markets[93] and thus reduce price volatility risks at the spot markets. Another goal is to protect consumers from paying excessive support costs by setting a fix price level which cannot be exceeded[94].

In order to apply for a CfD, RE producers must participate in the yearly allocation round and submit a bid. Bids are considered in ascendant order of the price they offered until the yearly budget for new projects is exhausted. The project that is last accepted sets the strike price for that year for all other projects accepted.[95] To date, there have been two allocation rounds.[96]

4.1.3 Mandatory acquisition (guaranteed acquisition) in Germany

According to the EEG, all RE installations below 100 kW of installed capacity are entitled to receive a FIT.[97] The duration of FIT payment is fixed for 20 years. The grid operator is responsible to preferentially dispatch the produced electricity, extend and adjust the grid up to the connection point of the RE plant. The project developer is responsible for connection of the plant to the closest grid connection point. This priority dispatch regulation applies to every RE power plant in Germany, not only to those smaller than 100 kW.

The FIT calculation is based on a transparent methodology taking into account the generation costs of each technology.[98] PV FITs are reduced based on a monthly digression rate, depending on technology and size (e. g. rooftop systems, installations on non-residential buildings, free-field installations). Additionally, the FITs for PV can be flexibly adjusted each quarter according to the so-called **"volume management strategy"**. It is based on the **"breathing cap"** degression system under which the FIT is decreased or increased each quarter depending on the capacity installed during the previous 12 months prior to the respective quarter. These regulations aim to further reduce the costs of PV support for end consumers and at the same time provide the PV producers with an investment security.

4.2 Conditions supporting PPA contracting in Europe

4.2.1 Organisation of the European electricity market

Currently, the electricity market in the EU is mainly organised as an **energy-only market**, because generators are remunerated for generated electricity only and do not receive remuneration for providing available generation capacities (**capacity market**). However, European countries have quite different market structures, which are often mixed structures consisting of energy-only markets and complementary mechanisms such as capacity remuneration and strategic reserve.[99]

There are two main types of energy-only wholesale markets:

- **stock exchange derivatives** and **spot market** and
- over-the-counter derivatives consisting of a long-term **bilateral over-the-counter (OTC) trading** and **organized OTC trading**.[100]

The above mentioned different types of electricity markets are arranged in a sequential order. They may start years ahead of delivery (derivatives: **future and forward market)** or, as it is the case on the spot market, shortly before the actual delivery takes place **(day-ahead and intra-day markets)**. On the spot market they can even end after the actual delivery **(day-after market**). Above all, there are the **balancing markets,** which are often operated and managed by the TSO(s) of a country. Balancing energy is an important ancillary service to stabilize the power system "through the continuous, real-time balancing of power demand and supply"[101].

In this overall structure, PPAs can be defined as part of the **bilateral OTC trading** in the EU, although currently RE does not yet play a significant role in this form of trading. Mainly large hydro power plants are financed through very long-term PPAs (up to 40 years) [102] that were closed many years ago in quite different surrounding market conditions.

4.2.2 Factors that support the utilisation of PPAs

In this section, the most important conditions and developments in regulation and electricity markets that facilitate PPA contracting in the EU will be discussed based on the perspectives of different involved actors. Afterwards, case studies of Germany and Sweden will be presented to illustrate which relevance the country-specific context has on the utilisation of PPAs.

From the RE producer's perspective

Offer price and revenues stability: RE has become cost competitive in a number of countries. The reason is that the technology costs fall and infrastructure capital costs remain at historically low rates. [103] As a consequence, wholesale electricity and balancing energy prices in Europe are expected to become more volatile due to the increasing share of variable RE and the decrease of baseload conventional generation[104]. In this market environment RE producers as well as electricity buyers can benefit from the price and revenue stability offered through PPAs because they allow stable refinancing cash-flows. A low-risk perception is vital for the bankability of any capital-intensive RE project. [105]

Reduce incentive policy dependence: Volatile wholesale electricity prices and the goal of most governments to reduce the financial support for RE enable and push RE producers to seek financing options outside the current support structures. Until now, the expansion of RE in Europe has been taking place almost entirely on the basis of targeted incentive policies. The support level of those policies is becoming increasingly competitive and participation in mechanisms such as auctions and CfDs is complex and contains relevant hurdles, especially for small producers. That triggers a development towards alternative financing options.

Follow-up financing option after support period: Within the next few years, an increasing number of RE installations will reach the end of their support period[106], especially in Germany. Many of these plants are expected to continue operation, especially in the case that repowering is technically feasible. Entering into PPAs may provide a good business case for the further operation of such RE power plants and can contribute to an increased resource efficiency.

From the buyer's perspective

Avoid market risks and price volatility: As it was mentioned, wholesale electricity and balancing energy prices will become more uncertain and volatile due to the increasing share of volatile RE in the system and the decrease of baseload conventional generation. Moreover, in the long term, wholesale electricity prices are expected to increase due to the upcoming changes in the EU ETS with increasing prices for carbon emissions. That affects especially the price level of electricity from fossil power plants.[107] These changes stem from already implemented EU ETS reforms, such as the market stability reserve; current political discussions on further reforms and resulting decisions will increase that dynamic. The retail electricity prices are also expected to increase due to the increasing costs for the grid infrastructure necessary to integrate RE (relevant for direct PPAs) Those developments may increase the competitiveness of RE in comparison to the fossil incumbents[108]. In some European countries in the Nordics, such as Denmark, retail electricity prices for large industrial buyers are very high, so PPAs for wind energy provide a viable alternative option to procure electricity on the wholesale market.[109] Generally, PPAs represent a good option for buyers to procure energy cost-effectively and avoid market price volatility. They can provide long-term cost stability, predictability, affordability and price visibility for buyers, especially corporations and industrial players with high sensitivity to predictable and competitive prices.

Improve sustainability performance: Large corporations are increasingly looking to reduce their environmental footprint and carbon emissions. [110] They adopt strategies of corporate social responsibility and commit to green agendas.[111] The reasons can be the wish to improve their corporate image and sustainability performance as well as imposed regulatory requirements such as quota systems for RE. As a result, many companies are seeking to satisfy their energy needs from RE sources[112] and prove that by buying RE electricity or the green electricity certificates (certificates of origin).

Use market opportunity for cost-effective procurement: As it was mentioned, within the next few years, an increasing number of RE installations will reach the end of their support period. Entering into PPAs with the operators of those RE power plants can provide a good business case for buyers to procure electricity at competitive costs. That situation may be a win-win for all involved and thus trigger greater utilization of PPAs.

From the governments` perspective

Convergence of support policy development and market-based possibilities: Ambitious RE and climate policy targets in the countries increase the need for electrification of different fields of consumption (e. g. transportation) and will likely lead to a growing demand for RE electricity. PPAs can potentially defray part of the public expense for RE support policies. But by adequate design, support policies may also work in conjunction with PPAs, without substituting each other. [113] Targeted interventions by governments can support the accelerated roll out of PPAs, whereas PPA can generate additional investment sources for RE projects.[114] In the future, support schemes such as FIP will be probably replaced by investments grants and other forms of government support. [115], which may be easily combined with PPAs, e. g. when a RE developer needs an investment capital.

Use PPAs in other fields of energy transformation with financing needs: Energy systems are becoming significantly more complex as a result of increasing RE penetration[116]. It requires increasing effort of governments and grid companies to plan, coordinate and fund the grid infrastructure, management and flexibility of electricity production and demand, energy storage and power-to-X technologies. [117] PPAs may play a vital role in these planning and coordination processes because they are a highly flexible tool that can serve several purposes and can even help to match system needs which are very difficult to regulate directly. One example is the use of power-to-X systems (e. g. for the production of hydrogen), which could be in the long term supplied from large-scale RE projects on the basis of PPAs[118].

Embrace the opportunity, integrate it into regulation: The EU has recognized the role of PPAs and is planning to improve the conditions for this mechanism, which should encourage producers and buyers to enter into PPAs. The new European Renewable Energy Directive (RED II) foresees a significant improvement for PPAs by removing administrative barriers and creating favorable regulatory frameworks. This includes the introduction of a legal definition of PPA, strengthening of the green electricity certificate system and support of the introduction and use of regional certification regimes and markets.

Future development

According to a recent study of Enervis Energy Advisors, PPA-funded wind and solar projects will account for only 1 % of Europe's installed RE capacity by 2020. But the share will increase significantly until the mid-2020s. For the beginning of the 2030s, Enervis expects that the expansion of RE will take place almost entirely on a PPA basis. Ten years later, even half of all installed wind and solar power plants in Europe will be based on PPA contracts. By then, PPAs will become the standard instrument for RE financing.[119]

In the following, two country examples (Germany and Sweden) will be presented in order to discuss specific conditions which support or hinder PPA contracting, related to regulation and market.

4.2.3 PPAs in Germany

Supporting factors for PPA in Germany

State support becomes financially unattractive for RE producers: Germany is an example of a state with rapidly changing RE market and ever-evolving support policy structure. In 2017 it introduced RE auction schemes which replaced the statutory FIP through auction-based FIP for wind and PV plants from 750 kWp upwards. The level of competition was satisfying in most of the auction rounds (for all technologies) and a general decrease in awarded price bids could be observed. According to Energy Brainpool, most of the onshore wind power installations that won the auctions in 2017 will earn more on the wholesale market than from the FIP supporting mechanism during the support period. For them the support policy is a hedge of the minimum revenue, even if the FIPs are unlikely to be paid out.[120] At the same time also the FITs and FIPs for power plants below 750 kWp have been decreased continuously due to the government policy of keeping the support for RE as low as possible and regular adaptation of the support level by the mechanism of the "breathing cap" (see section 4.1.3). These rapid cost and support decrease has let companies (especially of the wind and PV industry) to increasingly look for new and alternative marketing opportunities outside the existing support policy structure. PPAs provide a stable source of income in contrary to the state support, whose level is steadily adjusted (FIT) and dependent on the volatile spot market price (FIP). PPAs also make it possible to reach individual agreements with buyers that include more favorable price conditions as state support decreases.

State support poses hurdles to smaller RE producers: Another condition that may let actors decide to enter into PPAs rather than take part in auctions is the fact that auctions limit the market considerably in its volume as well as in its diversity. E. g., only 600 MWp of PV per year can be tendered, in addition, for the years 2019 to 2021, a further 4 GW in total will be awarded through special tenders.[121] Auctions also involve many legal hurdles[122]. In particular, many potential RE producers, such as municipal utilities, municipalities and citizen energy cooperatives do not decide to participate in the auctions because of the revenue uncertainty due to a quite complex calculation method of the FIP, which is periodically adjusted and depends on the location, the expenditures for land and planning approval procedures[123].

Germany has ambitious RE targets for electricity: German government has implemented ambitious RE targets for the electricity market and for carbon emission reduction. RE electricity is the single most important measure to enable the use of RE in other sectors (mobility, heating, industry) which further boosts the interest and need for RE electricity production. However, it is already foreseeable that with the current incentive system and market structure, both the RE and emission reduction goals are probably not achievable (e. g. due to low number of bids in the wind-onshore auctions). Therefore, it is expected that the government will pay more attention to non-state market instruments such as PPAs and develop appropriate conditions or eliminate obstacles for their implementation in order to accelerate the energy transition and reach renewable and climate policy targets.

Germany phases out nuclear and coal and the EU proposes new policies: Other factors that might increase the political and business interest in PPAs are the gradual phasing out of coal-fired and nuclear power plants in Germany, which may "push the utilities' ability to take on further market risks through PPAs"[124]. Also the national implementation of the Clean Energy for all Europeans-Package (Winter Package) with the revised version of the European Renewable Energy Directive (RED II) may accelerate the use of PPAs.

EEG support phases out: Last but not least, the phase-out of EEG support for an increasing number of RE power plants starting from 2020 additionally increases an interest in alternative financing options. Between 2021 and 2026 around 14.000 wind turbines with an installed cumulative capacity of 17 GW exit the support scheme and represent a viable market potential for new business models such as PPAs[125]. How could the further operation of those installations be economically viable in the future? One possible option is to enter into a PPA with a corporate or utility buyer interested in a long-term electricity delivery for a competitive price. By that, significant RE generation capacities could be further utilized in the system.

However, since PPAs may provide the RE operator of an old power plant much lower revenues in comparison to FIT (around 30 % of the previous revenues by full covering of operational costs)[126], it could be more attractive to sell whole power plants to utilities or wind energy companies. It may be a good business case for wind energy companies through selling RE electricity to other companies that are looking for viable possibilities of green energy procurement and at the same time offering cost benefits through favorable costs of operation and maintenance of the plants[127]

New opportunities for electricity traders and RE producers: For electricity traders, contracting of electricity from both old and new RE power plants via PPAs is also an option. The main reason that triggers this interest is the expected increase of the spot market electricity prices. Secondly, the current support scheme with the market premium is perceived as a "tight corset" which specifies exactly how the electricity has to be marketed and thus is very inflexible when creating the most suitable business model. [128] Sales of green electricity certificates is not possible for RE power plants that receive FIT or FIP. In the FIP model, RE electricity is marketed as a part of the total electricity mix, including conventionally generated power. By buying electricity in PPAs without FIP, RE producers could create new green electricity products for customers interested specifically in green energy. [129]

Possibilities of implementing PPAs in Germany

On the German electricity market there exist currently three main options of how to implement a PPA (see table 5). Those different possibilities for implementing PPAs depending on the lifecycle status of the RE power plant correspond with the diverse needs of the market actors. They have different motivations to enter into PPAs. Also the preferences regarding the detailed contract conditions, such as the contract duration, may differ. For example, RE project developers prefer long-term PPAs, whereas electricity traders are more interested in short-term contracts.[130] Currently, in Germany there is not one “usual” or preferred PPA model and that is also unlikely in the future. There will be many different PPA structures and they will be adapted individually by the actors to their specific needs. In any case, the role of PPAs in Germany in financing of new RE project will be constantly increasing.[131]

RE producers receiving FIP enter into PPAs	– relevant for operational projects – selling of certificates of origin is not possible – attractive for corporate customers wanting to hedge their power risks – feasible for off-site sleeved and VPPAs, but not for direct PPAs, because the electricity must be exported to the grid in order to receive FIP
RE producers that are no longer eligible to receive FIT/FIP enter into PPAs	– relevant for operational projects – selling of certificates of origin possible – feasible for all kinds of PPAs
RE producers voluntarily resign from their right to participate in auction or to receive FIP and enter into PPAs	– relevant for both operational and new projects – new projects more attractive due to the fact that they would be subject to fewer legal hurdles by not taking part in the auction process and not being bound by the statutory annual maximum capacity volumes – selling of certificates of origin possible – feasible for all kind of PPAs

Table 5 **Different possibilities for implementing PPAs on the German electricity market[132].**

Regulatory and market barriers in Germany

As mentioned in the previous section, in Germany currently PPAs are worse off than other marketing options for RE because operators cannot benefit from EEG support scheme and at the same time sell their electricity by means of green electricity certificates. Many corporate buyers are primarily interested in these proofs of origin in order to maintain their climate-friendly corporate image.

If a PPA is signed for a RE power plant that does not receive FIP, green electricity certificates may be conveyed or sold to the electricity buyer. This business case may gain more attention in Germany with an increasing need of companies to procure green electricity

One of the main market barriers is a lack of knowledge, experience and standards regarding the design and content of the PPA contracts, e. g. the sharing of risks and chances of market price fluctuations. However, there is little standardization potential due to the complexity of the product and specific requirements on the buyer's side (see above).

Other current market barriers for PPAs in Germany are:

- insolvency risk of the contract party,
- market risks/electricity price volatility,
- complexity and high transaction costs of PPAs and
- unfavorable financing conditions in comparison to the state support mechanism.[133]

Examples of PPAs in Germany

There are some examples of utility PPAs in Germany, with following utilities being involved as buyers: Statkraft, Greenpeace Energy, Enercon (Quandra Energy), Wemag and Engie[134]. Altogether the entire volume of PPA contracts in Germany is not higher than 100 MW[135].

In 2018, Norwegian energy group Statkraft signed a PPA with six community wind farms in Lower Saxony, which will allow them to continue their operations from 2021 onwards after expiry of the support period. The capacity of the wind farms amounts to 45 MW. The duration periods of the contracts are three to five years. Statkraft will supply the green electricity to a one German industrial company.[136] Also Greenpeace Energy, Enercon and Wemag will purchase electricity from old wind power plants, which will not receive any support from 2021 onwards. [137]

In case of Engie, the PPA covers the power generation from the Arkona offshore wind farm (OWP Arkona) that started to generate electricity in the summer of 2018. Under the terms of the agreement, Engie purchases the whole power generated by the wind farm (1,5 terawatt hour (TWh) per year) and markets it for a period of four years on the German day-ahead and intraday market. At the same time, Engie manages various market-related risks for the wind farm.[138]

To date there is only one example of a corporate PPA known in Germany: a 10 MW wind power plant developed and operated by WPD AG for a factory of BMW in Leipzig. WPD considered the factory processes and needs in the planning and design of the wind power plant in order to increase the full load hours and support the grid management and optimization of the factory.[139] In September 2019, another example is expected to follow: BayWa r.e. has signed a PPA with an industrial buyer for its 8.8 MW solar park in Mecklenburg-Vorpommern, which has started construction in June.[140]

Last year, BayWa r.e. built and sold a 175 MW PV power plant in Southern Spain to Meag. Meag signed a PPA with Statkraft as buyer for the electricity from this plant for 15 years at a price range of 35 – 50 €/MWh. In the next years, BayWa r.e. plans further solar power plant in Spain and other South European countries with a total capacity of more than 1 GW. According to BayWa's managing director, it is also possible in Germany to sell PV electricity from large-scale PV power plants without FIP. He estimates that in 1-2 years, the costs could decrease to 30 €/MWh. However, the main hurdle could be land use restrictions, necessary permits as well as owners' and communities' reluctance.[141]

Not only RE project developers and possible industrial buyers in Germany are increasingly interested in PPAs. Also lenders start to include products in their portfolios with the aim to help RE producers to obtain financing. The sustainable development lender Umweltbank has developed a financing product intended for large-scale PV power plants that includes a PPA. According to the bank, if a PPA for minimum five years is available at a fixed price, a loan with a term of up to 25 years may be granted. Ten years ago, Umweltbank started offering standardized contracts for FIT-backed solar projects.[142]

4.2.4 PPAs in Sweden

Supporting factors for PPA in Sweden

Sweden develops RE rapidly and PPAs are contributing to this growth: In July the Swedish Wind Energy Association (SWEA) reported that the country is on track to reach its 2030 RE target of 49 % electricity from RE sources by the end of 2018. [143] In June 2017 the Swedish parliament decided to increase the production of electricity from RE sources by further 18 TWh by 2030.[144] By 2040 Sweden wants to produce 100 % of its electricity from RE sources. Corporate PPAs are increasingly contributing to reaching these targets and have been growing in popularity in Sweden and also in Scandinavia as a whole. [145]

Favourable conditions for big data centres: The PPA market in Scandinavia is booming due to rapid development of data centres due to its cool climate, cheap electricity, good interconnections, and EU policies promoting cross-border digital corridors.[146]

Favourable support structure: Next reason for the intensive PPA development in Sweden is the RE support structure, which is based on green electricity certificate and quota system for utilities and companies. It generally increases the interest in RE, because corporations are able to receive green electricity certificates to meet sustainability targets. But this system does not guarantee the RE producer a specific price for the power generated. Thus the RE producer takes a market-driven price risk related to the sale of the electricity. Many financers, such as banks, require therefore that the price is hedged. One way to hedge the price is a corporate PPA between the RE producer and a corporate buyer. It offers the certainty that the RE generators need in a financial environment without state guarantees or subsidies.[147]

Stable and predictable regulatory framework for buyers and sellers: PPAs are particularly attractive in Sweden, because the market environment is stable and predictable for energy buyers and sellers, and this statement applies also to the whole Scandinavia[148]. Additionally, the power market is very liquid and transparent.[149]

Low electricity prices: Further supporting factors that make Sweden particularly attractive for PPAs are low electricity prices due to a decrease in the prices of fossil fuels and the growing supply from RE, including hydro[150]. According to Eurostat, electricity prices for non-household consumers in the second half of 2017 amounted to 0.15€/kWh in Germany and Italy, whereas in Sweden, Finland and Norway it was only 0.06-0.07

€/kWh. As a result, RE producers are interested in corporate PPAs to obtain financial certainty, and corporate buyers are eager to sign PPAs to obtain secure low long-term prices. [151]

Government support – cutting energy taxes and nuclear phase-out: Also important for the proliferation of corporate PPAs in Sweden is the government's explicit support which created suitable and predictable regulatory conditions for RE. In addition, the Swedish government has cut energy taxes and it has also decided to close two Vattenfall nuclear power plants - first in 2019 and second in 2020 – a decision which has opened the way for RE producers to bring forward projects to fill the generation gap[152].

Regulatory and market barriers in Sweden

The existing RE support scheme in Sweden, the quota system, puts an important obstacle for PPAs. The value of green electricity certificates collapsed through over-supply due to high RE installation numbers, low wholesale electricity prices and large sources of nuclear and hydro. These developments have been recognised by the Swedish government and an incremental reform of the RE support system is currently being carried out to address the issue of over-supply. This should improve the business case for new RE developments and reduce price pressure in PPAs. [153]

Examples of PPAs in Sweden

Sweden is the first European country where one of the international internet giants signed a PPA. In 2013, Google made a deal with OX2 for electricity delivery from the 72 MW Maevaara wind power plant. One year later Google signed several ten-year PPAs with another Swedish developer, Eolus, for the electricity output from several wind power plants in the South of Sweden totalling 59 MW, to power a data centre in Finland. In 2015, it signed another PPA with Eolus for the power from a 76 MW wind farm in Västernorrland County.[154]

Also major industrial players are signing PPAs in Sweden. The Norwegian company Norsk Hydro agreed in 2018 to buy 60 % of the electricity from the 353 MW Blakliden/Faebodberget wind power plant in Sweden developed by Vestas, Vattenfall and PKA. [155] In 2017, the same company signed the largest PPA in Europe to-date for the Markbygden ETT wind farm in northern Sweden with a projected total capacity of 650 MW. [156] Norsk Hydro will buy 1.65 GWh annually over the 19-year contract duration, which is about 80 % of the expected electricity generation.[157] This wind farm is just the first phase of a 4 GW-plus Markbygden cluster.

5 Success factors and limitations of PPAs

This section highlights the success factors of renewable PPAs from the perspectives of buyers and sellers and summarizes the potentials and limitations of PPAs as a RE procurement approach.

5.1 Success factors of PPA

A well-designed PPA could benefit multiple stakeholders, including the RE producer and the energy buyer. A PPA offers flexibility and creativity to corporations to procure RE that traditional utilities cannot provide. While using a PPA as a financial tool for RE procurements offers many benefits, it certainly is not a "one size fits all" solution for all buyers. With evolving policy, regulatory and market landscapes, sometimes an advantage could also fade away under changing circumstances.

From the buyer's perspective

- **Risk limitation:** First, a PPA, physical or VPPA, provides a hedge against future electricity price fluctuations. Electricity prices offered by the utility typically are subject to market variabilities (e. g. fuel costs, intermittent supply of generation assets) and other costs such as regulatory compliance and infrastructural investments. For example, in the deregulated markets of the U.S., California Independent System Operator(CAISO) has energy price cap and floor at the level of $1,000/MWh and -$150/MWh, respectively, while New York ISO (NYISO) and PJM Interconnection (PJM) have no price floor[158]. PPAs offer buyers the opportunity to lock-in electricity prices over the term of the PPA contract (typically 15-20 years). The PPA price creates a predictable expenditure that reduces financial risks and uncertainties for buyers. Although, price risk and basis risk (the price difference between hub and node) may take place when implementing a VPPA, settling VPPA by hub (average prices in region or zone) rather than by node (particular location on the transmission system) and setting a price floor and cap can mitigate these risks[159].
- **Low entry barriers:** Second, PPAs require minimal to no upfront capital expenditure and can save buyer money on day one of the contracts, which benefits both utility and corporate off-takers. Additionally, buyer is generally not responsible for ongoing operations and maintenance cost and monitoring of the system. This is particularly desirable for corporate buyers because operating and maintaining a power plant is beyond their core business. In addition, in the U.S., PPAs allow entities (e. g., non-profit organizations) that cannot make direct use of the tax credits to benefit them. For example, PPAs enable universities to benefit from renewable tax incentives indirectly[160]. However, such incentive policies could vary considerably by jurisdictions and change over time. With expiration or phasing out of RE incentives, the declining cost of RE is expected to drive the utilization of PPAs.
- **Increase of the own RE profile:** Lastly, PPA is an effective approach to procure relatively certain variable RE electricity. The developer is incentivized to maintain the system and keep it operating optimally because the PPA is mostly settled on energy output ($/MWh); the more energy the RE power plant generates, the more payment RE producer can receive, provided that the PPA covers the entire production. Moreover, many PPAs contain performance guarantees that protect buyers from production shortfalls. This advantage may erode or create some issues when oversupply and curtailment take place, which will be discussed in section 5.2.

From the developer's perspective

- **Revenue stability and RE bankability:** PPAs create a long-term, predictable cash flow that can either be sold off at a discounted value or can be retained for revenue generation over a long term. In this way, PPA participants can have a clear vision for their long-term plan rather than facing the price uncertainty.
- **Risk sharing:** Second, PPAs spread risks across several different parties such as developers, buyers, and financiers, and thus creates a more flexible risk-sharing approach. As discussed in section 3.3.1 in detail, risks (fuel, price, shape, operation and basis) along with RE procurement have not been allocated between the seller and buyer correctly. As a financial tool, PPA can re-allocate those risks.

From a market perspective

- **Design flexibility:** PPA opens up market opportunities by allowing customers to decide what price they are willing to pay for RE and to choose which financing method is most appropriate for them.
- **Price flexibility:** Compared with PPAs, government-driven RE incentives like FIT may not reflect the actual RE price in the context over ever-decreasing technology costs. Implementing market-based PPA can, therefore, alleviate public budgets and can protect RE producers from the uncertainty of wholesale markets as well as falling FIT/FIP prices. For example, in Germany FITs and FIPs are continuously decreasing. PPA also removes government allocation risks because government is not responsible for paying the generator for all or a portion of energy.

5.2 Limitations of PPAs

Like other financing options, PPAs have some limitations and disadvantages. Some of the limitations take place due to the characteristics of variable RE. For instance, because solar generates most of its output during the midday and the demand peak usually takes place during the sunset, the output from variable RE is often not simultaneous with the buyer load demand, known as shape risk. While buyers and sellers are familiar with different types of risks, negotiating a balanced contract remains challenging even with advances in economic modelling and best legal practices. Below is a brief summary of the key limitations associated with PPAs for RE.

Creditworthiness

PPAs require a creditworthy buyer to inspire the trust of investors and banks to protect the seller and the financiers from defaults. If the buyer is not creditworthy, a bank is unlikely to provide debt financing. The need for a creditworthy counterparty can impose significant barriers and transaction costs on sellers and can bar unrated customers (e. g. private companies without public financials) or customers with unfavourable credit (e. g. large and stable corporations facing macroeconomic issues in their industry) from the marketplace.

Market and regulation

The feasibility and viability of PPAs are **highly dependent on surrounding market and regulatory infrastructure** within which the sellers and buyers operate. For example, in the U.S., the sellers involved in the VPPAs must be located in competitive wholesale markets. Another example is that some third-party PPAs may not be economically viable if net metering is disallowed in the state, where the PV systems are located (see section 3.3).

Understanding market risks of PPA, especially VPPAs, is important. Because VPPAs rely on fluctuating market prices, it is crucial to understand the forces which influence the price formation. There are many factors which could impact future electricity pricing including RE penetration, natural gas pricing, transmission capacities and distribution grid upgrades, the regulatory environment and carbon emission pricing. Buyers need to have a thorough understanding of the market risks embedded in the transaction so they can make informed decisions about what risks they are and are not, willing to take. This enables them to ultimately structure a transaction in line with their specific risk tolerance.

Risk due to long contract duration

PPAs typically require a 15 –20-year term to ensure that systems are fully paid down, investors meet their returns, and the price per kWh is low enough to attract buyers. Contracts with long time horizons generally carry risks such as long-term market stability, developer viability, and mismatch with certain business or regulatory requirements. For corporations with shorter business strategy timeframes, a long-term PPA is not appropriate, and even for large buyers like utilities, the seller and its financers would have to critically consider the business stability such as the possibility of bankruptcy. For example, Pacific Gas and Electric Company (PG&E), an investor-owned utility in California has filed bankruptcy in 2019, and it has proposed a plan to renegotiate PPAs that include relatively high prices with RE producers[161]. In terms of seller viability, the bankruptcy and acquisition of RE producers also increase the risk of contracting PPA. Last but not least, corporate buyers could be subject to contracting limitations from their regulators or are unwilling to bear long-term risks as part of their financial policies or the nature of their businesses, which could prevent some entities from entering into long-term contracts. The recent trend in the U.S. suggests that more corporations prefer PPAs with a much shorter term (e. g., less than 10 years)[162].

Information asymmetry

PPA structures are complicated and keep evolving, so market participants will need some degree of familiarity with PPA contracts and pricing for a stable and efficient PPA marketplace to exist. Information asymmetry exists across all involved actors: seller, buyer and financer. Buyer, especially corporations, may have less information because they are not responsible for project development, operation and maintenance, and thus need to case disadvantages when negotiating the PPA price. Usually there is a learning curve associated with learning how to execute PPAs, what to look for in the terms and conditions, how to determine pricing and how to compare competing bids.

Curtailment

Some PPAs may suffer from revenue losses and increased risks for both, RE producer and buyer, when curtailment takes place. The specific impact depends on the risk allocation under the PPA and the extent of curtailment that takes place. Curtailment refers to the curtailed energy output that would otherwise be produced. In energy only PPA model, buyers have high risks because they are required to purchase all energy output, even the curtailed volumes. On the other hand, if the buyer has the right to choose whether to dispatch the electricity or not, the RE producer will bear the curtailment risk. Some innovative PPAs are emerging to mitigate curtailment risks, see section 3.3. for details.

Accounting treatment[163]

The accounting requirements for physical PPA and VPPAs are different and could mean the first make-or-break decision when buyers vet their interest in a potential PPA. In the U.S., physical PPAs require a licensed power marketer (an entity engaged in the purchase and sale of electricity) to facilitate the delivery of energy to the buyer's account. On the other hand, VPPAs can be subject to different accounting requirements. Because a VPPA is fixed for floating swap, it is subject to certain U.S. financial industry regulations, which require registration and reporting of the transactions by the buyers and sellers in the U.S. Before signing a VPPA contract, the buyer should seek to fully understand these accounting requirements.

6 PPAs in China: current policies and options for further action

6.1 Why PPAs could be an option for China's energy transition?

PPAs could help address major challenges that China faces in integrating RE into the power system and enable quicker RE deployment. In the following, a couple of those challenges and political goals are discussed:

6.1.1 Decouple RE deployment from government subsidies

In light of the huge deficit in its Renewable Energy Development Fund, from which the FIT is paid to RE producers, China is looking for market-based approaches to support RE development. Generous FIT and often slow adjustment to the FIT rates incurred significant social and capital costs as well as mismatch between RE supply and demand. The unsustainable FIT incentive motivated the Chinese government to introduce market-based elements for the calculations of FITs (see section 6.2). In order to decouple further RE development from government subsidies, the Chinese government also encourages subsidy-free RE development (see section 6.2). PPAs offer a financing tool to streamline RE investment and demand through a long-term contract between buyers and RE developers, provided that the surrounding market structure supports the creation of PPAs. European examples demonstrate that PPAs can be used to facilitate the transition from FIT to FIP and beyond to reduce the dependence of RE development on government subsidies.

6.1.2 Fulfil renewable obligations: RE consumption goals

PPAs could help provinces and corporations to achieve the new mandatory RE consumption goals. On 10 May 2019 China introduced the Mandatory Renewable Electricity Consumption Mechanism[164]. The official assessment and monitoring is slated to start in 2020. The documents published by NEA (National Energy Administration) in May 2019 foresee assigning a quota to provincial grid companies, state-owned and private distribution grid companies, electricity retail companies, industrial enterprises owning their own power plants, and large end-users participating in bilateral electricity trading. NEA will set RE consumption targets for provinces and provide measures to achieve them.[165] Companies covered by the scheme will receive green electricity certificates when they buy RE directly[166]. Because corporations currently have very limited choices (e. g., green certificates, direct investment in RE) to procure RE, PPAs could provide a valuable mechanism to allow corporations to sign contracts with RE developers to achieve their mandatory goals.

6.1.3 Reduce curtailment risks

China has made tremendous efforts to boost RE penetration and currently is a global leader in this field. By 2018, China has deployed over 170 GW and 180 GW solar and wind cumulatively[167]. But at the same time huge amounts of electricity generated from RE have been curtailed due to **transmission bottlenecks, non-merit based dispatch order and insufficient local consumption** where RE production is abundant, among other factors. In 2018, 7% and 3% of wind and solar were curtailed in China, respectively[168]. However, the regional imbalance between RE supply and electricity demand is a key factor contributing to the much higher curtailment rate in certain regions. For example, the quick expansion and oversupply of wind energy in north-western China means that some wind energy cannot make to the load centres near the coast while maintaining normal operation and reliability of the power system.[169] In Gansu Province the curtailment rate was 19 % for wind and 10 % for solar alone in 2018.[170] The "Renewable Energy Integration and Consumption Plan 2018-2020" released by NRDC in 2018 aims to mitigate and address RE curtailment issues[171]. PPAs can serve as a complementary tool to achieve a more balanced allocation of curtailment risks between renewable producers and buyers (see section 3.2.1). It can also help to better match RE electricity generation and demand and thus prevent generation overcapacity and grid congestion. On that end, PPAs may also support a **better planning and utilization of the grid infrastructure** (see section 6.3).

6.2 How newly established policies may facilitate PPA adoption in China?

China has already taken initial steps to facilitate the implementation of PPAs, especially for corporations. [172] Besides the already mentioned **green certificates and quota systems**, it has implemented various aspects of **wholesale electricity market reform** and is trying to adapt it to accommodate the needs of different market actors. The central government intended to reduce RE subsidies by introducing competition of FITs through auctions. According to policy released by NDRC in the end of April 2019, FIT level payments are subject to competition since July 2019. Local authorities are expected to **hold auctions for FITs** of wind and PV plants and special PV projects (including "Top Runner" and grid-supporting projects). For PV, the NEA will then allocate FIT payments only to the most competitive projects. In parallel, the Price Bureau of NDRC announced the level of PV FIT payments as a guidance for the auctions in July 2019. In addition, the government strongly encourages non-subsidized PV projects (known in China as Grid-Parity Projects), which will not receive any national subsidy. Green certificates will be granted for those projects as an additional source of revenue[173].

This new policy makes room for PPAs as an alternative financing option for new RE projects to secure revenues. What is more, the introduction of FIT competition and thus their market-based calculation provides a reference point for RE price calculation also outside the subsidy mechanism. It helps to determine the price in a PPA that is in line with the market, and thus encourage the market actors to choose this financing and purchasing option.

Last but not least, China has introduced in 2019 a **priority dispatch for PV and wind projects** that do not receive any subsidies and are situated in regions and provinces without grid congestion issues[174]. They will be able to sell electricity in excess of the quota[175]. **Grid companies** should not only transmit, distribute and sell the electricity from RE, but also procure it through long-term (20-years) PPAs for fixed prices[176]. The most of distribution and transmission system operators are state-owned, which gives Chinese authorities the power to impose on them the duty for a certain form of energy procurement.

6.3 Further options for actions in China to accelerate PPA utilisation

In the following, action options will be discussed that could enable better and quicker implementation of PPAs in China based on the experiences and lessons learned from the U.S. and Europe.

6.3.1 Structural market reform

An important condition for PPAs is a further vertical and horizontal unbundling, that is separation of generation, transmission, distribution and retail functions into multiple entities that compete with one another or provide services in different areas. In the U.S. and many European countries, full unbundling is still not achieved and the situation is quite diverse as well. But the experience with its implementation shows that it can be advantageous for the market actors. Unbundling provides the possibility of direct marketing of generated electricity to the consumers – on a spot market or over-the-counter. These marketing options are currently limited in China. Only large corporate consumers, who match the access conditions, are able to participate in direct purchase, e. g. procure electricity from RE generators[177]. Purchasing and retail functions are attributed to state-owned system operators only[178]. These vertically integrated, state-owned grid companies have thus monopolistic superiority in the Chinese retail and consumption market. There exists also an oligopoly on the generation side with five state-owned power generation companies[179], authorized by the government. Wholesale and retail power prices are regulated and the generators are rewarded based on the amount of electricity produced[180]. This inflexible market structure as well as the price regulation limit market access of other independent power producers. Moreover, decoupling retail from transmission and distribution tasks as well as enabling more competition in generation through equal and transparent grid access for all generators and energy sellers would encourage more actors to negotiate and enter into PPAs. At the moment, PPAs in China are often tripartite agreements between the buyer, the RE producer and a state-owned grid company[181]. Depending on grid company's role in the power system, whether to highly involve it in PPA contract or not varies by countries. For instance, grid companies in the EU are not parties in the PPAs and they basically provide the grid infrastructure to the energy producers to transmit or distribute the energy. The RE producers need to submit an application for the grid connection by the responsible grid operator and clarify the grid connection condition. In this way, without TSOs and DSOs acting as intermediaries in those contracts, electricity procurement through PPAs is easier and quicker to execute.

6.3.2 Introduce transmission and distribution fees

A crucial step in the unbundling process would be the establishment of approved, updated, transparently and publicly available transmission and distribution (T&D) fees. Currently, grid companies do not charge separate T&D fees because they make revenues both for providing grid infrastructure and for selling electricity to the consumers. The total costs incurred for that are not publicly available[182]. The Chinese government established T&D fees in 31 provinces and the city of Shenzhen during the first monitoring and regulation period of power sector reform (2015-2018). Nevertheless, the structure of T&D fees does not adapt well with the requirements of PPAs, because they are higher if the PPA buyer and seller are situated in different provinces, which may be the common situation. In this case the fees include also transmission costs between the provinces. In order to encourage companies and sellers to make use of PPAs as procurement method, rational T&D fees should be introduced.

6.3.3 Consequent priority dispatch for all RE

PPAs could be implemented more easily if RE had priority dispatch, because it improves the planning and financial certainty for the market actors. In the EU, priority dispatch has been a successful policy mechanism to support RE and better integrate them in the market for many years. Priority dispatch means, that it is on the basis of criteria other that economic. The new EU directive on the internal market for electricity introduced within the Winter Package in 2019 removed priority dispatch for large-scale installations so that they take on their own responsibility for balancing the system. China introduced priority dispatch for RE in 2016. This has been included in the set of measures adopted by NDRC and NEA in the policy document "Measures for the Administration of the Guaranteed Buyout of Electricity Generated by Renewable Energy Resources"[183]. However, this policy provides RE priority dispatch only in some cases. It applies to hydro and utility-scale wind and solar to guarantee a new (RE) power plant to run for a minimum number of hours per year. Energy output for these hours are must-take via physical PPAs or CfDs with grid companies (utilities). Additionally, utilities are required to purchase all power generated from distributed PV, biofuel, geothermal and marine.[184] What is more, as it was mentioned above, in 2019 China introduced a priority dispatch for subsidy-free PV and wind power plants in certain regions and provinces which are required to enter into PPAs with grid companies (utilities)[185]. In order to encourage also corporate PPAs, a priority dispatch for all RE, for the whole energy output and in all provinces would be helpful. China could consider also modifying it by linking it to certain conditions to avoid grid congestion (e. g. direct marketing on the spot market or availability of utility or corporate PPAs). In the future China could revise the decision about introducing priority dispatch for all RE based on the level of RE penetration, the status of electricity market reform and infrastructure constraints.

6.3.4 Enable price competition and introduce spot power markets

If PPAs are to become attractive and competitive in China, questions concerning market design and financial challenges need to be addressed. Implementing corporate PPAs in China is challenging in the current regulatory circumstances. A market-based approach would be more appropriate to enable price formation in a more competitive way. At present, regional FITs for RE in China are quite high and not awarded in a market-based manner[186]. The price of green certificates in China is tightly linked with FITs guaranteed over a 20-year period, because RE producers must choose between receiving either the revenue from the FIT or from the sale of green certificates[187]. Certificates are still not allowed to be traded, and represent a transfer of the FIT payment only from the government to the buyer. Hence they are not additional, and corporate buyers are not interested in paying a subsidy that the government is already obligated to pay[188]. This situation provides barely incentives for buyers to enter into PPAs. PPAs would especially start to be an option for corporations if they provided enough certainty to enable cost reduction. On the other hand, RE producers wish to make revenues at least at the FIT level. Only in provinces with high levels of curtailment or other special circumstances, RE producers have been willing to accept prices lower than the FIT[189]. But since FITs are expected to be reduced further in China[190], PPAs may become a competitive and attractive substitution.

Another feasible option would be to introduce a market-based FIT calculation, e. g. determined in auctions, that would provide an appropriate reference point for price calculation in PPAs reflecting market conditions and costs. As it was mentioned, FIT level payments in China are subject to competition since July 2019. However, there needs to be a mechanism providing a **market-based reference point for price** in the auctions, which would serve also as a reference price for the PPAs. Spot markets could provide such solution. Properly functioning spot power markets (day-ahead and intraday) are crucial mechanisms for the implementation of PPAs. Spot market provides a reference point for electricity price formation and is particularly important for the price calculation and contract structure in financial PPA mechanisms. Spot market prices could also help calculating FITs and thus also help determining prices in the PPAs that reflect market conditions and costs. Moreover, spot markets are often used in PPA structures to balance production and demand fluctuations. Depending on the PPA model, it is often impossible for reasons of technical and economic viability to match perfect the generation and demand between the PPA seller and buyer. Against this background, China should consider to implement several spot markets in different provinces that each cover a high electricity trading volumes, thus providing enough liquidity and reflecting actual power demand and supply information. In June 2019, eight spot market power pilots in China started commissioning[191] in order to gather knowledge about its functioning in the Chinese context. More far-reaching information on the possible roadmap forward for China on the implementation of spot markets is included in the CREO 2019.

6.3.5 Strengthen the green certificate system

As it could be seen on the U.S. and European examples, a functioning system of green electricity certificates may facilitate the implementation of PPAs. The reason is that companies are willing not only to procure RE directly, but also need to have a proof of that origin. In order to facilitate a system of voluntary RE purchases through PPAs, a credible and reliable market and transaction infrastructure is needed[192]. This infrastructure includes contracts, accounting infrastructure, tracking systems or registries and transaction certification. As it was mentioned, China has a voluntary green certificate program in place and in May 2019 it introduced a quota system (see the paragraph below). However, until now the voluntary certificate market has offered limited choices to market participants and was not very effective so far (see the paragraph above). Therefore, China could consider introducing mandatory-based green certificate system and trading leaned on the quota system. It could benefit the renewable quota policy and encourage PPA deployment. In this context it could also clarify the relationship between green certificates and FIT payments (see also the paragraph on price competition and spot markets). For example, the German case has shown that the inability to convey the green electricity certificates when FIT or FIP is granted for the generated electricity may hinder RE deployment based on PPAs. On the other hand, PPAs may replace FIT or FIP as an equally competitive and attractive financing option if introduced carefully.

What is more, at the moment green certificates can be obtained from onshore wind and solar PV, which do not represent on-site or behind-the-meter generation. This regulation limits the possibilities to enter into direct PPAs at all and thus should be improved. As for the tracking system developed by the China Renewable Energy Engineering Institute, it still needs to be implemented to full functionality, including the ability for corporate entities to hold their own account[193]. Also an appropriate transaction verification program, complementary to the activities of the China General Certification Centre, needs to be adopted. It would encourage PPA deployment through i. e. ensuring the benefits of green certificates and avoiding that they are double-sold or double-counted.[194]

6.3.6 Emphasize and execute strict RE quotas

Even more favourable for an increased use of PPAs are quota obligations, not only for utilities, but also companies, like in Sweden. The mandatory consumption mechanism introduced in China in 2019 could be developed in order to encourage PPA deployment. At the moment the quotas are set for this year and next year and thus are not intended as an incentive or support scheme for the industry’s long-term development, but rather as a minimum to ensure the absorption of RE already built. These schemes are therefore not “market mechanisms” but instead serve as administrative targets. China could establish a market-based quota system that sets long term targets and would therefore provide investors and stakeholders with a long-term view of what would be mandated by policy and thus stipulate the emergence of new RE projects and PPAs.

6.3.7 Provide reliable grid infrastructure

For the further PPA implementation, the availability of transmission lines and a reliable grid infrastructure are indispensable, because otherwise it is not guaranteed that the energy generated can be transmitted to the buyer. This uncertainty may hinder companies from entering into PPAs. China still has difficulties transmitting RE from the generation areas in the North and West to the areas of the highest demand on the East coast of the country. Also more intermeshed transmission lines between provinces are lacking which leads to inefficient RE deployment and curtailment. PPAs may support a better planning of the grid infrastructure, since the generation and demand can be better matched. Chinese grid planning authorities could take advantage of this PPA feature and try to coordinate the infrastructure planning along with the PPA dissemination. That would encourage PPA deployment as well as better, more efficient and economically effective infrastructure development and utilization.

6.3.8 Provide proper legal framework and assistance

Last but not least, a legal framework and assistance for designing, drafting and implementing of PPAs that is transparent, reliable, comprehensive, possibly standardized, uniform and easy in application should be established in order to reduce the complexity, uncertainties and risks associated with this voluntary procurement method. The more transparent and the more comparable, the better PPA integration may work across provinces in China. Especially referring to the U.S. experience could be helpful in this respect, as the PPA has a longer utilization history there than in Europe, where the legal framework is still under development.

7 Conclusions

The aim of the report was to present the main PPA variants on the European and U.S. electricity markets, the elements that support or hinder PPA contracting as well as innovative PPA approaches that support coordination with further RE deployment. Based on that analysis, the report explained advantages of PPAs in the Chinese context and provided options for China how to achieve a better implementation of PPAs. Below the most important findings of the report are shortly summarized.

Advantages of PPAs

- PPAs may provide a viable alternative to the existing RE financial support mechanisms and to the trading on the stock exchange.
- The most important features of PPAs are their long-term price fixation and bilateral character. Due to these attributes, PPAs offer price and revenue stability and planning security both for buyers and RE producers.
- PPAs enable high level of flexibility so that they can be adapted to different electricity consumers and diverse actor constellations easily. PPAs provide an attractive option both for utilities, companies and energy communities and can be concluded with different corporate buyers or aggregating buyer groups/consortia.
- PPAs may help corporations to fulfil RE quota obligations and reduce their environmental footprint and energy costs.
- For states and grid companies, PPAs can play a substantial role in supporting the processes of planning and coordinating of RE and energy infrastructure development.

Experiences in different countries

- **Main factors that boost the interest in PPAs in Germany:** Rapid decrease of RE costs and their support level, ending of EEG-support from 2020 for increasing number of RE power plants, ambitious RE targets for electricity generation, decision to gradually phase-out coal-fired and nuclear power generation
- **Main factors that contribute to PPA utilisation in Sweden:** Suitable wind and climate conditions, RE quota obligation for companies, RE support scheme that does not provide price guarantees for the sold electricity, low electricity prices compared to the rest of Europe, which level may be secured via RE PPAs.
- **Main factors that contribute to PPA utilisation in the U.S.**: Two decades' experience with PPA implementation, further development that addresses challenges along with PPA implementation, use of innovative approaches to assign risks to different stakeholders and to provide more opportunities for smaller customers, improvement of PPAs to combine with new generation types, operation and grid formats (such as RE-plus-storage system, active power control and improving operational approaches) that make RE more dispatchable.

Success factors and limitations of PPAs

- A successful PPA implementation relies on both policy and regulatory support and market structure.
- Standardize contract terms and conditions are prerequisites of negotiating any PPA.
- Large-scale contracting of PPAs requires uniform regulations. The more transparent and the more comparable, the better PPA integration works across states (U.S.), provinces (China) and national borders (EU).

- General familiarity with PPAs among all parties in the transaction, including buyers, developers, financiers, legal professionals, governments, and others helps to avoid information asymmetry.
- Deregulated wholesale and retail markets provide more flexible PPA approaches and enable more participation. Big buyers like utilities play a more substantial role when implementing PPA in the regulated market.
- The falling cost of RE makes the LCOE of RE competitive with fossil fuels.

Options for China

PPAs could help address major challenges that China faces in integrating RE into the power system: reduce curtailment and decouple RE deployment from public money management. It could also help to fulfil the political goals, e. g. RE consumption goals. The following key options have been identified for China in order to easier and quicker implement PPAs:

- **Structural market reform:** decoupling retail from transmission and distribution tasks as well as enabling more competition in generation through equal and transparent grid access for all generators and energy sellers.
- **Introducing rational T&D**: establishing of approved, updated, transparently and publicly available transmission and distribution (T&D) fees.
- **Introducing priority dispatch for RE:** introducing a priority dispatch for all RE, for the whole energy output and in all provinces and linking it to certain conditions to avoid grid congestion (e. g. direct marketing on the spot market or availability of utility or corporate PPA).
- **Enabling price competition and introducing spot power markets**: introducing a mechanism providing a market-based reference point for price in the auctions, which would serve also as a reference price for the PPAs. A spot market could provide such solution.
- **Strengthening the green certificate system and emphasizing and executing strict RE quotas**: introducing a mandatory-based green certificate system and trading leaned on the quota system, enabling obtaining green certificates also from on-site or behind-the-meter generation, implementing the full functionality of the tracking system, adopting of an appropriate transaction verification program, introducing market-based quota system, clarifying the relationship between green certificates and FIT payments – whether FIT may be attained when green certificate is conveyed.

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