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ANALYSIS OF AUCTION-BASED RENEWABLE ENERGY SUPPORT SCHEMES

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Uusiutuva energia on edullisempaa rakentaa kuin koskaan aikaisemmin ja teknologian kehittyessä niiden hinta jatkaa laskuaan. Verrattuna uusiutumattomaan energiaan, uusiutuva energia ei kuitenkaan ole vielä kilpailukykyinen markkinaehdoilla tapahtuvassa kilpailussa. Valtiot ja paikalliset päättäjätahot ovat silti halukkaita tukemaan uusiutuvaa energiaa ja erilaisia tukijärjestelmiä on ollut käytössä jo parin vuosikymmenen ajan. Tekniikan kehittyessä ja uusiutuvan energian yleistyessä, kysymykset kuluttajille suuntautuvasta rasitteesta ja järjestelmien kokonaiskustannuksista yhteiskunnalle ovat nousseet esille.

Tämä on johtanut kysyntään tukijärjestelmille, joissa kilpailu ja markkinahinta määräävät tuen määrän. Tämän opinnäytetyön aiheena oli tarjouskilpailuun perustuvat tukijärjestelmät. Tässä työssä tarkasteltiin aikaisemmin pidettyjä, meneillään olevia sekä tulevia uusiutuvan energian tarjouskilpailuja. Näistä tarkasteltiin niiden sijaintia, kilpailutuksen saavuttamaa hintatasoa sekä millä teknologioilla nämä käytiin. Löytöjen perusteella laadittiin teemapohjaisia kysymyksiä ja suoritettiin viisi asiantuntijahaastattelua. Kaikki asiantuntijat työskentelivät kyseisten tarjouskilpailutusten parissa ja harjoittivat useita eri ammatteja.

Tutkimus osoitti, että tarjouskilpailun tehokkuus ja onnistuminen ovat riippuvaisia tarjouskilpailun suunnittelijan oman alueensa markkina- ja kilpailutilanteen ymmärryksestä. Tarjouskilpailu täytyisi lähtökohtaisesti suunnitella tämän pohjalta. Kaikkein tärkein osa suunnittelussa olisi ymmärtää alueen kilpailutilanne ja sen riittävyys takaamaan tarjouskilpailulle suunnitellut tavoitteet. Lisäksi strategiset tarjoukset, jossa osallistuja tekee kannattamattoman tarjouksen, ovat aina jossain määrin ongelmana. Strategisten tarjouksien vaikutusten rajaaminen nähtiin tärkeäksi, jotta projektien realisaatio ei kärsisi. Toimivimmat ratkaisut vaikutuksien rajaamiseksi nähtiin olevan tarkat esivalintakriteerit, esim. vakuudet ja tarjouskilpailun ajoitus lähelle projektin loppua. Strategiset tarjoukset nähtiin olevan eniten esillä tarjouskilpailuissa, joissa taattiin yhtenäinen hinnoittelu.

Avainsanat uusiutuva energia, tarjouskilpailu, tukijärjestelmä, asiantuntija haastattelu

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ABSTRACT

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Renewable energy is cheaper than ever to build and costs are going down as the technologies develop. Yet, when competing with more established technologies, especially non-renewable ones, it is still difficult for renewable energy to match their prices. Nonetheless, governments and local authorities want to have renewable energy, having introduced support schemes of different kinds, dating back a couple of decades. However, as technologies develop and become less uncommon, the questions of consumer burden and the total costs of these systems to society have become major talking points.

This leads to auction-based support schemes, which were the focus of this thesis. These schemes introduce competition and market pricing into the mix. This research focused on previously held, ongoing and upcoming auctions and studied the locations where said auctions have been held and what prices have been achieved for specific technologies. Interviews were then held on topics that arose during the study of said auctions. The five participants interviewed were experts of various professions working with renewable energy auctions.

The study found that the effectiveness and success of auctions is largely dependent on the policy maker's understanding of their specific situation and then designing a scheme that is in-line with this understanding. The most crucial element to understand was the amount of competition and if it was sufficient enough in achieving the goals of the auction. It was also found that underbidding is always an issue in auctions and that limiting it is crucial if awarded projects are to be realized. To limit underbidding it was seen that different pre-qualification criteria, i.e. financial guarantees and the lateness of the auction, to be the most effective. Underbidding was also seen more in auctions with uniform pricing.

Keywords	renewable energy, auction-based, support scheme, expert interview

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ABBREVIATIONS

ACT	-	advanced conversion technology
CHP	-	combined heat and power
CSP	-	concentrated solar power
FIT	-	feed-in tariff
kW	-	kilowatt
kWh	-	kilo-watt hour
GW	-	Gigawatt
GWh	-	Giga-watt hour
MVA	-	Mega-volt ampere
MW	-	Mega-watt
MWh	-	Mega-watt hours
PV	-	photovoltaics
RE	-	renewable energy
RPS	-	renewable portfolio standards
REC	-	renewable energy certificates
RES	-	renewable energy source
TW	-	Tera-watt
TWh	-	Tera-watt hour

1 INTRODUCTION

The interest in renewable energy and the technologies that produce it has been universal in recent years. Climate change and the need to cut down greenhouse gas emissions have made countries look into building new renewable energy plants or replacing old energy production facilities with them. As is the case with every new technology, the competitiveness against more established technologies in the beginning is difficult. The competition is made especially difficult by how inexpensive non-renewable energy production is. This combined with the technological limitations of new technologies and the high initial investment costs required to build them, renewable energy is unable to compete with non-renewable energy directly. Because renewable energy is still deemed necessary, especially in lowering greenhouse gas emissions, governments have made several schemes to subsidize them. This paper analyses a few of these support mechanisms, focusing on the most recent one, renewable energy auctions.

The specific focus on renewable energy auctions stems from Finland’s phase-out of its current support system in exchange for a system that incorporates competition as a core element. The current system has been criticized for being too expensive for the tax payer. Competition could help in reducing the costs for the government, but what is a good competitive system?

This thesis’ main research problem is finding best practices in renewable energy auctions and the levels of support that have been achieved using said auctions. These findings are then compared to Finland’s latest law proposal that introduces competition to renewable energy support mechanism.

Because renewable energy auctions are quite new and have only gained popularity in recent years, the concept of support mechanisms as well as current and older support mechanisms are explained to increase the understanding of said auctions. Further, previously held auctions are catalogued, including their awarded prices as well as other relevant information available, in order to understand how widespread these auctions are, what price levels have been achieved and if there are any general themes in achieving those prices along with the technologies that participated in these auctions. After researching previously held auctions, a small number of experts are interviewed on auctions, asking specific questions that have come up while researching previously held auctions. Ultimately, this thesis' purpose is to increase the understanding of auctions as mechanisms of support, to increase the knowledge on the levels of support they can achieve with different technologies, but also to survey any underlying problems with auctions and what a good auction scheme composes of. For ease of understanding, support schemes, mechanisms and structures will be used inseparably and refer specifically in their use with renewable energy. The same is applied to auctions and tenders.

2 RENEWABLE ENERGY SUPPORT SCHEMES

To understand energy support mechanisms, one has to understand the need for them. In recent years, many countries have made pushes to transition from non-renewable methods, i.e. coal and oil, of energy production to more renewable energy solutions, i.e. wind and solar. One agreement to push these transitions is the Paris Agreement (2016) that has been signed by the majority of countries. In it countries agree to lower their impact on climate change, by decreasing their greenhouse gas emissions. This lead to all of European Union member states in having to set specific goals in reducing their emissions for years 2020 and 2030. Since producing energy, whether heat or electricity, is a major source of carbon emissions, accounting to 26% with air conditioning (Eurostat 2016), it has been seen as an apparent way to reduce emissions.

One reason countries still use non-renewable technologies is due to high investments costs of new technologies. Investing in new technology is almost always more expensive than running pre-existing equipment (Energy Innovation 2015). To make actual reductions in emissions, these plants need to be either replaced wholly or partially. Solar energy modules have seen huge drops in prices (Barbose & Darghouth 2016, 18) since the 1990's. However, these systems are still considerably more expensive than non-renewable energy production methods, especially coal, and many governments have used different kinds of support mechanisms in order to incentivize the building of various systems. In the following sections, the most common support schemes for renewable energy are explored following a reasoning to change into an auction system.

2.1 Quotas, RPS and REC

Most countries and regions still use either electric utility quotas or Renewable Portfolio Standards (RPS), also known as renewable energy certificates (REC) (REN21 2016, 114) or feed-in policies (feed-in tariffs or feed-in premiums) (REN21 2016, 109) to support renewable energy. However, there were no new countries that had adopted these methods of support in 2015 (REN21 2016, 109; 114) implying a decreasing trend in adoption.

Quotas, RPS or RECs, essentially all work the same way. Producers receive "credits" or "green certificates" for the renewable energy they produce. One credit usually represents one Mega-watt hour of renewable energy produced. These credits or certificates can then be traded or sold for proof of meeting obligations or making additional revenue. These credits or certificates can have set floor and/or ceiling prices, depending on the region. If a company has a surplus of credits they can sell them and if they are lacking credits, they can either build their own renewable energy production, buy electricity production from other producers or buy the credits from other producers. This system, when set up, is then regulated, usually by the government, certifying the credits and monitoring the compliance and enforcement (Mendonça 2009, 9-11).

2.2 Incentive schemes

Incentive schemes are still common ways to support renewable energy and have usually been the first support scheme introduced by governments. The schemes can be used in other contexts as well, not only energy production. Essentially incentive schemes levy the costs or other burdens of accepted projects. These could mean i.e. levied taxes, low-interest loans or loan guarantees, privileges or reduced requirements for construction permits, training programs for architects, public awareness campaigns, tax credits based on the produced electricity, eco-taxes etc. (Mendonça 2009, 29; 37-38; 61-63; 65-66; 125).

Incentives can kick start projects, but they rarely offer more than a small incentive, if at all, after the construction of the project is complete. Compared to the following feed-in tariff scheme, incentive schemes rarely address the issue of the unpredictability of the market. In these schemes, the risk of falling electricity prices is shared with the one who offers the support, which is usually the local government, whereas in the incentive schemes, the risks are mostly the project developers'.

2.3 Feed-in tariff

The basic concept of FIT is that they are either "fixed" or "premium" (Duffy, Rogers & Ayompe 2015, 226). In a fixed FIT system, the electricity producer is given a fixed rate for the energy produced, whereas premium FIT grants a "top-up" over the market price. Figure 1 gives a good overview of FIT.

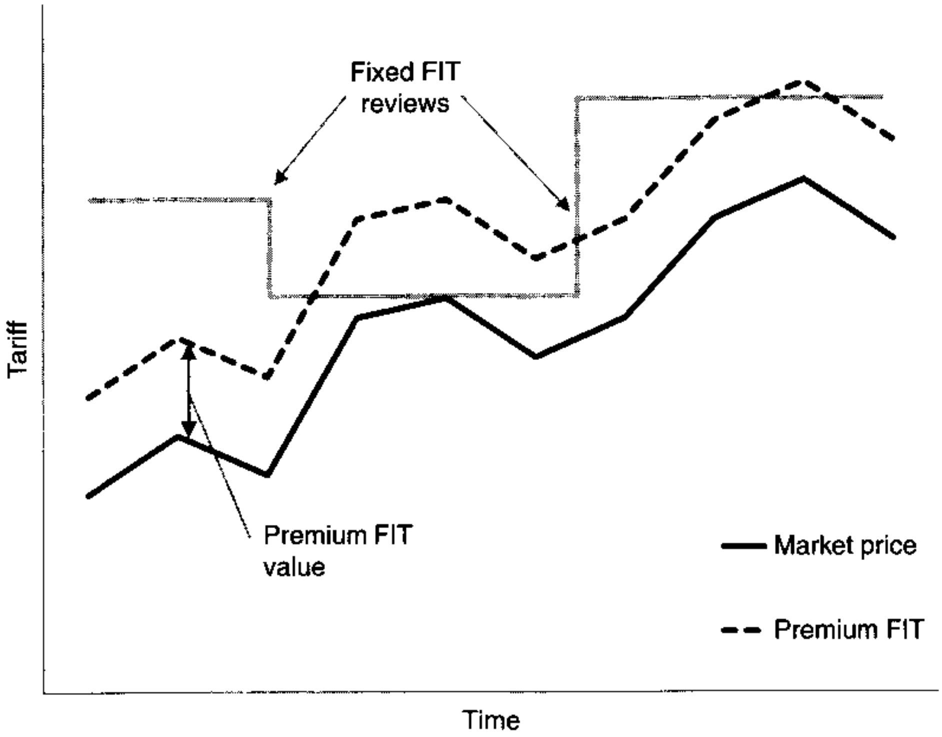

Figure 1. The relationship between energy market prices, premium and fixed feed-in tariffs (Duffy et al 2015, 226).

Duffy et al (2015, 226) also give an example of how the rate could be set for FITs. According to them, the FIT rate should be high enough to incentivize high resource projects. In practice, this could mean a high resource onshore wind project. These projects need a large investment to be built and unless the energy produced can cover these costs in the short-term, the project is then not viable for the scheme. Setting this rate is very difficult and requires good knowledge on both the market as well as the method of energy production. Duffy et al (2015, 227) conclude that "it is an inexact science which relies on uncertain data, thus resulting in uncertainty of the suitability of the FIT in achieving its intended targets." They recommend a regular review to counter this. This leads to the auction scheme that brings market pricing to the equation and lifts some of the burdens off of the auctioneer.

2.4 Auction/tendering scheme

The auction/tendering schemes are very much like FIT schemes in that it sets a rate of support for the producer. The rate is either a fixed or a premium feed-in tariff, depending on the auction. It differs in that the auctioneer sets an amount of renewable energy they want to be produced, whether the production method is neutral or specified and then the producers bid on the price of the tariff in a reverse auction. This introduces competition and, therefore, market pricing to the equation, moving some of the burden from the auctioneer to the bidder.

These auctions can have set ceiling prices, which can be both hidden or known prior to the auction by the bidders. The tariff can also be awarded uniformly that all of the winners get the same amount of support, regardless how low they bid or the tariff can be awarded on a player per player basis. Also, these can be technology as well as production amount specific (Mendonça 2009, 14-15) limiting the number of qualifying bidders. An example of this was the French auction for rooftop installed photovoltaic solar energy that had a set maximum power for the installation to limit the number of bidders to specifically small rooftop installations.

As a final note to the schemes, many countries have numerous of these systems in use at the same time, i.e. an incentive scheme and a FIT-scheme. That is why it is very difficult to compare auction prices between countries unless all of the variables are taken into account.

2.4.1 Reasons for switching to the auction support scheme

The European Commission released a communication at the end of 2013 calling for "genuinely competitive tendering or auctions, to let the market decide the most competitive bid for the specified source of energy" (European Commission 2013, 6). This in itself can be a reason to change the support scheme, but as the Commission wanted, only new schemes have to apply by their guidelines. There are, however, a few key differences that auctions have, that other schemes might not have, and with a few disadvantages as well.

Auctions do not differ from FIT schemes a lot on the surface. The winner or winners of an auction will still receive a feed-in tariff that is paid to them based on the amount of electricity produced, €/MWh. However, the key differences are in the way this price is achieved. The auctions always have a capacity or an amount of production that is bid upon. This amount is only a part of the total capacity that a FIT system has. Auctions are intended to be arranged at specific intervals, i.e. three to four times a year. This allows a more flexible, market-based bidding.

In static FIT systems, a project applies to the system and if they qualify, i.e. their permits and grid connections are accepted, the project can get into the FIT system. In the auction scheme, depending on the pre-qualification criteria, that might only make the bidder eligible to bid in the auction. To win the actual right to support, the bidder has to make a bid for the amount of premium or fixed support rate that they need to make their project financially viable. These bids are then awarded in an ascending order that the lowest bids are the winners. There can be several winners in the case that a single project does not cover the whole capacity of the auction. Depending on the auction design, bids that are under or over a certain pre-determined level or levels of support are automatically excluded. Often called ceiling or floor prices, these can be i.e. the previous auction's results or the previous FIT system's prices. Ceiling and/or floor pricing can also be set in order to avoid strategic bidding.

The main reason for choosing an auction over other systems is that it brings an unprecedented level of competitiveness to the support structure. Feed-in tariffs are unable to bring all but minor competitiveness, if at all, while keeping the tariff at a set level. Any unexpected market changes will impact the effectiveness of the scheme, i.e. electricity prices decreasing instead of rising. With the tendering system, if the auctions are arranged at short enough intervals, the price will be made on the market's terms and, with enough participants, will reflect the market and its current situation. Also, the tendering scheme shifts the analysis of the market, at least in part, to the developers from the arranging party.

Like any scheme, an auction system is not without its flaws. First major flaw it has that it needs true competition in order to be effective. If a country has only a small number of corporations building renewable energy and if these companies know each other well, this might affect their bids and the auction might not reach its effectiveness. Auctions also need to make sure that the winning bids are binding. If a bidder can make a bid, win an auction and never realize their project without receiving any real-world penalties, it will lead to low effectiveness of the auction. In the next chapter, the example of Finland, that is in the transition period between a FIT-scheme and an auction scheme, is introduced that gives a more practical view of these support schemes.

3 THE FINNISH SYSTEM

Currently Finland has a feed-in tariff system for renewable energy. It is a floating premium system that guarantees a project 83,5 €/MWh for their produced electricity. To jump start renewable energy projects, the support was 105,3 €/MWh for the first three years, until the end of 2015. However, at the moment, the actual amount of support is a maximum of 53,5 €/MWh as the guarantee is always subtracted of at least 30 €/MWh or the average electricity price for the past three months, whichever is higher. If the three-month average electricity price drops below 30 €/MWh, the support is always a maximum of 53,5 €/MWh (Government of Finland 2017, 4). For example, if the three-month average electricity price is 40 €/MWh, it is then subtracted from 83,5 €/MWh, leaving the total amount of support paid by the Energy Authority to 43,5 €/MWh.

Its total volume is 2500 mega-volt amperes (MVA) of renewable energy production of which 96% was filled as of April of 2017 (Finnish Energy Authority 2017). The renewable energy production methods that could apply to the system were wind energy, biogas and biomass for fuel (forest chips and forest industry by-products). Since these support schemes are fundamentally made to increase the level of sustainable energy production, this system has achieved its goal as the amount of wind energy production and capacity have skyrocketed after the implementation of the support scheme in 2012 (Finnish Wind Power Association 2017).

The current support level of 83,5 €/MWh is unsustainable, however, and the government is seeking a more cost-effective alternative. The reason why the feed-in tariff system turned to be more expensive than estimated, was the turn in electricity market prices. From the averages of 50 €/MWh at the start of the scheme, prices dropped to 30 €/MWh. The scheme had estimated that the prices would increase, but the actual opposite happened (Valtiontalouden tarkastusvirasto 2017, 28). The total expense of the support scheme was estimated to be from 1,7 to 2,5 billion €, but if the current electricity prices stay the same until the end of the program in 2030, the costs could go as high as 3,2 billion €.

Since the European Commission announced that all its member states should make their new renewable energy support mechanisms to include competitive elements, Finland is following this advice and the recent proposal for a change in legislation seems to prove the transition to a .

3.1 Proposal for new legislature and the new scheme

The Finnish government accepted the new National Energy and Climate Strategy for 2030 (Ministry of Economic Affairs and Employment 2017) in late November of 2016 that introduced a move to a new support scheme. The reasoning is that the subsidy should only be awarded to new renewable energy investments that are both cost-efficient as well competitive, shifting some of the costs from the government to the developer (Ministry of Economic Affairs and Employment 2017, 42-43). In the strategy, it was also announced that between 2018-2020 there will be 2 TWh of production capacity being put out to tender. The projects with the most potential and the ones that can be built most optimally, from the perspective of the public economy, will be selected. The exact details will be announced later as the government proposal is on the issue is drafted (Ministry of Economic Affairs and Employment 2017, 43).

These details are still being discussed upon by the Finnish parliament as of December 2017 as the changes in the support scheme require a change in legislation. A legislative proposal by the government to the parliament was issued in mid-September of 2017 (Government of Finland 2017). Both the Agriculture and Forestry Committee (2017) and Environment Committee (2017) have given their statements to the Commerce Committee about changes or improvement suggestions to the law. Both committees have concerns that the current proposal leaves smaller projects outside of the auction system and wish to see if there are any remedies to this.

Here is a short summary of the main points and reasoning of the law proposal. In order to achieve Finland’s long-term goals of becoming a carbon neutral society, it is necessary to decrease the current greenhouse gas emissions. Almost 80% of the current greenhouse gas emissions come from the production or consumption of energy, which includes transportation (Ministry of Economic Affairs and Employment 2014, 20) being an evident target for reducing greenhouse gas emissions. In the national climate and energy strategy (Ministry of Economic Affairs and Employment 2017, 41-42) it is mentioned that the actual production method that could apply for the support were wind, solar, CHP and some other new renewable technologies. This support scheme is also in line with Finland's renewable energy consumption goals for 2020 set by the European Union. The goal of 38% was already reached in 2014 and it is estimated that this goal will go rise above 40% before the end of the current Finnish electoral term (Government of Finland 2017, 10), which will end in 2019.

The proposal suggests that the support price would be achieved by using a closed tender mechanism in which every bidder would win their bid amount of support. It is also proposed that there would be a ceiling price of the current feed-in tariff's support cost of 83,5 €/MWh as it is seen important to make the auctions less expensive than the current system and it is not seen as limiting the number of bidders nor affecting the price too negatively. It was also proposed that the law would include the possibility for lowering said ceiling price.

For the actual method of support, a combination of a fixed and a sliding premium is proposed. The premium would be fixed when the market price of electricity is below 30 €/MWh and sliding when it is above 30 €/MWh. The length of the awarded support would be 12 years from the start the of production. To participate, one has to have a project of wind, solar, biogas, a wood fuel plant or a wave energy plant that is ready to be realized. The auction will be technology neutral and technologies will compete against each other. However, the law proposal acknowledges that the only technologies that currently have potential of being awarded the tariff are wind, biomass, especially wood dust and, in a minor part, biogas (Government of Finland 2017, 24-28). This is due to solar still having very high investment costs and wave-energy still being completely non-existent in Finland, therefore it is estimated to have very high investment costs.

The awarded premium would be determined based on a tender. The winner would receive the amount of support that they had bid on when the market price for electricity is equal or not higher than the reference price. The amount of support would be lowered when the market price is higher than the reference price, but lower than the sum of the reference price and premium. The premium would not be paid if the market price exceeded the sum of the reference price and the premium.

After the offer is accepted, the producer of electricity would be under an obligation to provide electricity with a renewable energy source. Failure to comply with the obligation would result in a compensation of underproduction paid to the government.

There were also some extra rules regarding electricity produced by wood fuel and biogas. The premium would not be paid for wood chips that were made of crude lumber that would applicable for refinement. Also, during a calendar year, at least 90% of the electricity produced would have to be produced with biogas in biogas plants and with wood fuels in wood fuel plants, but not with wood chips made of crude lumber applicable for refinement (Government of Finland 2017, 24-27).

4 PREVIOUSLY HELD RENEWABLE ENERGY AUCTIONS

Tendering or reverse auctions are now endorsed by the European Commission in being the preferred method of deciding the receivers of renewable energy tariffs. This, however, is only a recent development made in 2014 for tenders. There were countries within the European Union as well as outside of it that have used and have been using tenders as a way of deciding who to support with renewable energy tariffs.

Because these auctions are so new, there is little to none of conventional written books about the topic. However, there are still auctions that have been held in the past, dating back almost three decades, that can be used to understand the topic of auctions. This chapter covers various renewable energy auctions in different regions of the world. Most of them are from recent years, but some of them, like the Irish AER auctions, are from over two decades ago. The chapter shows how different, and similar, these auctions were in the past and nowadays, expanding the understanding of how auctions work.

4.1 Argentina

Argentina has held two renewable energy auctions, RenovARs, with a third on the horizon. They declared 2017 as the "Renewable Energy Year" (Mittal 2017) intending to increase its share of renewable energy in electricity consumption to 20% by 2025 and auctions being one of the methods to achieve that.

The first round of Argentina's renewable energy auction, RenovAR 1, was held in October 2016 (Meyers 2016). It awarded 1100 MW of capacity of which 90% were for wind and solar. The median price of the auction was $59,6/MWh (49,93 €). The auction was hugely popular. There were 123 bids of a total capacity of about 6 GW, covering the awarded capacity almost six-fold.

Round 1.5 of RenovAR was held in November 2016 (Tisheva 2016). A capacity of 1281,5 MW was awarded for a total of 30 projects. Ten of these were wind project for a capacity of 765,4 MW and the rest were solar projects for a total of 516,2 MW (numbers do not add up due to rounding). This capacity was more than twice the government was originally seeking, which was 600 MW. The average price was $54/MWh and the lowest bid was for the Pampa wind project, $46/MWh (38,54 €).

As of 24th January 2017, 23 of the 59 winning projects from RenovAR 1 and RenovAR 1.5 have signed deals with Argentina Ministry of Mines and Energy (Morais 2016).

4.2 Brazil

Brazil has been sort of a pioneer in the renewable energy auction scene, holding its first biomass and small hydro auction in 2007 and 2009 for wind energy and having technology-neutral auctions from 2005 that have had renewable energy technologies since 2011 (Förster & Amazo 2016, 7-8). The most interesting auction were the ones arranged between 2009 and 2013. These auctions were for different technologies.

These auctions seemed to have a high level of competitiveness, that was shown in both the auctioned capacity and the prices. A total of 11,7 GW of capacity was auctioned in the auctions held between 2009 and 2013 and a price of $61/MWh (51,06 €) (Förster & Amazo 2016, 14). In Figure 2 a comparison between the previous Proinfa auction results and the results of the auctions between 2009 and 2013.

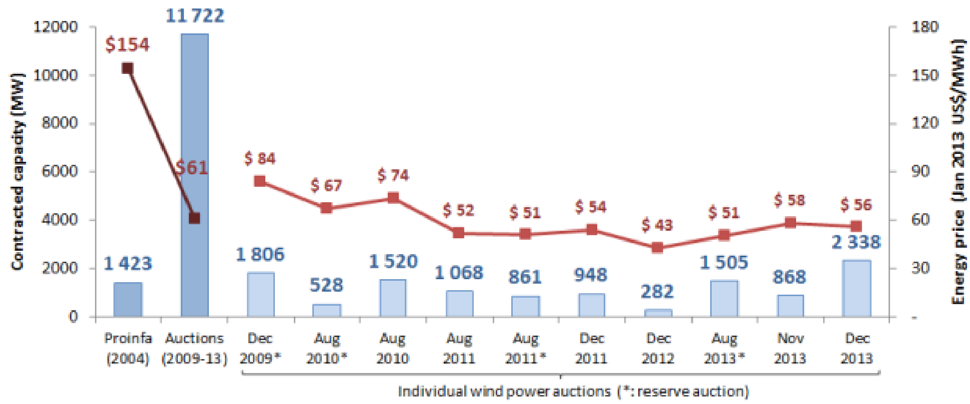

Figure 2. Highlight on auctions involving wind power: Contracted amount and prices (Azuela, Barroso, Khanna, Wang, Wu & Cunha 2014, 10)

Later, Brazil turned its focus on solar PV and arranged three auctions in October 2014, August 2015 and November 2015 that awarded <1 GW, <830 MW and <920 GW of capacity, respectively. The prices were R$ 220/MWh (58,68 €) for the first auction, R$ 301/MWh (80,29 €) for the second and R$ 297/MWh (79,22 €) for the third auction (Förster & Amazo 2016, 16).

4.3 Canada

Canada already has a solid renewable energy foundation, generating 63% of their total consumption of electricity by hydropower. Because of this, they have the most renewable electricity system of the G8 countries (Canadian Hydropower Association 2017). To diversify the renewable energy portfolio from hydro, different approaches have been tried out.

Ontario's Independent Electricity System Operator, IESO's approach was to hold Canada's first renewable energy competitive tender in 2016 (Bailey 2016). The auctioned capacity was 299,5 MW, divided among five wind projects. The average price was C$ 8,59c/kWh (5,697 €c), which was significantly lower than the previous feed-in tariff, C$ 13,5c/kWh. No new energy auctions have been announced since.

4.4 Chile

Chile held a very successful auction in August of 2016 (Thomson, Lombrana and Dezem 2016). The auction reached the then lowest global price for a solar tariff, $23,1/MWh (Saurabh 2016). Making the auction even more impressive is that the average price of the auction was $47,59/MWh making it a significant reduction compared to the previous tender's price of $79,34/MWh, which was held the year before. The tender also had renewable energy winning more than 50% share of the power (Sustainable Energy for All 2016), which was mostly wind and solar (Saurabh 2016). The renewable energy projects represent a capacity of more than 2 GW (Sustainable Energy for All 2016).

The generation put out to tender was 12,34 TWh per year. Mainstream won 30% of that capacity and Endesa, part of Enel SpA, won 40%. According to Thomson et al (2016) "the contracts represented almost a third of supply to regulated customers in Chile".

Differing from other auction schemes, Chilean system is not technology specific. Developers offer a certain amount of capacity at a set price, but do not disclose the method of production. Bids are then arranged in ascending order until the preset capacity is filled (Thomson et al 2016).

4.5 Denmark

Denmark has the highest proportion of wind power in the world with 42,1% of its total electricity consumption coming from wind (Jacobsen 2016). To increase the proportion even further, but to also make the market determine the price, at least in some regard, it is only natural then, that renewable energy auctions are held there. As proven by the cross-border auctions with Germany together with its own auctions, Denmark has a very capable auction system in driving down prices.

4.5.1 Danish wind auctions

Denmark held two energy wind auction schemes in 2004 and onward. "Udbud efter forhandling" (public auction with prequalification round) and "offentigt udbud" (pure public auction). The former being for auctions of the offshore wind farms of Horns Rev 2, the first try of Rødsand 2, Horns Rev 3 and nearshore areas, while the latter being a retry of Rødsand 2 and an offshore wind farm of Anholt (Kitzing & Wendring 2015, 2-3).

- "Udbud efter forhandling" had investors pre-selected in the first round whom had to meet prequalification criteria. Negotiations and discussions took place between the first and the final round.
- In "offentigt udbud" there were no prequalifications nor any discussions or negotiations between the bidders and the authorities.

A total of six auctions have been held from 2004 onward to 2016. The auctions with their sizes, contracted prices and dates from first announcement to final bid in chronological order:

- Horns Rev 2
    - 200 MW.
    - Contracted Price: 51,8 øre/kWh (6,9 €c/kWh).
    - July 2004 – April 2008.
- Rødsand 2 (1st try)
    - 200 MW.
    - Contracted Price: 49,9 øre/kWh (6,7 €c/kWh).
    - November 2004 – May 2006.
- Rødsand 2 (2nd try)
    - 200 MW.
    - Contracted Price: 62,9 øre/kWh (8,5 €c/kWh).
    - February 2008 – April 2008.
- Anholt
    - 390-400 MW.
    - Contracted Price: 105,1 øre/kWh (14,1 €c/kWh).
    - April 2009 – April 2010.
- Horns Rev 3
    - 390-410 MW.

  - Contracted Price: 77,0 øre/kWh (10,3, €c/kWh).
  - December 2013 – February 2015 (Kitzing & Wendring 2015, 7-8).
- Nearshore areas
  - 350 MW.
  - Contracted Price: 63,8 €/MWh (Weston 2016a).
  - February 2015 – September 2016 (Vattenfall Ab 2016a).
- Kriegers Flak
  - 600 MW.
  - Contracted Price: 49,9 €/MWh (Weston 2016b).
  - May 2015 – November 2016 (Vattenfall Ab 2016b).

The capacities auctioned varied between 200 MW to 600 MW (Vattenfall Ab 2016b) and 350 MW in the nearshore areas (Kitzing & Wendring 2015, 8). The auctions in all, excluding nearshore areas, had to be covered by a single bidder. The bidding was done by using static sealed bidding.

With the exclusion of the first try of Rødsand 2, all the auctions were realized on-schedule. Rødsand 2 had a 20-month delay due to the first round's winner withdrawing from the contract. Their justification for the withdrawal were the increased prices of the offshore wind turbines that had only two suppliers at the time. One can assume, however, that underbidding took place, as the second try's winner was also E.ON Sverige, who also won the first try (Kitzing & Wendring 2015, 20-21).

4.5.2 Danish solar PV auctions

Denmark held a solar PV auction at the end of 2016 (Falbe-Hansen 2016). These auctions had remarkably low tariffs, even if only for a relatively small, 21,6 MW, capacity. The nine winning tenders of the total 36 had a tariff of 12,89 Danish øre (~1,72€c) per kWh.

This tender was held only shortly after a German, cross-border PV tender that awarded 50 MW of capacity to Denmark (See part 4.8.2). Both tenders were cross-border, being open for bids to place solar farms in both countries up to a limit of 2,4 MW, however, no offers were submitted (Falbe-Hansen 2016).

4.6 Dubai

Dubai held an 800 MW auction for the Sheikh Maktoum Solar Park, which is an ongoing project to become the world’s largest PV solar park (Parkinson 2016a). This auction reached the lowest unsubsidized solar bid globally, $2,99c/kWh. The bid was made by a consortium of Masdar and FRV, developers from Abu Dhabi and Spain, respectively.

Parkinson (2016a) goes on to speculate on the reasons of how this low price was achieved. Since Dubai has a lot of low-cost labor and Masdar is backed and owned by Abu Dhabi sovereign wealth fund who can offer finance rates no bank can, he speculates that these have large implications on the price of the auction. He clarifies, however, that these prices are part of a wider trend due to price halving in the 12-month period prior to this auction (Parkinson 2016a). German cleantech advisory group Apricum said, regarding the low prices of the auction, that “the results unequivocally demonstrate that large-scale solar power can now regularly beat fossil-fuel power plants on cost” (Borgmann 2016).

These results can be compared to the results of a similar auction held for the same exact solar park in 2014. That auction was held for 100 MW of capacity, which was won by a Riyadh-based Acwa Power with a bid of $5,98c/kWh (Upadhyay 2014). To put that into perspective, that was also the lowest ever bid of its time on solar power.

In September of 2017, The Dubai Electricity and Water Authority held an auction to extend the Mohammed bin Rashid Al Matoum Solar Complex by 700 MW (Graves & Everington 2017). They announced that the auction was won by Acwa Power and Shanghai Power with a bid of 7,3 $c/kWh (6,18 €c). Their bid was for concentrated solar power (CSP) plant, which is more expensive to build, but compared to more tradition PV-systems, it has the ability to store its power when the sun is down.

4.7 France

Being a major part of the European Union, France, too, has committed to increasing their renewable energy supply. France's goals are to have 40% of its electricity supply from renewables by 2030 and 27% by 2020. France even has specific targets for different production methods: 8 GW for Solar PV, 19 GW for onshore wind, 6 GW for offshore wind and 2,3 GW for biomass. France will also decrease its dependency on nuclear power from 75% of total production to 50% by 2025. France has promoted the change to renewable energy supply through feed-in tariffs and tax benefits, as well as auction systems for solar PV, wind and biomass.

4.7.1 Small-scale PV Auctions in 2011-2014.

France has arranged several small-scale PV auctions from 2011 onwards (Förster 2016, 6). These first auctions were aimed towards small, non-residential rooftop installations varying between 100-250 kW in size. Five auctions were held in 2012 and three auctions in 2014, with the total auctioned amount being 360 MW. The results of the auctions varied between the years.

As can be seen in Figure 3, there was a lot of fluctuation in the number of bids with the least number of bids in the last auction in 2014. The average price was reduced by a third from the first auction in 2012 to the last one in 2014.

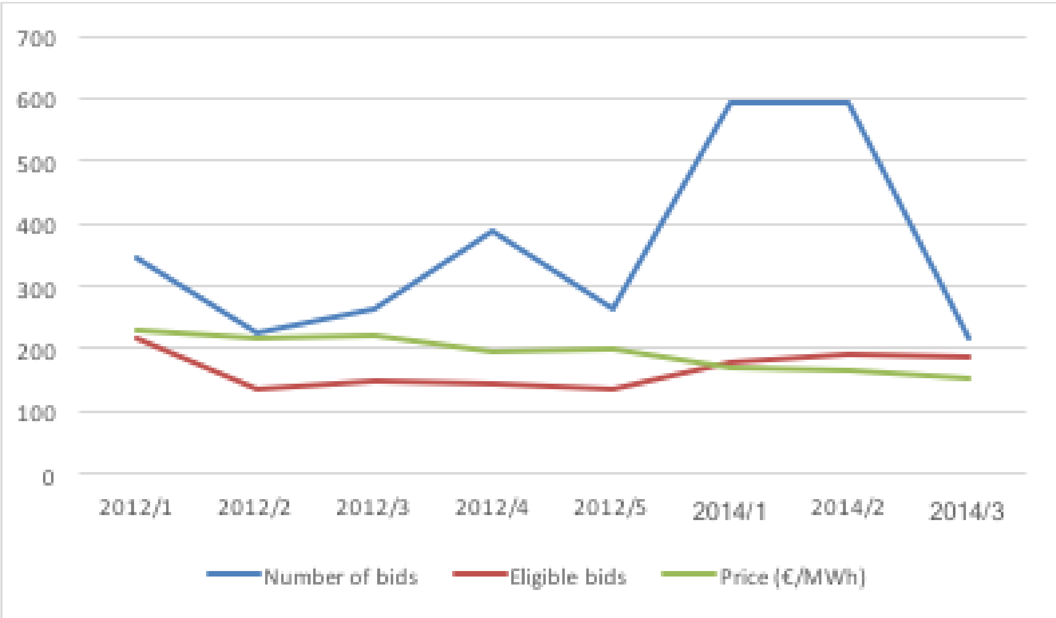

Figure 3. French small-scale PV auction results (Förster 2016, 12).

Förster (2016) goes over the key lessons learned in these auctions:

- Small-scale auctions can be successful and an easily accessible online platform for the auction can entice participants to bid in high numbers.
- Obscure documentation requirements will negatively affect eligible bids, which can lower competition, and therefore, the effectiveness of the auction.
- As these auctions were aimed towards smaller installations, these will include small player such as individuals, with a matching capability and experience in handling costs required to obtain required documentation. If these are needlessly complex, making an eligible bid is limited to installations of bigger players who have the required resources to obtain such documentation, leading to less competition.

4.7.2 France's solar tenders from 2015 onwards.

France held another tender in late 2015, where they awarded 800 MW of contracts to 212 bidders (De Clercq 2015). Prices of the auction were at 124 €/MWh for small roof installations and 129 €/MWh for large roof installations.

In the fall of 2016, France's the energy Ministry announced six tenders for a combined 3000 MW of solar plants. These will be 500 MW tenders each, held six months apart in 2017 to 2020 (De Clercq 2016).

In 2017 the first of the six tenders were held and 534 MW of contracts were awarded to 79 ground-mounted PV projects (Bellini 2017a). The average price was 62,5 €/MWh. This was with the addition of 3 €/MWh if the project was crowdfunded, which around 60% of them were.

4.8 Germany

Germany is one of the technological giants of Europe, and they are no different when it comes to renewable energy. Pushing against climate-change, Germany hopes to have banned combustion engines by 2030, and by 2050, to have their carbon emissions at 20% of their 1990 values. On April 30th, 2017, 85% of Germany's electricity consumption was generated by renewables (Houser 2017).

That is why, it is no wonder why Germany is one of the leading countries in the world with their renewable energy auctions. The first ever zero-subsidy off-shore wind project proved also that they have a working formula for the auctions as well. Holding cross-border auctions with Denmark has added a level of versatility unprecedented by other renewable energy auctions.

4.8.1 Pilot scheme for ground-mounted PV

As a part of Germany's renewable energy consumption targets, an experimental pilot auction for gathering information on best-methods was established (Tiedemann 2015, 5-6).

There were nine rounds set for the auction, from April 2015 to December 2017. The volume of the auction varied from 100 MW-200 MW in capacity, totaling at 1,2 GW. The auctions had ceiling prices, which were 11,29 €c/kWh for the first round and 11,18 €c/kWh for the second.

First round had 170 bids and the second had 136 bids. There were 25 winning bids and the second round had 33. The average price for the first round was 9,17 €c/kWh of which the minimum bid was 8,48 €c/kWh and maximum 9,43 €c/kWh. The average price for the second round was even lower at 8,49 €c/kWh (Tiedemann 2015, 12-13).

Tiedemann (2015, 16) concluded his report in a suggestions and lessons learnt section. He notes that there is some leeway with the realization period that allows bidders to delay their projects to some degree. This could allow the bidders to wait and see if PV modules become less expensive, decreasing the efficiency of the support scheme. He also notes that some participants claimed that there was deliberate underbidding, but he could not verify these claims.

4.8.2 German-Danish cross-border solar auction in 2016

The German Federal Network Agency held a solar PV tender in late 2016 for a capacity of 50 MW (Clover 2016). The tender was first ever cross-border tender in Europe. It offered bidding locations for both Denmark and Germany. Unfortunately for Germany, Danish locations were more apt as solar farms can be built on agricultural land, unlike in Germany where that is forbidden by the German Energiewende (Clover 2016).

Of a total of 43 bids, five won with a surcharge tariff of 5,38€c/kWh. This was even lower than the 7,23€c/kWh that was reached in the last national tender that was held only months prior, in August of that year (Clover 2016). Previous auctions lead to prices of 8 €c/kWh in April of 2016, 8,49 €c/kWh in August of 2016 and 9,17 €c/kWh for the first one held in April of 2015 (Meza 2016).

4.8.3 First ever zero-subsidy offshore wind auction

In April of 2017, Germany closed their first offshore auction. The capacity auctioned was for 1490 MW. The prices were estimated to drop from previous auctions, as is the case with these auctions. Bloomberg New Energy Finance's estimates ran at 55 €/MWh, but even those estimates were broken. The average weighted price was 4,40 €/MWh (Andresen 2017), and one of the project, EnBW's

He Dreiht facility, offered a bid of 0 €/MWh. David Hostert, a wind-energy analyst for Bloomberg New Energy Finance, said that subsidy-free offshore wind is "a moon-landing moment".

4.9 Greece

Greece held their first solar PV tender in December 2016 (Tsagas 2016). This pilot tender was only for solar PV for a capacity of 40 MW. This tender was divided into two categories, project for up to 1 MW and projects between 1-10 MW. Greece's auction scheme is a premium based system where a variable premium is paid on top of the standard market price. This depends on set market variable, i.e. system's marginal price, and the bid's set tariff.

The prices reached were not particularly impressive. The prices came mostly from the second category, for projects between 1-10 MW, and were between 79,97-88€/MWh. The above-mentioned Dubai's, Denmark's and Germany's prices for solar energy were all cheaper. Tsagas (2016) speculates that the high prices are due to the political uncertainty of the country as well as incompetent economic and energy policies. There were also retroactive feed-in tariff cuts, which are sure to cut down investor confidence in projects like these (Pv magazine 2014).

4.10 India

India has arranged several RES auctions to-date and has announced that this trend is to continue. These auctions have been for both wind and solar with no end in sight.

4.10.1 Indian solar auctions

In November 2015, a bid of INR 4,63/kWh (5,976 €c) won the 500 MW solar auction in Andhra Pradesh (Das 2015).

A few months later Finnish based Fortum won a 70 MW solar plant in Bhadla Solar Park with a bid of INR 4,34/kWh (5,6 €c) (Jai 2016).

In February 2017, Solar tariff dropped even further to INR 2,97/kWh (3,833 €c) in 750 MW Rewa Solar Park in Madhya Pradesh, although the actual leveled tariff was INR 3,30/kWh (4,259 €c) (Press Trust of India 2017).

In April of 2017, solar tariffs kept dropping even lower to INR 2,62/kWh. 50 MW were awarded to Phelan Energy and 100 MW Avaada Power for that tariff. Softbank Cleantech won 100 MW of capacity with a bid of INR 2,63/kWh (3,394 €c) (Press Trust of India 2017).

Only a few days after the previous Bhadla solar park bid was announced, a new bid for the 500 MW part of the park received a bid of INR 2,44/kWh (3,149 €c) for 200 MW of the capacity. Another winner SGB Cleantech One made a bid of INR 2,45/kWh (3,162 €c) (Shumkov 2017a).

4.10.2 India's 2016 wind auction

The auction was issued in October 2016 and the bids were announced in February 2017 (Tenddulkar 2017). The auctioned capacity was 1 GW and it was oversubscribed over two-fold with bids worth nearly 2,6 GW. Lowest bids were at INR 3,46/kWh (4,466 €c/kWh). Mytrah Group, Ostro Kutch Wind, Green Infra and Inox Wind Infrastructure all won contracts worth 250 MW.

4.11 Ireland

Ireland was one of the first European countries to try out the tendering support scheme, called auctions of the alternative energy requirement program. They held their first round of six auctions in 1995 and the last one in 2003. Some of the auctions were open to several technologies and some were technology-specific, like AER II that was aimed at waste incineration and biomass, and AER IV for combined heat and power (CHP) systems (Steinhilber 2016, 7).

The auction included ceiling prices, which were 5,216 €c/kWh for large-scale wind, 5,742 €c/kWh for small-scale wind, 8,4 €c/kWh for offshore wind, 7,018 €c/kWh for hydro, 6,412 €c/kWh for biomass, 7 €c/kWh for anaerobic digestion biomass and 7 €c/kWh for combined heat and power biomass. These ceiling prices could be exceeded, but there would be no guarantee the bid would be accepted by the auctioneer, even if it would be lowest bid (Steinhilber 2016, 9-10).

As prices of the winning projects were deemed commercially-sensitive information, no actual prices are known. Steinhilber assumed in her text, however, that most bidders bid at or close to the ceiling price, so estimating the total budgetary expenditure of realized projects after the AER IV would amount to around 35 million € (Steinhilber 2016, 7).

The first four tenders had major problems. Obtaining planning permits for the plants was one of the major problems with other smaller problems such as issues with connecting to the electricity grid (Steinhilber 2016, 10) and difficulties in accessing the sites (IRENA 2012, 95). This lead to low realization and in AER V bidders were required to have secured planning permissions.

In the end, Ireland's early try at the renewable energy tendering scheme was not very effective. Less than half of the proposed volume was ever realized of the winners (Steinhilber 2016, 8).

As of 2017 there is no support scheme for new renewable energy in place. The REFIT scheme that superseded the above-mentioned auctions, had an application deadline on the 31st December 2015. However, the Minister for Communications, Climate Action and Environment Denis Naughten announced a decision by the ministry to extend the deadlines for being connected and the deadline to meet the Clarification Notice until the 31st December 2017 (IWEA 2016).

4.12 Italy

Italy is targeting 26,4% of electricity from renewable sources by 2020 according to their National Renewable Energy Action Plan. These auctions are to bring Italy closer to their 2020 targets.

4.12.1 The Registry and the Lowest Bid Auctions in 2013-2015

Italy has two types of auctions, that became effective in the beginning of 2013, which differ in their mechanisms. “The Registry” is a multi-criteria auction that accepts bids by qualitative criteria only and is for medium sized projects can take part it. “The Lowest Bid Auction”, however, is closer to a more traditional reverse auction or a tender and is for large sized projects. It has a “base tariff” that acts as a ceiling price for the auction (Tiedemann, Förster and Wigand 2016, 6-7).

Most of the projects accepted to “the Registry” have fewer than 5 MW of production capacity, “Lowest Bid Auction” covers projects beyond that capacity with no upper limit (Tiedemann et al 2016, 7).

As seen in Table 1, the total auctioned production capacity was around 1 GW in “the Registry” and around 4,5 MW in the “Lowest Bid Auction”. These production capacities were further split for different technologies (Tiedemann et al 2016, 8).

Table 1. Volumes of the two Italian tendering schemes for 2013-2015 (Tiedemann et al 2016, 8).

Volume of the tender	**2013**	**2014**	**2015**	**Total**
The Registry	368 MW	328 MW	325 MW	1021 MW
Lowest Bid Auction	1710 MW	1494 MW	1349 MW	4553 MW

Interestingly, this auction method had taken both under- and over-bidding into account. The was a -2% floor and -30% ceiling deductions for all technologies to prevent them.

To analyze the results of the auction, it must first be understood how effective was the auction at drawing in bidders.

Table 2 shows clearly that only onshore wind exceeded their auctioned capacity. This lead to lower competition as can be seen from the results of the auction. The average price for the first round was 11,8 €c/kWh, for the second round 11,1 €c/kWh and for the third round 8,7 €c/kWh (Tiedemann et al 2016, 12).

Table 2. Results of the first three auction rounds (Tiedemann et al 2016, 11).

	1st procedure		**2nd procedure**		**3rd procedure**	
	Available capacity	Bidding capacity	Available capacity	Bidding capacity	Available capacity	Bidding capacity
	MW	MW	MW	MW	MW	MW
Wind onshore	500	442	400	1086	356	1261
Wind offshore	600	30	620	0	650	0
Hydro	50	0	50	0	50	0
Geothermal	40	40	0	0		
Biomass	120	13	107	0	64	17
Waste	350	33	317	34	249	18

4.12.2 June 2016 renewable energy auction

In June 2016 Italy launched a renewable energy auction that was concluded in mid-December 2016 and awarded 869,8 MW of production capacity. 800 MW of that were onshore wind projects, 20 MW of bioenergy, a 19,8 MW geothermal power plant and 30 MW for Italy’s first offshore wind farm off the coast of Taranto (Tsanova 2016).

Onshore wind, that had bids over 2 GW in capacity, received the largest drop in the reference price, 40%, and an average price of 66 €/MWh. The other winning technologies, however, had no competition and maintained relatively high prices. Offshore wind had a tariff of 161,7 €/MWh (Offshore Wind 2016), which was a drop of 2% from the reference price. Geothermal and bioenergy had small drops of 2% and 5,15%, respectively (Tsanova 2016).

4.13 Mexico

Mexico has held and will hold renewable energy auctions as a part of their energy reform. This reform aims to have 35% of Mexico's energy mix be from renewables by 2024 (López 2017a).

4.13.1 First renewable energy auction 1-LTPA

Mexico's first renewable energy auction's results were published on 29th of March 2016 and corrected on the 30th (Aymami 2016). Total generation awarded was 5385 GWh/year and 5 million green certificates with no firm capacity auctioned. This was due to the unattractiveness of the penalties that came with non-compliance of the firm capacity obligations (García & Pinzón 2017). Solar PV was a big winner in the auction, being awarded 74% of the total generation. The auction also set a record for the lowest solar PV price ever, $35,5/MWh (29,33 €) with an average of $45,15/MWh (37,72 €). Wind was not far behind, with its lowest bid coming at $42,9/MWh (35,20 €), averaging at $55/MWh (46,10 €), but due to Mexico's limited wind resources compared to solar, solar PV was the clear winner of the auction.

Despite the auction covering only about 2% of Mexico's total energy production, it increased their renewable generation capacity of by over 50% (Aymami 2016).

4.13.2 Second renewable energy auction 2-LTPA

The second round of the auction now also saw firm capacity being awarded (García & Pinzón 2017). This round 8,9 TWh/year of generation capacity, almost 9,3 million green certificates together with 1187 MW of firm capacity was awarded. 45% of the capacity was awarded to solar and 26% to wind projects (James 2017).

The second round had more variety in its technologies than the first round where only solar and wind were the winners. 25 MW was awarded to geothermal and 68 MW to hydroelectric projects. Combined cycle projects were awarded 899 MW on production. Rest of the awarded generation and firm capacity went to wind and solar (García & Pinzón 2017).

The prices were also lowered from the previous auction. Average wind prices were $38,36/MWh and average solar prices were $36,12/MWh, both seeing significant drops (James 2017).

Where the second round differed massively from the first round was that in the first round, the government was the only buyer, but in the second round a true brokering system between private sector buyers and sellers was established. Developers were also attracted to this auction as power purchase agreements (PPAs) of 15 years was agreed upon for the projects of this auction (James 2017).

4.14 Morocco

Morocco’s wind auction was yet another record-breaker (Parkinson 2016b) securing an average bid of $30/MWh, the lowest wind tariff at the time. The tender was for a capacity of 850 MW for five large-scale wind projects. Figure 4 shows these five projects’ locations: 150MW Tanger 2 in the northern part of the country, 300MW at Tiskrad, Laayoune, 200MW at Jbel Lahdid,100MW near Boujdour, and 100MW at Midelt.

Figure 4. Morocco's 850MW tender's five projects (Parkinson 2016b).

The lowest bidder was not explicitly announced, but Parkinson (2016b) speculated, based on reports from December 2015, that Italian Enel Green Power, a Moroccan Nareva Holdings and turbine builder Siemens had made the lowest bid, without specifying the price. This was later confirmed (Yaneva 2017).

4.15 Poland

Poland held its renewable energy trial auctions at the end of 2016. As seen in Figure 5, there were four rounds held, in which three were successful.

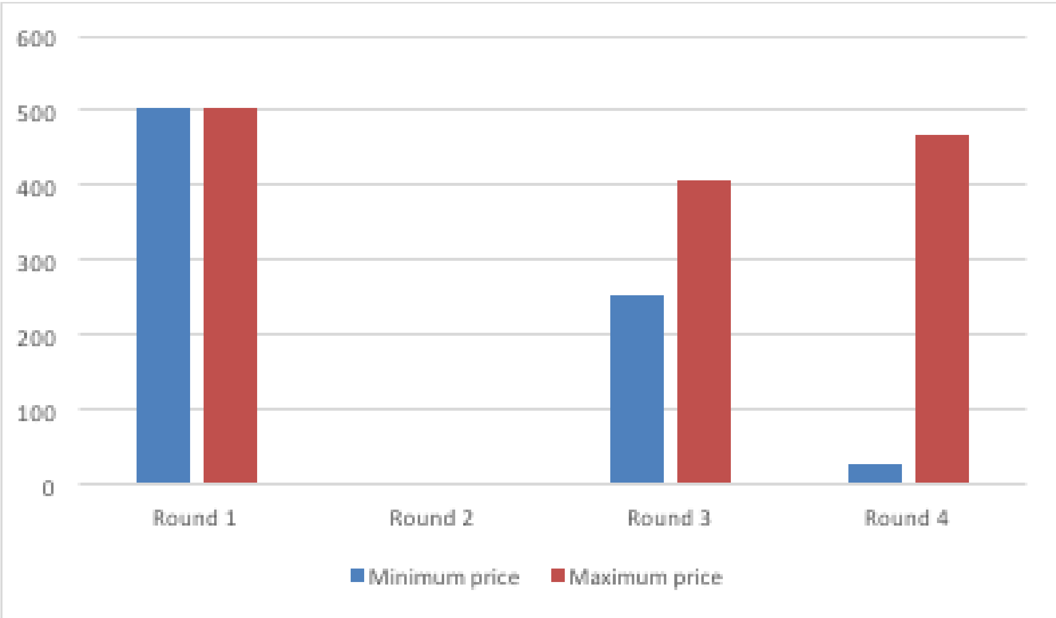

Figure 5. Polish Renewable Energy Auction results (Energy Regulatory Office 2017a, b, c).

All four rounds had different technological requirements. Round one was for producers of electricity generated with agricultural biogas of no more than 1 MW. Round two was for existing migrating agricultural biogas plants of no more than 1 MW in power, but due to only three participants, it was not held. Round three was for installations with a total production higher than 3504 MWh/MW/year regardless of the source of origin. Round four was for new renewable energy producers that were no more than 1 MW in power (Janicka 2017, 3).

The first round had seven winning bids with six winning manufacturers. Minimum price was PLN 502.23/MWh (approx. 118,94€/MWh) and the maximum price was PLN 504.57/MWh (approx. 119,50€/MWh) (Energy Regulatory Office 2017a). The second round was not successful as fewer than three valid bids were submitted (Energy Regulatory Office 2017b). The third round was more successful with 84 winning bids from 62 manufacturers. The prices were also reduced with the minimum price awarded being PLN 253,5/MWh (approx. 60,04€/MWh) and the maximum price awarded being PLN 408,8/MWh (approx. 96,82€/MWh) (Energy Regulatory Office 2017c). The fourth and final auction had 49 winning bids from 40 manufacturers. The minimum price dropped even further to PLN 30/MWh (approx. 7,10€/MWh) while the maximum price was somewhere between the first and the third auction at PLN 468/MWh (approx. 110,84€/MWh).

The auction, however, had many issues. There were technical problems with the electronical auction platform preventing some participants to be unable to bid as well as controversy on the baskets for new and existing projects as well as the possibility to be invalidated by the European Commission if deemed incompliant with the EU state aid regulations (Janicka 2017, 1-2). There were also problems with the specific requirements to fit different "technology baskets" as some, i.e. hydro power plants, could fit into more than one basket, making it hard to predict which RES installations would compete bid against each other in each basket. According to Janicka (2017, 2) there were seven, under 1 MW agricultural biogas plants and 49 others under 1 MW installations, which were mainly hydropower plants, that migrated to the new support scheme.

4.16 Spanish renewable energy auctions

Spain announced the results of their 3 GW renewable energy auction on 17th of May 2017 (Wind Europe 2017). 99% of the contracts went to wind projects (McGovern 2017). The results were so dominated by wind that the Spanish solar association UNEF claims solar PV was discriminated against and announced that they will appeal to the Competition Directorate General of the European Commission against the results of the auction (López 2017b). According to Kenning (2017) the low amount of solar PV projects was due to the floor price implemented in the auction. The floor price was high enough so that most wind and solar project could reach a tie. In case of a tie, the project with longer operating hours would win the bid, and wind has longer operating hours by default compared to solar.

Whether these allegations are true or not, the auction was still very competitive and the price of 43€/MWh is the lowest-ever for European onshore wind (Wind Europe 2017).

4.17 The United Kingdom

The United Kingdom held its first round of Contracts for Difference (CfD) auctions that are part of a wider Electricity Marker Reform. They are multi-unit, sealed-bid, uniform price auctions that have a technology-specific ceiling prices Introduced in October 2014 with winners announced in February 2015 and for projects of more than 5 MW of capacity. (Fitch-Roy & Woodman 2016, 7; 9).

Over 2,1 GW of renewable energy contracts were awarded, most of which were for wind, both on- and offshore projects (Boutin, Davies & Davies 2015). Onshore wind prices varied between £79,23-82,5/MWh. The two offshore projects had prices of £114,39 and £119,89 per MWh. Solar PV prices varied between £50-79,23/MWh. There were two CHP projects that both were awarded £80/MWh and three ACT projects that had prices varying between £114,39-119,89/MWh. All, but wind projects, on- and offshore, had less than 100 MW of capacity awarded to them (Boutin et al 2015).

4.18 The United States

California held its first round of renewable auction mechanism (RAM) in 2011. A total of six rounds of the auctions were held, last one ending on 21st of August 2015 (Fitch-Roy 2015, 7). The total amount auctioned was 1299 MW and was open to medium-sized projects sized from 3-20 MW (Fitch-Roy 2015, 8-10).

The first five auctions saw many bids and as well as a lot of bidders. 1391 bids were placed by 161 entities, totaling over 20 GW of renewable capacity (Fitch-Roy 2015, 14). However, some of these entities were not capable on delivering on their bids. Fitch-Roy continues that even when the pre-qualification explicitly stated that new of inexperienced actors would be excluded, only 50 entities had reached the procurement process by February 2015, most of which were large specialist development companies.

Despite RAM being specifically designed to encourage smaller projects to participate, most of the project were the maximum size. Fitch-Roy (2015, 15-16) also continued that the projects would probably have been even larger in size if there would have been no maximum size.

The prices of the first three auctions, RAM 1-3, were $90/MWh (102, 38€), $88,75/MWh (100,11 €), and $79,82/MWh (89,87 €), respectively. Comparing these internationally, however, is not simple, as solar projects have a 30% investment tax credit and wind projects that were started before 2015 have $23/MWh production tax credit (Fitch-Roy 2015, 19).

5 ONGOING AND UPCOMING AUCTIONS BY COUNTRY

5.1 Argentina

According to Meyers (2016) Argentina is planning their second round of RenovAR for May 2017. That has since changed to July or August of 2017 according to Argentina's Energy Minister Juan Jose Aranguren (Dezem & Gilbert 2017). According to him, some the winners of the previously held auctions are still looking for financing for their projects and they do not want to "generate a bottleneck on the financing side". It remains to be seen if the developers

5.2 Chile

In a meeting in Berlin, Germany on May 29th, 2017 the next Chilean auction was announced (Bellini 2017b). The auction was postponed to December from its originally announced date of October. The auctioned capacity was announced to be 2 GW.

In the meeting, Rodrigo Castillo, the managing director of the Chilean Energy Federation, said to pv magazine (Bellini 2017b) that it is not important if the projects undercut the previous auction's $29/MWh bid, but, more importantly, that they go under the average of the that said auction, which was around $40/MWh. The auctions will have a maximum price, that is not disclosed during the auction. Castillo said, however, that bids rarely hit that ceiling price.

Andrés Romero, head of the National Commission for Energy of Chile, informed on Chile's upcoming auction for the period of 2018-2020. He said that 2018, 2019 and 2020 was to have allocations of 1,6 GW, 8,8 GW, and 4,1 GW of new energy production capacity, respectively.

5.3 Germany

Germany had its first offshore wind auction at the start of April 2017. The second round of that auction is to take place at the same time in 2018. The volume for that auction will be 1550 MW plus 60 MW that was left from the first round, totaling 1610 MW (Offshore Wind, 2017).

5.4 Iberian Peninsula

The Iberian Energy Derivatives Exchange (2017) holds quarterly solar auctions on an on-going basis. These auctions have only a singular buyer, a Spanish utility company Endesa. However, these auctions are more of a financial tool for solar producers in reducing the volatility of their income (Kenning 2015).

5.5 India

At the time of writing, a solar auction of Tamil Nadu 1,5 GW in capacity is on-going and the winners will be announced after June 15th 2017.

India is planning on holding 4 GW of wind power tenders in 2018 (Shumkov 2017b). Ashvini Kumar, the managing director of Solar Energy Corp of India said that the government believes that India could add 5-6 GW of wind capacity every fiscal year. This comes just after the Ministry of New & Renewable Energy published draft guidelines for wind power auctions which are intended for grid-connected projects of above 5 MW.

5.6 Italy

Italy has a plan to start its solar auctions in 2020. This is part of Italy’s strategy in reaching its 27% share of renewable target by 2030, the same target set by the European Commission (Bellini 2017c).

5.7 Mexico

On 8th of May 2017 Mexico announced the draft version of rules of their third clean energy auction on (Tsanova 2017a). The final bidding rules will be published on 27th of June, the list of qualified bidders at the end of July and final results of the auction on 22nd of November. The bidding projects should be operational by January 1st, 2020.

5.8 Russia

At the end of May 2017, Russia announced the largest-ever renewable energy auction of 1,9 GW (Hirtenstein & Bierman 2017). The auction lasts from May 29th to June 9th 2017.

The Russian renewable energy industry, especially wind, has not seen much growth in recent years. This is due to strict local-content restrictions made in 2012 and 2014 for clean energy that restrict the installation of i.e. wind turbines if they are not produced locally. The amount of the local production in 2017 was fixed at 40%. As there are no wind turbine manufacturers in Russia, this has crippled the Russian wind industry.

The turning point is that Rosatom, the regulatory body of the Russian nuclear complex, will retool their existing factories to manufacture the turbines for the auction and are looking to co-operate with current manufacturers, like Siemens AG, General Electric Co. and Vestas Wind Systems A/S (Hirtenstein & Bierman 2017).

5.9 Spain

As previously mentioned, Spain held a 3 GW auction for renewable energy and its results were announced on 17th of May 2017. Only a little over a week after announcing those results on 25th of May, the Spanish Ministry of Industry announced that another 3 GW auction will be held “before the summer” (Bellini 2017d).

5.10 The United Kingdom

In April of 2017 the United Kingdom announced the second round of the CfD auctions (Hatchwell 2017). The auction ran from 3rd to the 21st of April. The auctions are open to “less established technologies” that include offshore wind, waste-to-energy technologies, biomass, wave, tidal and geothermal projects (Weston 2016c). The results of the auction have not been announced as of time of writing. The British Department for Business, Energy and Industrial Strategy also has allocated £730 million of annual support for three CfD auctions during the tenure of the current parliament (Hatchwell 2017).

5.11 Tunisia

Tunisia announced on the 11^{th} of May 2017 a 210 MW wind and solar auction with a deadline on the 15^{th} of November for qualified bidders (Tsanova 2017b).

5.12 Turkey

Turkey announced a date for its upcoming, 1 GW wind power tender (Tsanova 2017c). The auction will be held on the 27^{th} of July 2017. The price ceiling has been set at $0,07/KWh. Other rules included a 65% local-content requirement as well as the hiring of local labor.

6 EMPIRICAL SECTION

Since the weight of this research was on understanding renewable energy auctions, the logical method for collecting more data was conducting qualitative interviews of experts in the field. Qualitative methods are used when there is need for a deeper understanding of the issue or issues and the need for so called “insider view” (Ghauri & Grønhaug 2010, 105-106). These issues are important, as the subject matter of the thesis is very specialized and requires expert knowledge.

6.1 Semi-structured interview

The specific qualitative method to be used was chosen to be a semi-structured phone or mail interview. With a semi-structured interview, many of the different aspects can be pre-determined. This allows the researcher to focus on specific topics and issues that are covered in the interview, helps in forming the questions asked during the interview and also limiting the number of participants (Ghauri & Grønhaug 2010, 125-126).

Phone and mail interviews were used for practical purposes. Most of the experts interviewed were international, making the travel and time expenses for face-to-face interviews unreasonable. Phone interviews were recorded for analysis and transcript purposes of which the interviewees were informed prior to the interview. Interviewees were also guaranteed confidentiality and that their answers would be handled anonymously.

6.2 Interviews

Altogether 12 experts were contacted by email, of which five agreed to an interview. One interview was conducted by email and four interviews by phone. The experts were chosen using the sources found in chapters four to five and contacting the ones who had several publications about auctions. These publications indicated their expertise on the subject and the potential for an expert insight. The interviews were conducted from late-October to mid-November of 2017.

The email sent to the potential interview candidates contained the request for an interview, the topic of the interview, whether they would like to have the interview by phone or by email, a guarantee of confidentiality and the general questions of which the interviewee would answer to. This was in part so that the interviewee could prepare for the interview or answer the questions by email if they chose to do so. The basic layout of the email can be found at the end of this thesis (Appendix 1). This layout was customized depending on the receiver in order to make it stand All of the phone interviews were conducted with LeadDesk, a cloud contact center software. Using this program allowed the recording of calls, ease of calling international phone numbers, real-time monitoring the length of the interview as well as increasing the reliability and quality of the call, and therefore the recording's quality, by using a computer's Internet connection instead of a cellphone in making the call.

The order of which the questions were asked was similar for all of the interviewees. Follow-up questions were asked if a question was not answered fully. If the interviewee answered the question in a previous answer, a question was omitted. The answers show saturation, important for a qualitative research, as most of the interviewees were of the same mind on most of the topics. After all of the phone interviews had been done, recordings of the calls were listened, transcribed into reports and analyzed.

7 ANALYSIS

In this section, both the auction results and the conducted interviews are analyzed, starting with the former. The auction results are only gone through in a minor part as comparisons of price are only nominal in providing new information. The interview answers will be analyzed thematically as the questions asked from the respondents were in themes and varied depending on the respondent's answers. These answers will be then derived in the following conclusion section.

7.1 Auction results analyzed

This thesis covered 67 rounds of auctions which were held in 17 different countries or regions. Of these rounds, 43 were held from 2015 onwards and 53 from 2013 onwards. These accounted for 64% and 79% of the total number of auctions, respectively. The auction data cut-off date for auctions is the end of June 2017 and auctions conducted or announced later than that were not included in the thesis. The auctions had varying prices, Italy's off-shore project in late 2016 being awarded the highest bid of 161,70 €/MWh and the lowest average bid was with Germany's recent off-shore auction, a weighed price of 4,40 €/MW, in May of 2017. Evident from these prices, even same technologies can have so much variation in pricing that comparisons are difficult, if not impossible.

It can be informative to see trends with auctions, and below in Figure 6 the trend of auction prices regardless of technology can be seen. Yet, there might be a myriad of reasons why this has been happening, i.e. lowering technology costs, increased public knowledge and understanding of auctions, increased competition, or other unspecified reasons. Therefore, making any set conclusions cannot be made on the issue.

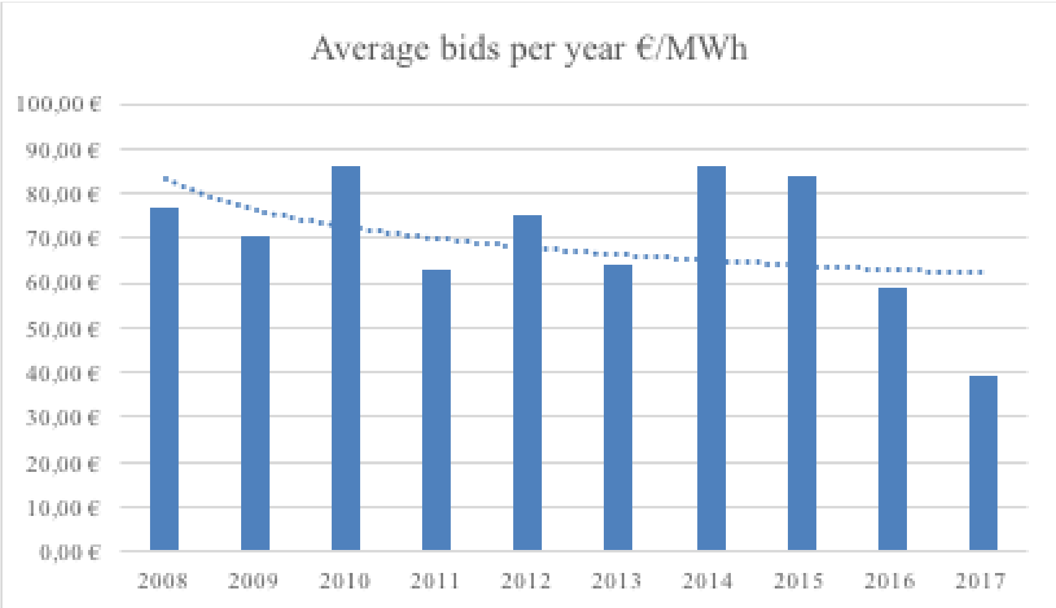

Figure 6 Average bids per year 2008-2017

7.2 Interview analysis

The participants were asked questions about five basic themes concerning renewable energy auctions. The total number of questions varied from seven to eleven questions depending on the number of follow-up questions asked. The questions laying out the themes for the interview are included at the end of this thesis (Appendix 2). The average length of the phone interviews was 35 minutes. The participants are only referred to, since they were guaranteed confidentiality.

At the start of the interview, participants were asked to give a short introduction about themselves, validating their expertise in the field. The experts interviewed worked in different professions, but all were working with renewable energy auctions in different degrees. This question gave more background information on the interviewees and was worked also as a soft start for the interview.

7.2.1 Effectiveness & auction design

The first theme was in regard to the auction design. More specifically, what makes a good auction and if there is such a thing as a best system in regard to high effectiveness. All of the participants agreed on the issue and one participant summed it up by saying that there is no "football league of auction systems". According to the interviewees, auctions have a certain framework, which is then applied to the specific needs of the country and its policies. One respondent listed six basic elements that are needed for an effective auction:

1. Incentives – what is on offer and awarded once the auction is won.
2. Pre-qualification criteria – when in the project is allowed to participate.
3. Auction mechanism used – choosing pricing models, dynamic or static systems etc.
4. Post-auction procedure – what happens after the auction, i.e. deadlines, penalties, rights of successful bidders.
5. Participating institutions – who designs and runs the auction, who is responsible for following up contracting parties etc.
6. Conforming above elements – Making sure that all of the above elements are in line with each other.

In the last step, international experiences were cited for being potentially useful in determining the need to make changes to specific elements. One interviewee questioned on how to even define effectiveness as it used to be measured by the maximum project build out, but nowadays leaning towards achieving very specific goals and these goals varying from country to country. The interviewee mentioned that measuring a high realization rate as a way to measure effectiveness might not be an accurate measure of effectiveness, either. It is a very narrow definition and it might not be an accurate measure in the energy transition. One participant said that all auctions have one thing in common and that is getting the best price, however the "best price" differs depending on the specifications of the auctions, therefore making comparisons between different kinds of auctions difficult.

Examining the first theme's answers, certain themes were pronounced. Auctions have a framework that should be modified based on the needs on a case by case basis. Measuring effectiveness of an auction is also largely dependent on how the framework is applied and what were the goals set for the auction.

7.2.2 Crucial parts in making successful of an auction

The second theme was about the most crucial parts on making an auction successful, not only effective. All of the respondents agreed that having an ample amount of competition was key in an auction's success. Another issue that was acknowledged was the attractiveness of the auction regarding the incentives. If the incentive is not attractive enough, the auction is likely to perform poorly.

One respondent brought up attractiveness also in regard to the transaction costs and risks to the bidder with specific, real world examples. If the application process to an auction is significantly more complex compared to the previous system, bidders have a higher change to apply with errors. This can lead to, like in the German ground-mounted PV project, bidders being excluded from the bid due to formal errors. In this case, it was later ratified by having more information available on the regulator's website as well as having public information events. Another example was the French PV auction where some bidders said to have completely abstained from the participating in the auction, because some pre-qualification requirements were not clear on how to comply with them.

One participant noted that in order for one to make a successful auction, the most crucial part is in understanding their current situation. This is before starting any design on the auction as so much is dependent on that understanding. The respondent specified that the success is very dependent on individual goals that are hoped for the auction to achieve. The respondent also declared three general things that auctions need to ensure in order to be successful:

1. Bids need to be binding.
2. The best bid should win.
3. Winners delivering at said price.

Examining the second theme's answers, they were somewhat parallel with the previous theme's answers as success and effectiveness of an auction are connected. However, as these answers noted, in order to have a successful auction, there needs to be enough competition, bids need to be serious as well as binding and these bids need to result in realized projects.

7.2.3 The effect of the length of the realization period

The third theme was about the length of the realization period or the lead time that is in between winning the bid and the actual realization of the project and how it affects auction results. Respondents had different answers which were somewhat clashing, but in general agreed on the issue. The general agreement was that the length is very dependent on the situation, but mostly about the pre-qualification criteria and the technology that was used.

For the pre-qualification criteria, couple specific examples were mentioned, in particular of solar and onshore wind lead times, which vary significantly from each other. Solar can have a lead time of 6-18 months of time from early planning to start of operation while onshore wind can be up to 5-6 years. One respondent said that the length of time should also be dependent on the grid availability of the country.

Examining the third theme's answers, the length of the realization period needs to be in-line with both the technologies used and with the pre-qualification criteria. Meaning that with loose pre-qualification criteria, a short realization period might end with low realization of projects as there is not enough time to build the projects. How it affects the actual bid depends on the amount of pre-qualification criteria. A well-designed realization period might not make the bids lower or higher, but instead more realistic as it will align with the project's goals.

7.2.4 Existence of underbidding and how to deal with it

The fourth theme was about underbidding occurring in auctions, the rate of which it occurs, if at all, and if it is seen as a problem. Here the respondents somewhat disagreed with each other.

One respondent noted that underbidding is not common and that temporary financial guarantees, so called bid bonds that most auctions have, often prevent this kind of behavior with another respondent agreeing with them. One respondent saw it as quite a problem and that it is seen for various reasons. They pointed out that bidders are often in a competitive environment, they have to make very competitive bids and in order to do so, they often have to estimate information and what the future might bring. If the market is not developing like they expect it to, then there is a high risk that their bid is not economical anymore, leading to underbidding.

Another agreed that competitors might not be underbidding on purpose, but because of their inexperience, lack of information or unrealistically optimistic market expectations among other possible reasons. Their bid turned out that it was not reflective of the real situation and eventually turning into an unrealizable bid. One interviewee commented that underbidding should not even exist as it is illogical for bidders to make bids that would lead to a loss for them. However, according to the interviewee, this was not the reality. Underbidding was happening unconsciously, for the reasons mentioned above, but also intentionally. These could be strategic bids to guarantee a win in the auction. This kind of behavior is seen more often in auctions where there is uniform pricing, which another respondent agreed with. This could be due to trying to hide their true prices, wanting others to calculate their support figures for them or for other unspecified reasons. This could be levied with auction mechanisms that award player-specific prices and with stricter pre-qualification criteria, as told prior in the text.

Examining the fourth theme’s answers, respondents agreed upon that pre-qualification criteria, i.e. financial guarantees, having late auctions etc., are needed in order to mitigate underbidding. Some did not see it as a problem due to auctions having these criteria and others saw it as a problem whether or not the criteria were there. Although, auctions with uniform, rather than player-specific, pricing are riskier of having underbidding.

7.2.5 Technology-neutral or specific

The fifth and final theme was about technologies in renewable energy auctions and if these auctions should be technology specific or technology neutral. Here is where the interviewees had the most differing answers.

One respondent's point was that because the European Commission has to approve all of the new designs in the EU, it is easier to get an auction approved that is technology neutral compared to a technology specific auction. Another respondent said the opposite and was for technology specific auctions, or at least technology specific baskets within auctions. Reasoning behind this was that technologies are so different, it is hard to make an auction that is not discriminating in one form or another. Also, technologies have different resource availability from country to country as well as being in different stages of R&D, it would be unfair to put them on the same line, when it comes to support.

One respondent dismissed the concept of technologically neutral auctions completely, claiming that they are always biased in one way or another, whether for political or geological reasons. One participant was more neutral with them and approaching them from a country specific view-point. They brought up the goals of the auction. If the only goal is to find the most cost-effective technology, then technology neutral auctioncould be the preferred option, but in order to increase different technologies, like both solar and wind, arranging technology specific auctions for the different technologies might be more suitable.

Examining the fifth and final theme's answers, whether having technologically neutral or technology-specific auctions is not completely agreed upon. Arguments for both sides exist, but in general it was agreed upon that it should depend on the goals of the auction. If an auction's goal is to have the most cost-effective technology, technology neutral auctions might be the system-of-choice. If the goal is to support an array of renewable energy, new and older, the more established ones will win in technology neutral auctions as newer, more investment-heavy, technologies would not be able to compete.

8 CONCLUSION AND DISCUSSION

Comparing auctions with each other is often difficult as specific situations are very different. Even country specific auctions are difficult compare to each other, as markets and the rules of the auction can change overtime. Taking this into consideration, more in-depth analysis of auction pricing needs to be done by a separate study and no definitive conclusions can be made based on auction results mentioned in this thesis.

That said, looking at the current trend, a cautious remark from the limited number of auctions covered by this study can be made. Auctions have been able to bring the prices down, in general. What is clear, also, is that auctions are more popular than ever and the trend of adoption seems to be going up, as countries and regions are implementing competitive elements in their support schemes. However, the effectiveness and success of these auctions seems to be largely dependent on the country or region, its situation and how policy makers have understood said situation.

The opinion of the author is that focusing solely on the price it not reflective of other factors. Every country has very specific situations, not only politically, but also geographically. This is reflected in the technologies that can be used. It is logical that in a desert environment, producing energy with hydropower will be a lot more expensive than in an environment where rivers and potential reservoir areas are more common. This is the same for countries in the Northern hemisphere, where the sun is available in limited quantities in winter times. If cost-effectiveness is the only considered factor for auctions, geography is always more pronounced.

However, diversification of energy production should also be considered. This can be seen in Denmark where there is a heavy emphasis on wind energy and when the production does not meet the country’s demands, importation of electricity from nearby countries is required. The more diverse a country’s production is, less of the importation is needed in, i.e. less windy seasons, lessening the burden of other countries as well.

Therefore, the conclusion of this thesis is that when designing auctions, it is profoundly important to understand the reasons for having said auction. After understanding the reasons for having the auction are clear, only then should the design of the auction begin. This design should then be in-line with the situation. Underbidding was found to be a prevalent issue in auctions and the need to limit its effect is important. Having well-designed pre-qualification criteria was seen as a good counteraction. Underbidding was also more pronounced in auctions with uniform pricing. Finally, technology neutral auctions were seen important in auctions driving for cost-effectiveness. However, if the goal is to support all types of renewable energy, technology specific auctions or, alternatively, baskets for different technologies in a single auction, should be considered instead.

In regard to the Finnish system, most of these issues are considered, however, the technology neutral aspect of the auction, seems to imply that only onshore wind will be able to compete in the auctions. Offshore wind and solar are still seen as too expensive, biomass and biogas too small in order to provide actual competition and other technologies too immature to even be considered to compete in the auctions. It seems that the technology neutral aspect of the auction is just there to please the European Commission that had included it in their directive. Yet, the law proposal might and presumably will change before it is approved in late 2017 or early 2018. Time will tell if any other technology than onshore wind can compete in these auctions.

Onto the main limitations of this research which were regarding the auctions and the number of experts interviewed. The list of auctions in the thesis is in no way conclusive and a separate study could be conducted in cataloguing previously held auctions. However, the list of auctions and the references in this work should be vast enough for any researcher to use as a starting point for their research, especially since the amount of written work on the issue is very limited.

The second limitation was regarding the number of experts interviewed. Getting more experts presumably could have given the study a more comprehensive view of the issues with auctions. This study was also limited by the method interview. A face-to-face interview is usually the superior method of acquiring qualitative data. These interviews were ruled out for practical reasons, mainly due to experts residing internationally in different countries and arranging travel and scheduling the times for the interviews would have become too resource-heavy. Future studies that are either located closer to experts or have the resources for international travel, could get more comprehensive view with face-to-face interviews.

Here in the end of the thesis, the author would like to personally thank all of the participants of the interviews that gave their time for this thesis. Without you, this thesis would not have been completed. Also, a thank you to the issuing company for giving the topic for this thesis and the help provided with it.

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Interview request

To Whom It May Concern:

My name is Otto Niskala and I am a student of Vaasa University of Applied Sciences in Finland. I am e-mailing you because of my thesis work regarding renewable energy auctions.

I would like to ask you a few questions regarding the subject. The questions will only take a few minutes of your time and would greatly help in getting a general consensus of the subject and help any future researchers studying the subject to find a starting point. All the answers will be anonymous and answers cannot be pointed to any one individual.

Here are my questions:

1. In your opinion, what are currently the best renewable energy auction/tendering systems in use? Have there been better systems in past?

2. What makes this/these systems superior to others?

3. How much do you think the procurement period (the time between end of the auction and the start of production) affects the auction results? What amount of time do you think would be the perfect balance between low tariffs and actual realization of the projects?

4. Do you think underbidding is an actual problem in renewable energy auctions or is it just a rare occurrence?

5. Finally, in your opinion, is it better to make technology specific energy auctions or should these auctions always include several different technologies? Which production technologies show the most potential globally?

If you could answer these questions, preferably by the 20th of November, I would greatly appreciate it. I can also do the interview by phone if it is more convenient for you. This is a very new topic and it is hard to find experts that specialize in this field. Please let me know, if I have the wrong email for this query. Also, if you know someone who would like to participate in this study, you can forward these questions to them and they can send their answers to my email address.

Hope you have the time to help me with my study.

Interview questions

1. In your opinion, which current renewable energy auction system/systems are the most effective? Have there been better systems in past?

2. What are the most crucial parts of designing an auction?

3. How much do you think the procurement period (the time between end of the auction and the start of production) affects the auction results? Do extensive pre-qualification criteria help in lowering that time and increase the realization rate or do they negatively affect the auction results?

4. Do you think underbidding is a problem in renewable energy auctions? Is there an example of a good solution to it?

5. Finally, in your opinion, is it better to make technology specific energy auctions or should these auctions always include several different technologies and why?