Interreg
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European Regional Development Fund

WP T1 | ACTIVITY T1.3 | DELIVERABLE T1.3.1

REPORT ON THE POSSIBILITIES TO INCREASE THE RES-BASE AT EACH OF THE THREE cVPP

PARTNER RESPONSIBLE: FOUNDATION SUSTAINABLE PROJECTS LOENEN

28-12-2018

Project number: NWE 588

Project acronym: cVPP

Project full title: Community-based Virtual Power Plant (cVPP): a novel model of radical decarbonisation based on empowerment of low-carbon community driven energy initiatives

Project start date: 20-Sep-2017 (36 months)

Project end date: 19-Sep-2020

Work Package: WP T1 Conceptualisation of a transnational cVPP

Deliverable No: T1.3.1

Due date: November 2018

Submission date: 28-12-2018

WP Leader: Foundation Sustainable Projects Loenen (DPL)

Partners involved: Foundation Sustainable Projects Loenen (DPL), Eindhoven University of Technology (TU/e), Tipperary Energy Agency (TEA), EnerGent

Version: 1.0

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Table of Contents

1 INTRODUCTION

This specific report focusses on the possible renewable sources that communities may have available within their area. The report is not meant to be an exhaustive overview of RES available in Europe, but will focus on those forms that are (relatively) readily available and describe newer emerging forms in less detail.

The purpose of this document is to be a reference document to assist local energy communities to make an informed decision (concerning techno-economic developments) on the most suitable form(s) of Renewable Energy Sources for their local situation. First of all, it will be applied by the three Implementing Partners.

- Implementing Partner (IP) Loenen will use it as a basis for Deliverable I1.3.1: Investment & implementation plan additional RES, Deliverable I1.3.2: Feasibility study further expansion of RES, and D I1.3.3: cVPP demonstration roof.
- IP Tipperary will use it for Deliverable I2.3.1: Investment and implementation plan for additional RES in Tipperary.
- IP Energent will use it for Deliverable I3.3.1: Selection of the cVPP investment portfolio, and Deliverable I3.3.2: Roll-out of the cVPP investment package in the (extended) 'Buurzame Stroom Area'.

The aim of the report is to educate communities on both technical and financial aspects (possibilities and risks) of investing in such Renewable technologies as part of a cVPP solution.

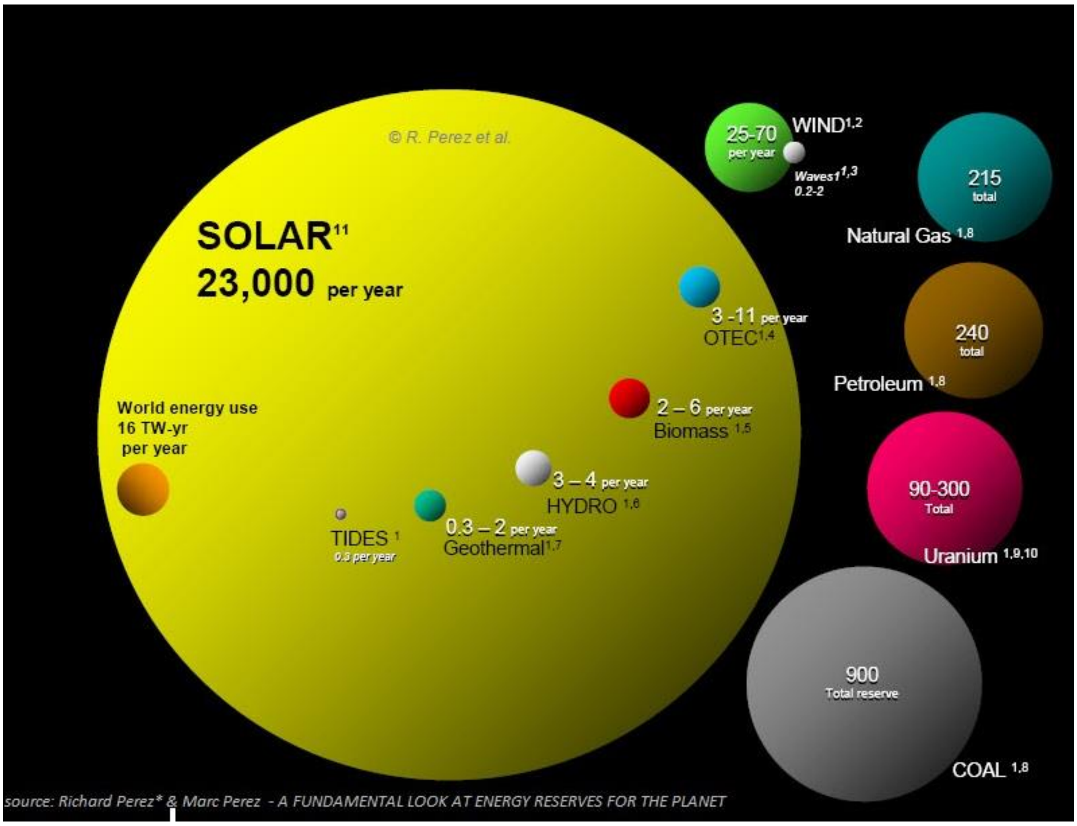
Renewable energy sources are abundant. The challenge is to convert them into usable, practical forms like electricity and heat:

From\to	**Electricity**	**Thermal**	**Stored energy**
Solar	PV, CSP	CSP, heat panels	Biomass
Wind	Turbines		
Hydro	Turbines		Reservoirs
Waves	Wave machines		
Tidal	Barrages		
Geothermal	Geo-plants	Geo-plants	

2 TYPES AND CHARACTERISTICS OF RENEWABLE ENERGY SOURCES

2.1 TYPES OF RES

The picture below shows our planets energy reserves. Amazingly solar energy is larger than all others combined! Ultimately it all comes from the sun, except nuclear energy.



source: Richard Perez* & Marc Perez - A FUNDAMENTAL LOOK AT ENERGY RESERVES FOR THE PLANET

2.1.1 Solar energy

Direct solar irradiation is by far the biggest energy source available. The earth intercepts 175 000 TW of radiated energy in total, which corresponds to 1350 W/m2 on the earth surface. Correcting for an angle of incidence, reflection, atmospheric losses and the day and night cycle gives 170 W/m2 as an annual mean for the total earth surface, or 22 000 TW for the earth as a whole. Spatial differences are considerable: for Western Europe 110 W/m2 is the annual mean value, for equatorial regions this is 250–300 W/m2 . Due to the fact that not all earth surface is available and making assumptions on the technically possible conversion efficiencies, studies arrive at estimates for the technical solar power potential of 100–300 TW, which is enough to cover the whole world energy use.

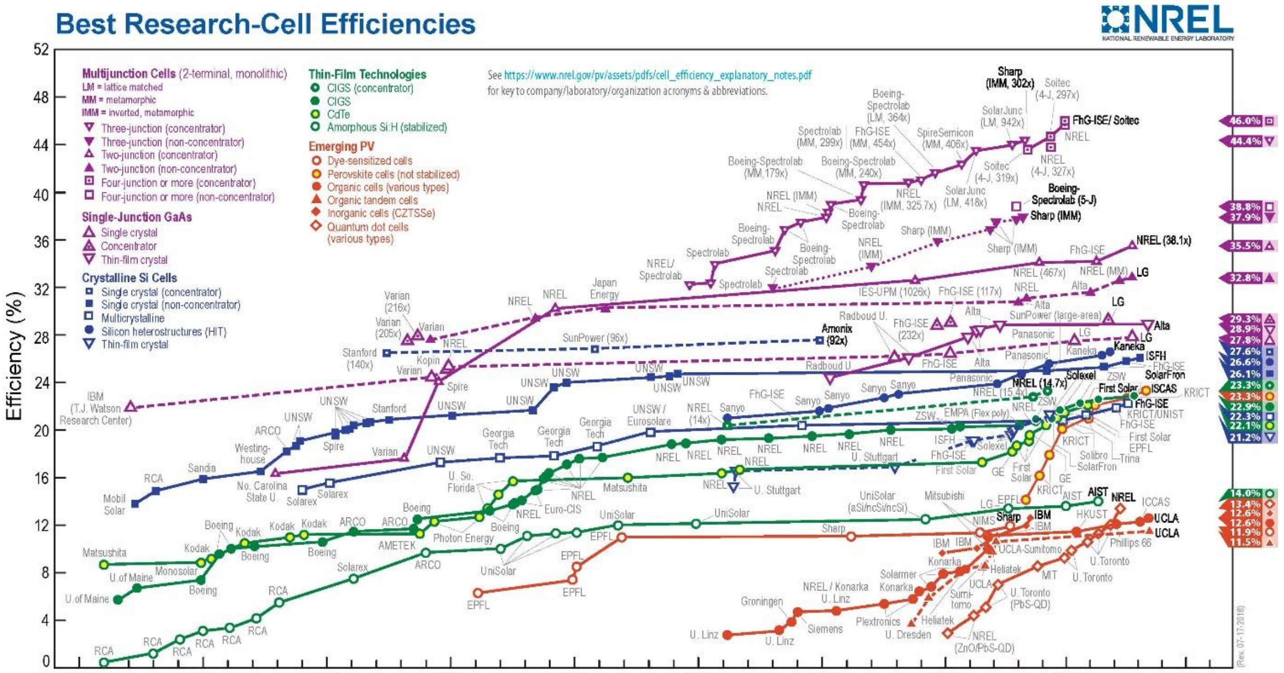
2.1.1.1 Solar to Electrical: photovoltaics

The technology of converting sunlight directly into electricity using solar cells is known as photovoltaics (PV). The main working principle is described in many textbooks and not explained here. Crystalline silicon technology was the technology used when solar cell development started. This technology has disadvantages like its need for high-grade silicon and its costly fabrication, as well as a limited efficiency. Therefore, different technologies arose, with the aim of increasing efficiency, reducing costs or both. At the moment, the various cells can be characterized into four categories:

- Crystalline silicon technology, which is despite the disadvantages still the most widely used;
- Thin film cells, which require less material and are less fragile, but have lower efficiency.
- Multi-junction cells based on III-V semiconductors, which sometimes need solar concentration to reach their maximum conversion efficiency;
- Novel concepts like polymer cells and dye-sensitized cells, which are potentially cheaper to produce but are still experimental.

Research is going on in all four categories, and efficiencies are still increasing. At the time of writing this report, the current state of affairs is the following:

- Crystalline silicon technology reached a cell efficiency of almost 28 %;
- Thin film cells did reach 14 % for silicon and 23 % for CIGS materials Emerging technologies are Perovskite cells (23%) and quantum dot cells (14%)
- For multi-junction cells, the current world record is 46 % conversion efficiency



All these efficiencies are obtained on the cell level. Solar cells have to be combined into modules to reach useful voltage levels. If cells are combined into modules, the cells cannot individually operate at their maximum power point, which leads to overall losses in efficiency. As an example is used a drop from 21 % cell efficiency to 18.4 % module efficiency, so a loss of 12 %. There will be more losses if these modules are combined into arrays.

The state of the art for commercially available panels is that almost all available panels are nowadays silicon panels. Very high-grade panels can reach over 20 % maximum efficiency, but 15-18 % maximum efficiency is more usual, and 17 % can be considered as the current standard efficiency. In the longer run, efficiencies of 18–22 % are expected for crystalline silicon panels. As a rule of thumb PV harvest some 10W/m2 (= net 5%).

2.1.1.2 Concentrating solar power

In CSP technologies, the available solar radiation is concentrated to reach higher temperatures. Different systems are developed, and all of them are directly used to convert the generated heat into electricity. Therefore, this conversion is assessed too. It should be noted that all CSP technologies depend on direct solar radiation. This limits the applicability to areas where direct solar radiation is abundantly available. The Sahara desert is an often mentioned possibility and is the subject of an impressive plan to deliver a significant portion of Europe's electricity demand by CSP projects in this desert. Apart from this, there are already several plants in operation in different parts of the world.

At the moment, three technologies are applied in commercial or semi-commercial plants:

- Parabolic dishes, which look like satellite dishes, with a Stirling engine in its focus point.

- Solar power towers or heliostats, in which the heat is concentrated at the top of a tower in a heat reservoir using a field of mirrors.
- Parabolic trough systems, in which the plant consists out of many parabolic-shaped mirrors which track the sun in one axis.

As CSP is large scale technology, it is not further considered here.

2.1.1.3 Solar thermal panels

Solar irradiation can be converted into heat in different ways. Technologies differ mainly based on the difference in the final temperature of the heat produced. When hot water for domestic use is needed, solar thermal panel technology can be used. Solar thermal panel technology and other technologies for low temperatures are relatively simple and mature, and will be covered shortly below.

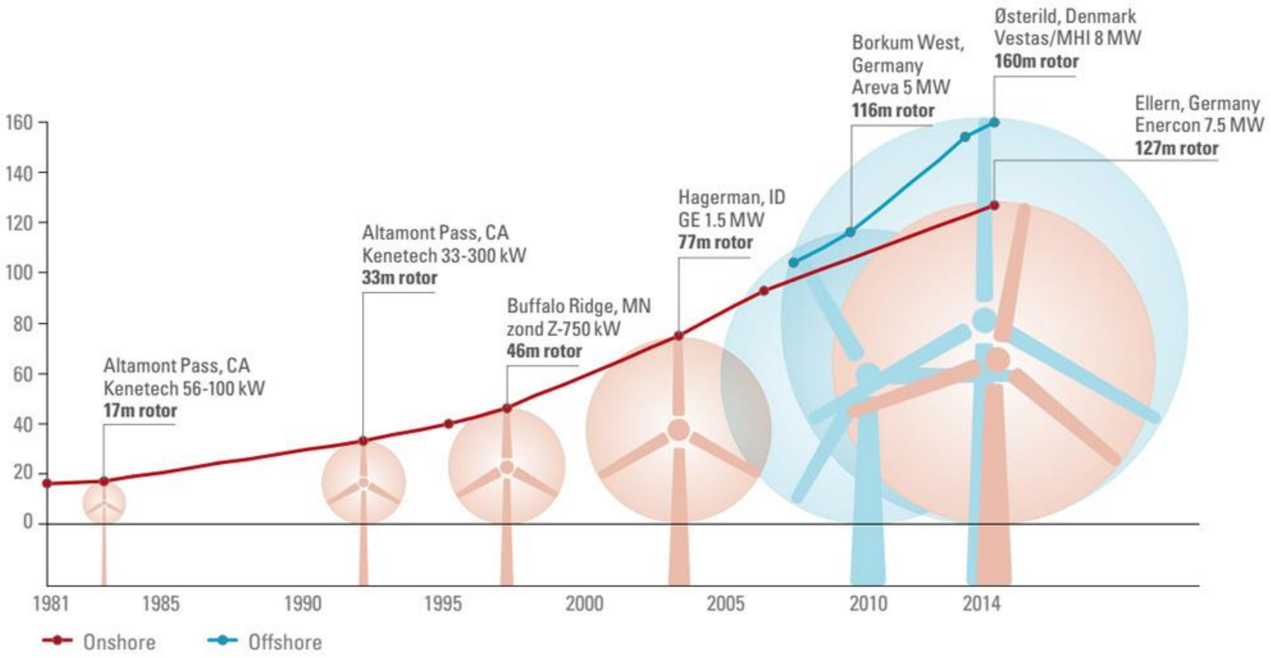
Regarding low-temperature technologies, most technologies are improvements on the flat-plate collector. They are stationary devices, absorbing the solar radiation by an absorber plate which is designed to absorb radiation optimally and lose as little as heat possible. These devices use both direct as well as diffuse radiation. The basic conversion efficiency is determined by the amount of energy that can be absorbed in the system fluid and the thermal losses to the environment. The efficiency decreases with the desired output temperature and is typically 40–60 % for domestic heating applications. These efficiencies are close to the physical limits, therefore significant improvements are only to be expected with new materials with better properties.

2.1.2 Wind

Wind is caused by solar irradiation: the sun heats the earth surface unevenly which leads to air movement. Therefore, the maximum potential of wind energy will only be a fraction of the maximum potential of solar energy. The exact amount of available wind energy is difficult to estimate, because it is highly dependent on geographical features, feasible height of wind turbines and estimated feasibility of off-shore wind. Therefore, the estimates for the theoretical as well as the technical potential vary with more than one order of magnitude. The technical potential is calculated to be at least 2 TW to 46.7 TW. A commonly cited number is 53.000 TWh per year in theoretically available onshore wind power, which is equal to 6 TW. Off-shore resources estimations depend highly on assumed allowable distance from shore and allowable water depth, a global assessment has not yet been executed. In any case, it is currently a very fast growing renewable energy source. However, off-shore wind is not further discussed here, as it is not a likely part of a cVPP.

Wind is always converted to electrical energy using wind turbines. Wind energy is often quoted as a very important renewable resource in Europe and has a lot of proponents and opponents. Some important aspects of wind turbines that bother people are its aesthetics, the noise they generate and the shadow caused by the moving blades. From a power systems perspective, wind turbines are mainly characterized by their intermittency: they only deliver power when the wind is blowing. Wind turbines and wind farms can be placed both onshore as well as offshore: onshore is cheaper, but leads to more problems in terms of visibility and noise. Offshore is more expensive, but wind speeds are higher and less turbulent at sea.

Wind turbines are in general considered as a mature technology. This is confirmed by looking at the development of wind energy technology in recent years: while advances in aerodynamics, structural dynamics and meteorology have contributed to a annula increase in yield per wind turbine, all efforts did not lead to radically new designs but to improvements of the existing basic design of the wind turbine. The trend led to bigger wind turbines over the years, which are more cost effective. Major improvements in power control and transmission systems are reported, better aerofoils improved efficiency, and recently control strategies are have been developed.



Considering power conversion efficiency, wind turbines are governed by the well-known Betz' law, which shows that a perfect wind turbine can only convert 16/27 part (about 59 %) of the available wind power into mechanical power. At the moment, big wind turbines already come close to the Betz' limit: two-blade turbines reach 52 % at optimum wind speed, three blade turbines reach 50 % at optimum wind speed. For lower wind speeds the conversion efficiency drops, and for too high wind speeds the turbines have to be stalled to prevent damage. This leads to a load factor of 30 % in UK, 22 % in the Netherlands, and 19 % in Germany.

In a wind farm, turbines need to be spaced to prevent standing in the turbulence of other windmills. A distance of 7 times the blade diameter can be taken as a rule of thumb (which might be a bit too pessimistic: studies suggest approximately 5.3 times the blade diameter). A wind turbine at the Dutch coast generates around 100 to 150 W/m^2, where the area is measured in *vertical* square meters. Using the rule of thumb, this translates to a net power revenue for wind turbine parks of 2 to 3 W/m^2 in the horizontal area.

2.1.2.1 Large versus small wind turbines

Although the wind turbine quest is for ever-larger turbines for an obvious economy of scale, micro turbines should not be forgotten. The mentioned disadvantages to the public may be far less, and they could be achievable for certain local energy communities, where other options fail. Small turbines are typically of the 1-300kW class. They are a niche product in comparison to standard wind turbines, but may apply to the cVPP project.

The smallest range are called “urban wind turbines” and are typically maximum 20 kW class.

There are three types of these urban wind turbines:

- Horizontal axis wind turbine
- Vertical axis wind turbine
- Energy ball and wind wall turbines

In the first place, there are the horizontal axis wind turbines, which are 'traditional' wind turbines with two, three or more blades attached to a horizontal axis. The optimal position of these turbines is with the blades towards the wind. Locations in an open field are the most favourable for these turbines. They perform worse in a turbulent environment because they have to search for the optimum mode again and again.

Another type of wind turbine is the vertical axis wind turbine, which has been specially developed for use in built environment areas. Because of their construction, these wind turbines are always in the right position in relation to the wind. In the past, the vertical axis of the wind turbines were divided into two categories, namely Savonius and Darrieus. With the Savonius type, the wind pushes the blades away. As a result, the wind turbine can never move faster than the wind itself: the blades move with the wind. This is called the resistance principle. With Darrieus type, the blade profile ensures that the blades rotate faster than the wind. This is called the elevator principle. In modern wind turbines, the shape of the rotor is often optimized for certain applications. This created new forms that no longer fit within the definitions of Savonius and Darrieus wind turbines.

The newest types among the urban wind turbines are the Energy Ball and the WindWall. The Energy Ball wind turbine, also called Venturi, has a horizontal axis to which the arcuate blades are attached. All blades together form an openwork ball that turns towards the wind with the help of a tail. The WindWall wind turbine is also a wind turbine with arcuate blades and a horizontal shaft which in this case is in a fixed position with respect to the roof. As a result, this wind turbine can only catch the wind from one direction. This limits the applicability of WindWall to the locations with the wind from a predominantly constant direction.

Energyball turbine (left) and WindWall turbine (right)

2.1.3 Hydro

Hydropower is the potential energy available in water at elevated heights that will flow to sea level at a later time. All this water was once evaporated by solar irradiation, and therefore also hydropower potential can only be a fraction of the power in solar irradiation. It is currently by far the most intensively used sustainable energy source. In Europe and the USA, more than 70 % of the technically feasible potential is already used, but in other continents a lot of potential is left. In total, around one-third of the global technical potential is already used. The total theoretical potential is stated to be 4.6 to 7.2 TW, while the technical potential is around 1.5-2 TW.

Like windpower, also hydroelectricity can be divided into different scales: from the massive dams like the Three Gorges Dam and the Hoover Dam to small run-of-the-river schemes which are less ecologically damaging but also deliver much less power. Large hydropower schemes have also been controversial, mainly on account of population displacement, fish and ecological issues, and poor river flow management. Such problems usually result from insufficient impact mitigation, inadequate legal framework and corruption. The basic principle in all hydroelectric schemes is the same: the kinetic energy is converted into electricity using a specially designed turbine.

The conversion efficiency of a hydro power plant is a function of a head (height difference) and discharge rate. The maximum efficiencies are high: modern plants can convert more than 95 per cent of moving water's energy into electricity. Even plants installed at the beginning of the 20th century still run at 80–90 %. The efficiency reduces with size. Micro-hydro systems tend to be in the range of 60 to 80 % efficient.

In terms of conversion efficiency, there is not much to be gained. Modern hydro power research is mainly directed to cost-effectiveness improvements. There are also many proposals for using hydropower mainly as an energy storage option, especially because the energy conversion is very efficient.

2.1.4 Biomass/biogas and Energy from Waste

Biomass

Nature uses the incoming solar irradiation extensively to grow plants. This is also the most obvious and straightforward way in a sustainable energy system to transform solar energy into chemical (stored) energy: use natural photosynthesis to create biomass.

Biomass can be turned into electricity and heat in a variety of ways. A big application is co-firing (combustion) in coal- or gas fired steam plant or 100% biomass firing in a steam plant. This can also be done in a CHP set-up: Combined Heat and Power. Such set up can start at the low MW level and can be very helpful in an energy system based on PV and Wind, as it is a stored form of energy that can follow demand.

Another alternative is gasification, where the biomass is first turned into gaseous fuel before being combusted in (mostly) a STAG unit (Steam and Gas turbine). Such a system is environmentally better and can reach high efficiencies. However, operating such technologies also requires a high level of technical knowledge and is not considered here further for cVPP technology.

Biogas is a special form of biomass. It is usually the result of a fermentation process of (for example) cattle and other biomass waste. It can be used in similar ways as above, but the gas itself is much easier to process (once available).

Energy to Waste can also be considered in a similar way. It is the combustion of combustible waste into electricity and/or heat. Again a technology that requires a high level of technical knowledge and is not considered here further for cVPP technology.

2.1.5 Other RES

2.1.5.1 Wave to Electrical

Most ocean waves are caused by wind. Therefore, the available wave energy can only be a fraction of the available wind energy. It is estimated that 60 TW of energy is transferred from wind to ocean waves. Waves can propagate over long distances without losing much energy. The energy available in ocean waves can be harvested along the coastline, and is measured in kilowatts per meter of the wave crest. Several sources calculate a mean available energy of 40 to 50 kW/m, amounting to 2 TW in total. The technically feasible amount of energy to be harvested is around 0.2– 0.5 TW.

The conversion of wave energy into electrical energy is a relatively new technology, for which many concepts are being developed. There are 6 main types to be distinguished, which are all under full development. The Pelamis wave machines (picture) are the most well-known example of this technology. They are already in operation and can capture 10 kW per meter which corresponds to an efficiency of 20 %. For some other devices, efficiencies up to 25 % for moderate water power levels of 10 kW/m are projected.

2.1.5.2 Tidal to Electrical: barrages and tidal current energy

Tidal energy results from the movement of the Earth, through the gravitational field gradients of the Moon and the Sun. The resulting kinetic energy dissipates as friction, slowing down the rotation of the Earth. The total dissipation of tidal energy is estimated to be 3.7 TW. The technical potential energy is, of course, much lower. Therefore, it is not surprising that there are severe doubts whether tidal and wave energy can ever deliver a significant contribution to world energy generation. Tidal energy can be used in two ways: by making a barrage and using the height differences created by the tides (tidal range energy) and by using the tidal currents directly (tidal current energy). Because of their very limited applicability, they are no further discussed here.

2.1.5.3 Geothermal to Electrical and Thermal: geothermal power plants

There are two types of geothermal energy. At every location, there is geothermal energy available due to radioactive decay in the earth crust and the core heat trickling through. At hot spots like for instance on Iceland, there is more power available due to the volcanic activity. For sustainable use of geothermal power, one needs to calculate how much heat is available sustainably (!). If heat is extracted faster than the sustainable rate, the energy is still low carbon but not really sustainable. The geothermal heat is then mined rather than used sustainably.

The total potential of the power available at every location is quite low: the flow of energy flowing into the crust from the inside of the earth is approximately 32 TW, but this cannot all be used.

On a small scale, low temperature geothermal heat can be used for domestic heating. Underground heat pumps, preferably used with one heat reservoir for a block of houses instead of for every house individually, is an attractive way to heat houses and commercial buildings.

To use geothermal energy for electricity production, higher temperatures are required. The process is composed of two stages: first, to recover the heat from underground, and second, to convert it into electricity. The first stage has an efficiency of about 40 %, constant over all kinds of system (or well) arrangements, fracture spacing, and permeability. This estimate is mainly based on existing geothermal plants, which are normally built on sites where heat is easily available. For wide scale exploitation of geothermal energy, systems that can use heat stored lower in the ground are needed. These Engineered Geothermal Systems (EGSs) can also reach 40 %, and are expected to reach 45 % recovery efficiency in the near future. Again as these are complex and expensive systems, they are no further discussed here.

2.1.5.4 Other energy sources (non-nuclear)

Sometimes, more experimental energy sources are mentioned which are not further explored in this report. For completeness they are mentioned here shortly:

- *Ocean Thermal Energy Conversion* is a technology which uses the ocean's temperature gradient to generate energy. The potential of this technology is tremendous (100-230 TW), but there seems to be not too much research activity going on. One of the reasons may be that practical gradients are only in the order of 20 °C, which results in a poor Carnot efficiency. The US Navy is designing an OTEC plant. The website www.otecnews.org has the latest news on this subject.
- *Osmotic power* uses the salinity gradient in water, for instance at a place where a river flows into the sea. The theoretical potential is 5.4 TW. A first pilot plant opened in November 2009 in Norway, and the first commercial plant was announced in 2015, but is not clear whether that happened. For this technology, scaling up might be a problem due to the need of high-quality membranes of considerable size. An alternative technology using capacitors instead of

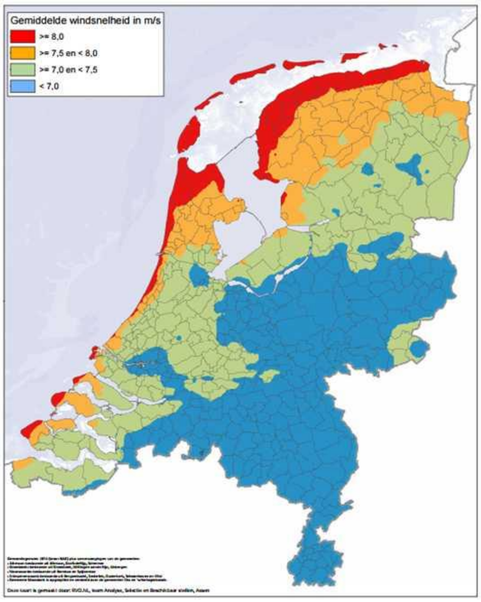
membranes is recently proposed, but has to be scaled up too before something can be said about its economic potential.

2.1.5.6 Conclusions

Based on the above, it becomes clear that for c-VPP project technology three main RES apply: solar, on-shore wind and biomass. Other forms are either too large scale, too far away, too complex or not mature yet. In the next chapters, the focus will be on these three forms of RES only.

2.2 CHARACTERISTICS OF RES

2.2.1 Availability



When looking for new renewable energy sources, it is important to check the local availability of those sources. Not every location has as much sun, wind and/or biomass available. For sun and wind, there are usually national solar and wind maps available that indicate local solar irradiance. In the map below the average wind speed over a year for the Netherlands is indicated.

At IRENA, they give the solar and wind potential worldwide in a map:

http://www.irena.org/newsroom/articles/2016/Aug/New-Solar--Wind-Maps-Downloadable-on-IRENA-Global-Atlas.

In the Netherlands, there is even a GIS that gives the solar potential at the house level, which is very helpful for home-owners.

The availability of biomass will largely depend on space, farming, and available local forestry. The issue with biomass is that it usually mainly contains water, which means that it should not be transported over long distances (or dried thoroughly prior to that). Furthermore, with biomass several possible adverse effects need to be taken into account, like environmental impact, wildlife/biodiversity, mineral depletion, etc.

Biomass can be created all over the world and transported to the highest bidder. This should not lead to an unequal distribution of costs and benefits between countries. The demand for biomass must always match sustainable availability and come from renewable applications. Where other / better options for sustainability are available, biomass flows should not be used.

2.2.2 Deploy ability/dispatchability

An essential feature of PV and wind is the non-dispatchable character of these RES. PV will only work during daylight and at variable levels, depending on the weather. During periods of snow it will not work at all, possibly for days or weeks. Obviously, most PV-production is in summertime, although too high temperatures also decrease the achievable amount of electricity. Sometimes best production is in springtime when the sun is already strong, but the temperatures may still be low.

Wind electricity production depends on the level of wind force. Too weak or too strong winds will lead to non-production. Opposite to PV, most wind energy is produced in wintertime, when there is more wind (at least in the Netherlands!).

PV and wind can be therefore quite complimentary to each other, if looked at from a seasonal perspective.

However, Germany with some 30GW of PV and Wind each, sometimes still experience a “Dunkel-flaute” (translated as Dark-calm), meaning no sun, no wind and very low production of renewable energy. Obviously, this can create huge problems if no reserve capacity or storage is available.

Therefore, biomass, as a stored form of energy, can be an excellent addition to the energy mix. Biomass, in the form of wood pellets, biogas or other forms can be dispatched as required if the other types are not available, possibly without the need to fall back on fossil fuels. Especially for longer periods that cannot be overcome by energy/electricity storage. When using biomass also a combination of power and heat (CHP) can be considered.

2.2.3 Applications/applicability

With respect to the applicability of these RES, PV is the most flexible, commoditized option. A single homeowner can install PV on his roof at any desired level, usually at some 3-5 kWp. With the current cost level, this will cost around 5-8.000 euro. Based on the energy costs and taxing scheme and or feed-in tariffs such costs can be recovered within some 5-10 years. In the Netherlands, the tax system aims at a payback time of 7 years on average. In Belgium, this is about 8 years.

Germany is well known for its feed-in tariff that has largely boosted PV and wind in Germany, where even electricity for the general market is highly subsidized.

Besides residential PV, a community can also choose for a collective PV roof or even a large solar farm (MWp-level). There is an economy of scale in larger parks, but such an economy can also be found in joint procurement of PV (although it will never be as cheap as one large solar farm).

For wind, the situation is different. Windmill capacity can range from 1kW to 3 MW (onshore), meaning that investments can go up to some 3-4 million euro. Large windmills will always be a serious professional investment, but can be done by local energy communities. However, a lot of space is required and also a tedious legal process.

Smaller windmills may be less difficult, but are also less economical. Still, they could be alternatives for communities with limited space and/or limited appeal to the large turbines in their territories.

Solid biomass can typically be used at a 1-10 MW level, but requires a professional organization (educated staff, environmental control, etc.) and a well-chosen/designed conversion technology, pre-treatment process and by-products handling. Not an easy task for an average community. The technologies are available, however mostly applied in Scandinavia, Austria etc.

Biogas is easier to handle. It can be used in many types of application like gas motors, small CHP, hybrid heat pumps, etc.

2.2.4 Levelized cost of electricity

Investments in RES, especially at the community level are significant to very significant investments (multi-euro). They are usually also long term investments (10+ year). At the same time the energy market is volatile, depending on supply and demand, technological advancements, and last but not least policies at both national, European level and international level.

For solar and wind, the main costs are at the beginning, while for biomass there are also significant operational costs (fuel, maintenance).

Therefore, it is of vital importance to have a full understanding of the total cost of the project over the complete lifetime of the asset. In the energy business, a method has been developed to get a good insight into the viability and vulnerabilities (risks) of a project. When seeking external financing, such analyses will have to be made to make the project bankable. This approach is called the Levelized Cost of Electricity (LCOE) and can be applied to all sorts of projects. Such an LCOE-analyses look at items like:

- Investment costs
- Depreciation
- Interest rate
- Discount rate
- Fixed operational cost
- Variable operational costs
- CO2 price
- Fuel costs
- Subsidy schemes
- Revenues
- Etc.

Based on the above an “average” production cost price per energy unit (e.g. kWh) is calculated and compared to the energy prices development scenarios. Based on that the rate of return can be estimated.

2.2.4.1 LCOE calculator

In general, a LCOE calculator is a complex calculation spreadsheet where all above-mentioned variables are input. The figure below expresses such a calculation for PV:

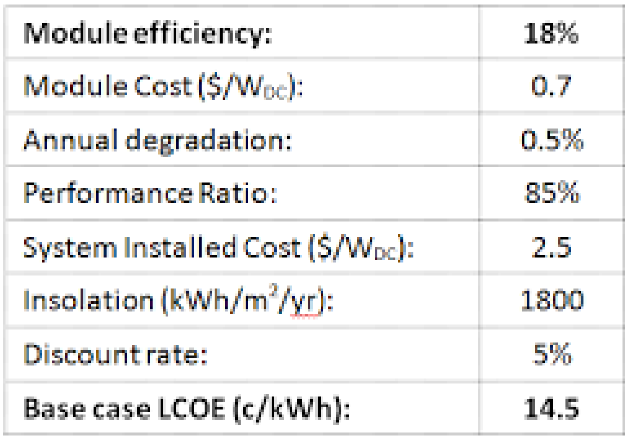
$$LCOE_{residential} \approx \frac{PC - CBI - PVPBI + \sum_{n=1}^{N} \frac{LP_n}{(1+d)^n} - \sum_{n=1}^{N} \frac{INT_n}{(1+d)^n} * ETR + \sum_{n=1}^{N} \frac{OM_n}{(1+d)^n}}{\sum_{n=1}^{N} \frac{EO_n}{(1+d)^n}}$$

where PC = Project cost
CBI = Cost based incentive
OMn = Operations & maintenance (e.g. inverter replacement cost) in period n
EOn = Energy output in period n
d = Discount rate
PVPBI = Present value of performance benefit incentive
LPn = Loan payment in period n
INTn = Interest payment in period n
ETR = Effective tax rate

It is too complicated to elaborate a model here, but some websites give the opportunity to use it yourself, although it is not easy. For example, Stanford provides a more global model, while the Danish Energy Agency provides a very comprehensive model.

- Stanford university LCOE
- LCOE calculator Danish Energy Agency

As an example, a calculation of the net kWh-price could look like this:



Module efficiency:	**18%**
Module Cost ($/W$_{DC}$):	0.7
Annual degradation:	0.5%
Performance Ratio:	85%
System Installed Cost ($/W$_{DC}$):	2.5
Insolation (kWh/m^2/yr):	1800
Discount rate:	5%
Base case LCOE (c/kWh):	**14.5**

2.3 LATEST DEVELOPMENTS IN MAIN RES-TECHNOLOGIES

2.3.1 Outlook of PV

The theoretical limits for solar cells are known in detail. These bounds apply to all conventional PV cell techniques, including thin film cells and multi-junction cell. It is important to note that crystalline silicon cells already 90+ % of their theoretical maximum efficiency and that the multi-junction record is already at 80+ % of its theoretical maximum. The other types of cells do mainly aim for higher cost-efficiencies, not for a higher conversion efficiency than crystalline silicon cells. For polymer cells, for instance, the main research effort is directed towards increasing stability and improving the technology. The maximum expected efficiency in polymer cells will not reach the heights of those of silicon cells: 12 % is seen as the highest practical maximum achievable in the future, except if a revolutionary breakthrough will take place. Concerning potential future commercial module efficiency, the following expectations are made: 18– 23 % for crystalline silicon and 15–18 % for thin film technologies. There are concerns about the availability of resources in the long run. At the current rate of production, there will be enough indium and gallium for a long time, but when stepping up to a higher production rate, especially indium could become a problem. The prices for silicon have already temporarily increased severely due to shortages.

Polymer cells currently use indium too, but the expectation is that this can be replaced with another material.

If these solar cell technologies will be the technologies of the future, not much efficiency growth is to be expected. Due to theoretical efficiency limits, conversion efficiency growth of cells is limited. At the system level, there is an inevitable loss due to the need for protection against weather conditions, mounting, wiring, and the losses in electronics. Building solar farms is a relatively new technology, so due to learning effects some of these losses will decrease. This can however never be very much.

To summarize this: although there are a lot of different PV technologies developing, the main goal is to bring down the price per Watt by using less or cheaper materials. In the final comparison, module efficiencies are taken because single cells are not applicable in real life. Currently, commercially available modules reach on average 16 % efficiency, 18 % or slightly higher is expected, and the theoretical limit for single layer cells is 30 %.

2.3.2 Wind Outlook

Regarding the conversion estimate, maximum power output is close to its theoretical maximum (80%). In the literature, there are no alternative wind turbine designs to be found that claim to do better. The main research effort is in offshore wind power, which increases the amount of energy output by making more sites available for wind power, but does not increase the conversion factor.

A relatively new development that is in fact circumventing the Betz' limit is the design of kite generators. These generators use high altitude kites to generate energy and claim to be very cost-efficient and more energy-efficient than a wind turbine at the same location. Prototypes are being tested, and no full-scale model is yet developed. This might, however, be a very interesting development.

To summarize: the wind energy to electricity conversion estimate for the current state of the art is 50 % at its nominal wind speed, and this is not expected to increase much in the near future. It depends strongly on the load factor of the specific windmill. However, promising new developments in altitude wind power are expected, with a yet unknown conversion percentage.

2.3.3 Biomass

Several different production technologies have been developed to convert biomass into heat and electricity. The different methods of refining biomass are under constant development.

The focus of the development is on continuous streamlining. The conversion of raw material into more energy-dense forms facilitates transport, storage and use through the rest of the value chain. One example currently under development that would simplify future imports is the thermal processing of biofuels to produce a more efficient type of pellet with a higher energy value.

Competitiveness depends on the price of CO2 emissions.

It is currently more expensive to produce electricity from biomass than from fossil fuels such as coal. The price difference is affected by various types of economic control instruments such as emission rights for CO2. Increased CO2 prices would, therefore, support the conversion of the energy system to the benefit of biomass. International trade in biomass for power generation is still limited. Future increases in biomass trade will most likely mean that fuel is produced far from where it is consumed. This highlights the need for a standardised global system for trade and certification.

Also, the will be increasing competition from other applications than electricity or heat generation. Biomass could also be used to produce material and replace fossil fuel in chemical processes. Another fast developing application is the use of biomass for biofuel used in transportation, e.g. biodiesel.

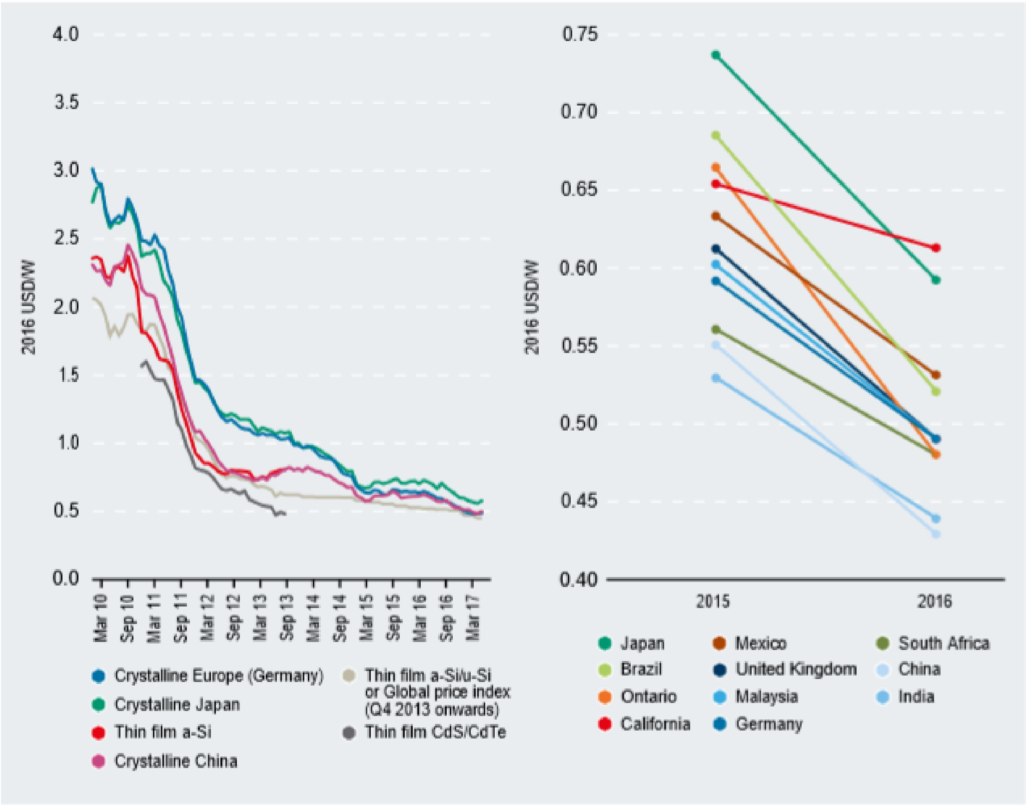
3 INVESTMENT CONSIDERATIONS

3.1 COST TRENDS

An excellent source for cost trends is the International Renewable Energy Agency. They have recently released a comprehensive report on cost development of all RE technologies, based on worldwide data.

For example for solar PV:

Figure 3.3 Average monthly European solar PV module prices by module technology and manufacturer, March 2010—May 2017 (left) and average yearly module prices by market in 2015 and 2016 (right)



Source: GlobalData, 2017; pvXchange, 2017; Photon Consulting, 2017.

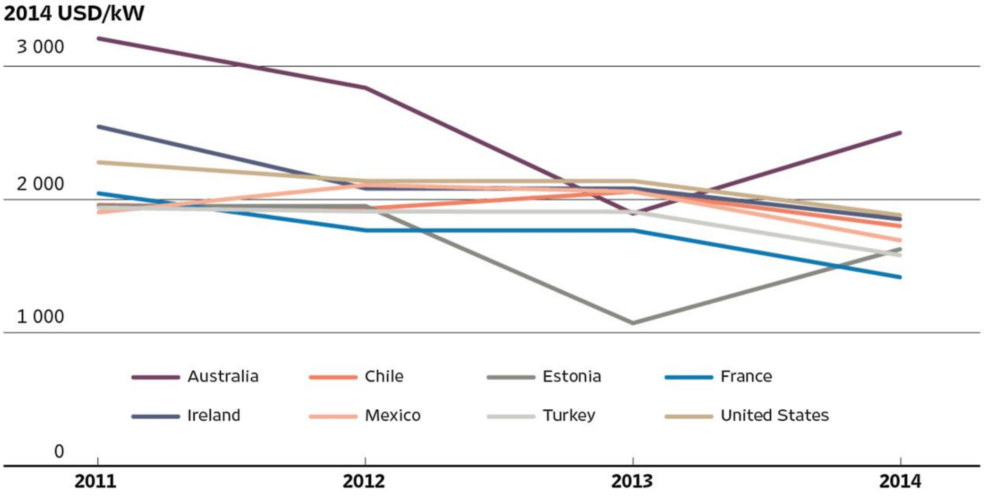
From this graph, it can be seen that the prices have dropped dramatically over the last 7 years, but data also seem to suggest that prices are starting to level off somewhat.

For wind, the cost reduction is not that fast, but a downward trend is also here noticeable. For wind projects, apart from the hardware, the development costs are rather high compared to a PV-farm.

RENEWABLE POWER GENERATION COSTS IN 2014

IRENA International Renewable Energy Agency

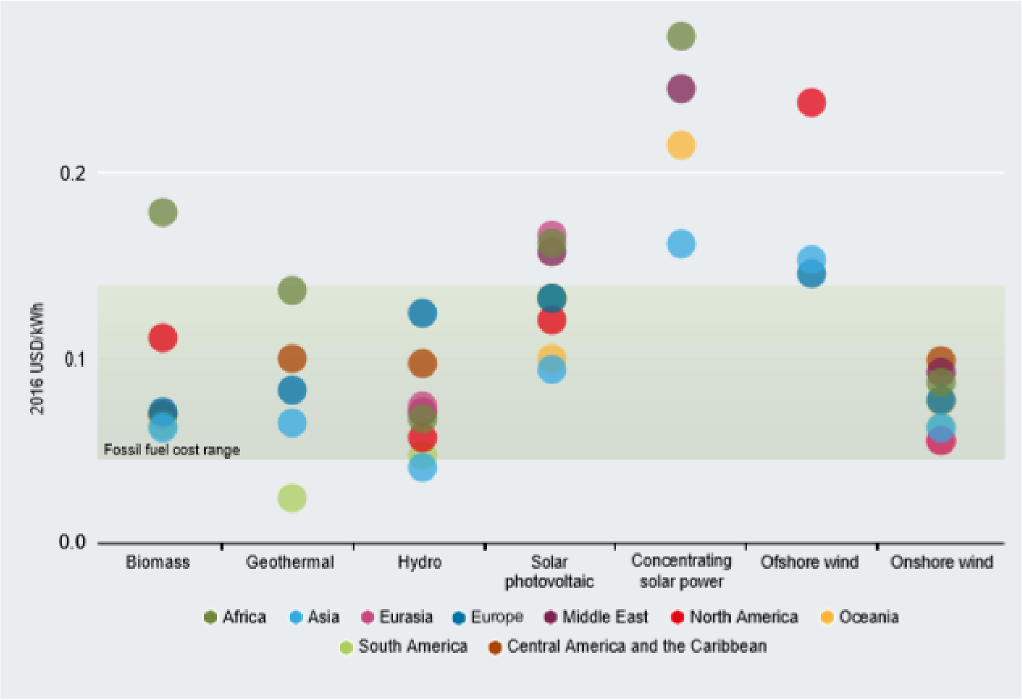
FIGURE 4.7: EVOLUTION OF TOTAL INSTALLED COSTS OF COMMISSIONED AND PROPOSED LARGE WIND FARMS IN SELECTED OECD COUNTRIES, 2011-2014



Source: IRENA Renewable Cost Database

A nice overview of the levelized costs of electricity by technology (and region) is given in:

Figure 2.3 Regional weighted average levelised cost of electricity by renewable power generation technology, 2016 and 2017



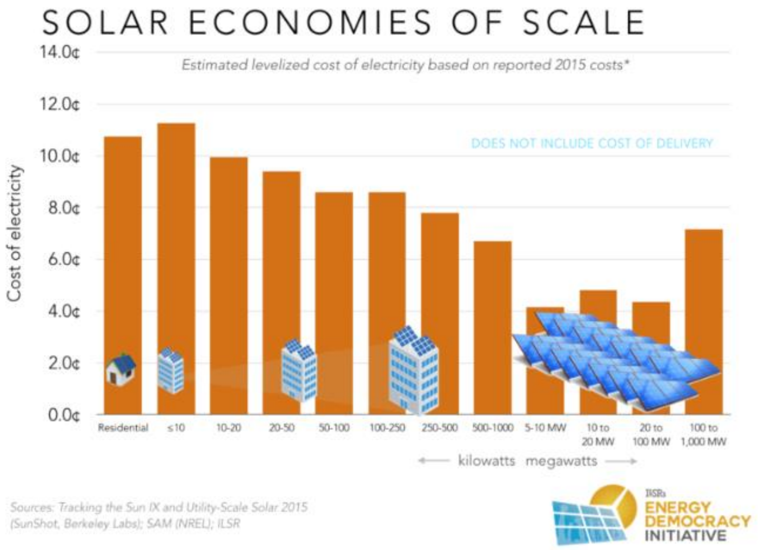
Source: IRENA Renewable Cost Database.

As can be seen here, despite the enormous cost reduction of PV, it is still in the upper end.

3.2 SCALE EFFECTS

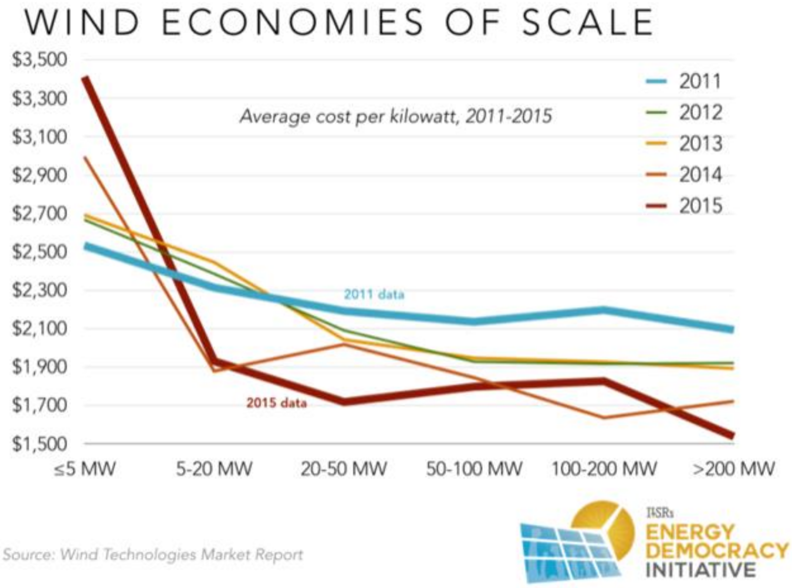
As is generally known, applying laws of economics and physics and producing in larger quantities reduces the costs of production. This is called economies of scale. The question is if and how this also applies to RES like solar PV and wind. Below some graphs are shown from the situation in North America. But there is no reason that the same will not be valid for Europe.

For solar PV the trend is shown below:



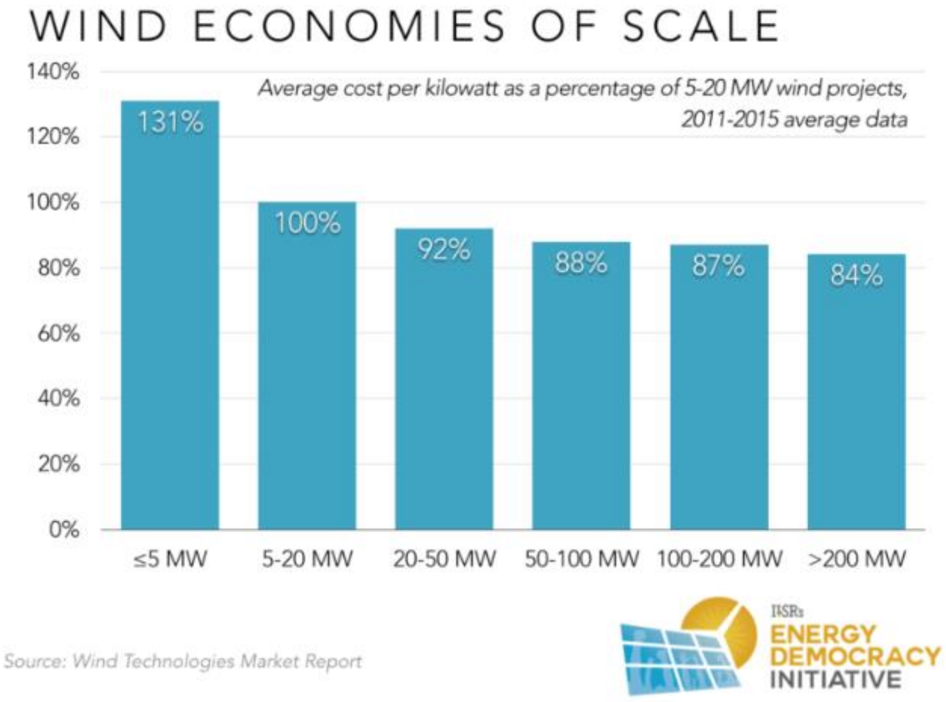
Sources: Tracking the Sun IX and Utility-Scale Solar 2015 (SunShot, Berkeley Labs); SAM (NREL); ILSR

For wind the graphs looks similar:



Source: Wind Technologies Market Report

Although the five lines above show the gradual increase in economies of scale of larger wind farms, combining the lines into a five-year average is also instructive. The chart below shows the cost per kilowatt for wind farms of increasing size as a percentage of projects sized 5 to 20 megawatts. The lesson is that two--thirds of the economies of scale of wind farms is captured when projects exceed 5 megawatts of total capacity.



The reason that the economies of scale are captured, could be that the larger farms have to be connected to the transmission grid at higher costs than smaller plants at the lower grid level.

The conclusion is that RES benefits as well from the economy of scale, also there seems to be a typically maximum probably caused by grid costs. For the c-VPP scale this is probably not a limiting factor, so there one should try to reach scale effects as much as possible. This is further elaborated in chapter 3.6.2 for joint procurement.

3.3 OPERATIONAL COSTS

3.3.1 Maintenance

After a RES has been put into operation, there are costs involved to keep them safe, efficient and reliable in operation with the aim to achieve the predicted energy production and lifetime. Common maintenance strategies are based on a healthy balance between Safety, Reliability, Availability, Performance and Costs. The approach to keep an optimum value for your assets is also known as Asset Management. A norm/standard that deals with this is ISO 55000.

For RES in this context, there is a wide variety of maintenance activities that are in place. Some examples are:

- PV: maintenance is rather limited. Depending on the local situation, cleaning of the panels should be done about once a year. This could be combined with a visual inspection. Dirt is decreasing the production. Balance must be sought in cleaning costs and loss of production costs. When the performance is monitored, deviations to what is expected as a production number can be identified. This could be dirt or defect cells in panels. Inverters have an expected lifetime of 10 to 15 years, so costs to have it replaced must be considered. A figure could be to count <= 2% of the investment costs.
- Wind: wind turbines are more complex installations, with rotating equipment installed like gearbox, generator, brake, and bearings. Also, electrical and control equipment is installed. To keep safe and reliable operation during lifetime (20 years), yearly inspection and maintenance is executed. Normally, this takes about 1 to 2 days. Including unplanned outages, a wind turbine has availability of about 98%. Nowadays, turbine manufacturers offer maintenance contracts for a longer period (10 to 15 years) at fixed costs per installed capacity. Costs indication is circa 20 to 30 Euro/kW or 0,01 Euro/kWh. For off-shore wind turbines, this is not valid, as this is a much more complex situation.
- Biomass: here maintenance is very much depending on the application of biomass. Just burning it to produce heat is totally different than co-firing biomass in a coal fired power plant. Also, gasification requires a different installation and related maintenance. Of course, here as well, the size of the installation will determine what level of professionalism (and thus costs) is required.

3.3.2 Operation

Apart from maintenance, some RES requires daily operation (manpower). This might be on site, but could also be remote (control room).

- PV: no extensive operation effort is required. It might be that, for larger solar parks, there is remote monitoring. In case there are sudden deviations detected by the software, an inspection is necessary and planned. Normally, an owner or operator of a PV installation is monitoring the production by computer or cell-phone.
- Wind: for wind turbines, the day-to-day operation requires no operation effort. Normally all is automated. There are companies that offer remote monitoring and services in case of disturbances.
- Biomass: biomass is often more labor intensive to operate. Depending on the scale and application, biomass must be sourced, delivered and put in the installation to burn or be gasified. The ash or remaining material must be removed and disposed of. The process must be monitored and sometimes it is necessary to make adaptions in the process. Part of this might be automated, but usually manpower is required, sometimes in 7/24 shifts. These personnel can also perform day-to-day maintenance if needed. There are of course costs related to this that must be part of the business case.

3.4 NETWORK COST CONSIDERATIONS

The network costs are explained according to the Dutch energy market structure. Unlike some other European countries, in the Dutch power sector, the producers and retailers are privatized by law since 2006, whereas the (inter)national Transmission System Operators (TSO) and regionally-bounded Distribution System Operators (DSO) remained semi-public companies. One should only consider the costs of the TSO & DSO to be network costs. In the figure below, the difference between the TSO (TenneT) and a DSO (in this case Liander) is illustrated.

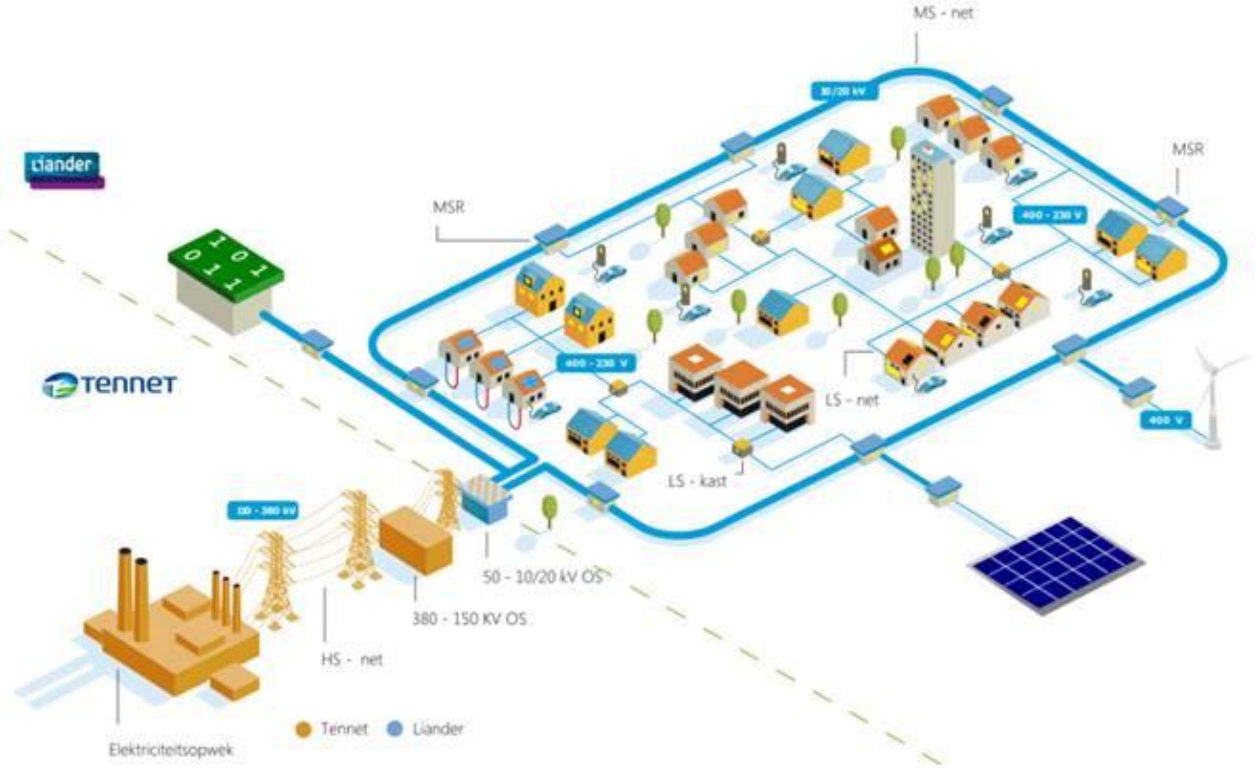


Figure: Dutch Energy Network Scheme

3.4.1 Network costs

When discussing network costs, we will elaborate on the different periodic network costs that are charged to customers. It has to be taken into account that these costs do not always represent the actual costs that are endured by the TSO or DSO to maintain the connection of a specific customer. For example, a consumer (<55 kVA) that lives at quite a distance from the main distribution, net will be charged the same network costs as a consumer (<55kVA) who has a similar network connection but is situated close to the main distribution net. Next to that, over the different European countries, laws with regard to network costs and metering services differ and therefore shall always be looked into.

In general, the periodic network costs can be divided into the connection costs, transportation costs, costs for metering services and other network costs. The latter is charged in case the connection point exceeds a specific distance between the connection point and main distribution net, applicable to customers with a capacity over 55kVA. In the table below these costs are outlined against the types of customers according to the Dutch market structure. Please note that the specific costs increase by network connection capacity.

Capacity of connection	**Type of Network**	**Type of customer**	**Connection costs / Costs paid to**	**Transportation costs/ Costs paid to**	**Metering Services**	**Other Network-costs**[1]
<55kVA	Low Voltage Network	Consumers & SMEs	$ / Paid through retailer	$ / Paid through retailer	Included in connection costs	Not applicable
55 - 100kVA	Low Voltage Network	Producers & MEs	$-$$ / Paid directly to DSO	$-$$ / Paid directly to DSO	Charged by mandatory metering company	Periodically charged by DSO if applicable
100kVA - 160kVA	Low Voltage Network	Producers & MEs	$$ / Paid directly to DSO	$$ / Paid directly to DSO	Charged by mandatory metering company	Periodically charged by DSO if applicable
160kVA – 2MVA	Medium Voltage Network	Producers & LMEs	$$-$$$ / Paid directly to DSO	$$-$$$ / Paid directly to DSO	Charged by mandatory metering company	Periodically charged by DSO if applicable
2MVA - 10MVA	Medium Voltage Network	Producers & LMEs	$$$ / Paid directly to DSO	$$$ / Paid directly to DSO	Charged by mandatory metering company	Periodically charged by DSO if applicable
>10MVA	High Voltage Network	Producers & LEs	$$$-$$$$ / Paid directly to DSO or TSO	$$$-$$$$ / Paid directly to DSO or TSO	Charged by mandatory metering company	Periodically charged by DSO if applicable

In addition to the aforementioned costs, a remark has to be made with regard to ‘Public grid reinforcement costs’. These are the costs a DSO makes to reinforce the rest of their grid, order than the creation of the connection itself, to ensure sufficient capacity for the (additional) RES. As these reinforcements are not made to connect the RES directly, these costs are socialized via the regulated tariffs and are therefore distributed among all customers. In addition, homeowners do not pay per kW, so they are not encouraged to avoid the peaks in their production or consumption. A solar park developer pays per kW, but the ‘Public grid reinforcement costs’ will not be charged to the solar park developer. This policy results in no economic motivation to prevent these ‘Public grid reinforcement costs’. The figures and text below illustrate this situation.

‘Business as usual’ illustrates the situation where the ‘Public grid reinforcement costs’ are not included in the cost for the developer. In the lower part, the combination of renewable energy with a windfarm is visualised. With ‘connect to windfarm’ the RES is curtailed according to the amount of wind. With this

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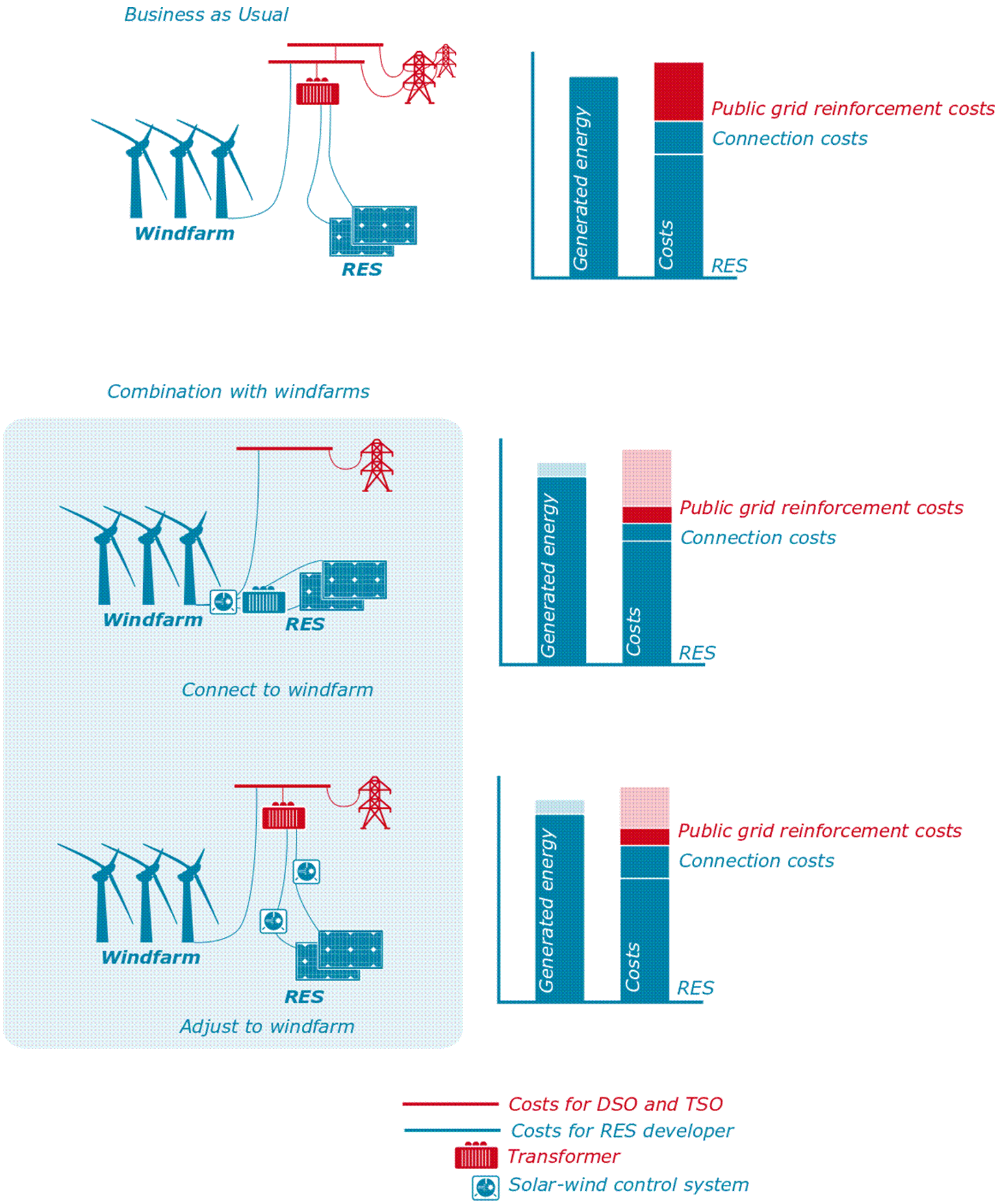
[1] Applicable in case of exceeding the maximum distance between connection and the main distribution net. This distance is arbitrarily set by the DSO.

construction, the connection cable can be shorter and the ‘Public grid reinforcement costs’ are reduced. With ‘adjust to windfarm’ the RES is curtailed according to the amount of wind but now on the scale of a substation. In this situation, all wind production on one substation is taking into account for the curtailment.



3.4.2 Potential network issues, connection constraints/possibilities

The power grid is originally designed to obtain and distribute electricity from a few large centralized sources (power plants) to the consumers. Due to the ongoing fast increase of decentralized renewable energy production, the system changes from a centralized system to a decentralized system. Although it is technically possible to decentralize production (electricity flows both ways), this change brings considerate challenges to the existing grid structure.

3.4.2.1 Network challenges/issues

Increase in power of both production as demand: The lower levels of the power grid are designed to cope with small amounts of energy demand per household. Due to the sudden increasing amount of demand (heat pumps, electric vehicles) and production power (solar and wind) the connection constraints are approached or even exceeded. This can result in congestion and even blackouts when the constraints are exceeded too far or for too long.

High simultaneity: The usual energy consumption has very low simultaneity. Devices are rarely turned on simultaneously and the energy demanding devices which are turned on at the same time (for a longer period of time) have relatively low power demand (lights, televisions). RES, on the other hand, have a very high simultaneity. Every solar panel in a grid district peaks at the same time and every heat pump turns on simultaneously when the temperature drops. The current grids are not designed to cope with such an increase in simultaneity and power.

Example: The capacity(power) reserved for a Dutch household is circa 1,2 kW. If everyone would turn on their electric kettle (circa 2 kW) at the same time a blackout is inevitable.

Example: The so-called 'Duck curve' illustrates the increase in solar power, simultaneity and need for flexible ramp up/down capacity in the near future.

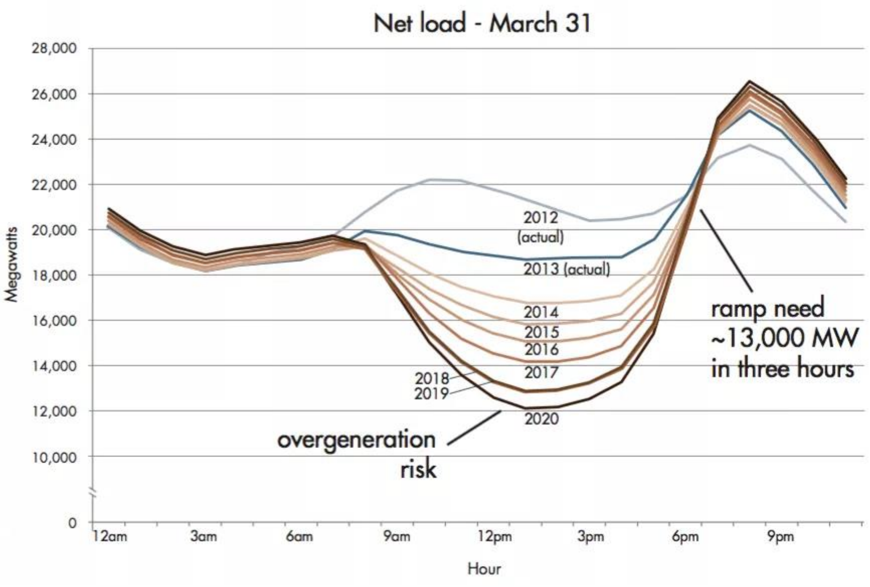


Figure 2: The duck curve shows steep ramping needs and overgeneration risk

https://www.caiso.com/Documents/FlexibleResourcesHelpRenewables_FastFacts.pdf

Voltages increase: Where energy production causes an increase in voltage levels, demand causes a decrease in voltage levels. The electricity grid is designed to keep the voltage level at the end of the cable to meet a minimal required bandwidth of 230 Volts +/-10%. When RES feed power back into the grid, they cause voltage levels to rise. With an overload of RE, it is possible that the voltage levels increase beyond the required bandwidth and trigger safety switches or safeguards.

Example: A solar-inverter increases its voltage to feed electricity back into the grid. When there is little demand or when multiple systems are feeding-in the voltage level can increase beyond the required bandwidth setting off the safety switch inside the inverter causing it to turn off.

Manufacturability: Due to the economic prosperity and decreasing costs for RES there is an enormous increase in applications for new or reinforced grid connections. Since the past few years, it increasingly becomes a challenge to carry out all these applications as there aren't enough trained professionals to carry out the required grid modifications.

Regulations fall behind: The technology and the availability of RES are developing faster than regulators can keep up with. Therefore, situations arise where existing regulations haven't been adressing these.

Costs & decision challenges: Usually, electricity cables have an operational lifespan of 40 years, and thus take 40 years to depreciate fully. Investments, but also re-constructions of the energy networks are therefore very costly and involve a great amount of uncertainty as the technology-improvements in RES are rapidly following up on each other. As the network costs ultimately trickle down to all the users, the decisions to (re-)construct cables or grid sections for the next 40 years are made with great caution.

3.4.2.2 Possibilities

Although regulations still fall behind, there are already network companies working on measurements to prevent blackouts due to RES, increase RES without the usual grid reinforcements and prepare grids and markets for a flexible and carbon-free energy system. Some examples:

Cable Pooling: Every solaror windfarm has its own grid connection. The capacity of the connection is only used depending on the production of energy, so only when the wind blows or the sun shines. Due to the relatively low production factor of wind (2000-4000 out of 8760 hours) and solar (1000 out of 8760 hours) and their complementary profiles (due to natural phenomena), it is perfectly possible to combine the production of both solar and wind on one connection. It would be necessary to tune down one of the two production sites when both the sun as wind reach optimal input, losing only 3% of energy, but avoiding significant grid costs and labour.

Curtailment: Grid connections are always designed on the peak performance a machine or installation requires or produces. When the same design methodology is used on the intermittent character of RES, the maximum capacity of the connection will rarely be used, and therefore will be very expensive per kWh. This capacity is also reserved on the grid station and cannot be used for other purposes. When the sporadic, occurring peaks are flattened, it is often possible to engineer a production site with a smaller grid connection (or make a bigger site with the same connection) and make more use of the reserved grid capacity.

Abandon redundancy: Large consumption customers are often connected with more than one cable. This is done to ensure their daily operation when one of the cables fail. For RES it is relatively less important to have a redundant connection because it has less consequences when the production is not available. This, again, avoids significant grid costs and labour. The higher risk and lower grid costs could be offset by a (financial) reward or agreement between the involved parties.

Flexibility: With RES the time of demand and supply of electricity will increasingly become an issue. Solar energy is produced during the day, and there is also a need for electricity during the night. It is possible to shift the demand or store the supply, so the grid balance is restored. This is called flexibility. Some home appliances have flexibility, but also large production facilities have flexibility. Arrangements with the owner of the flexibility are necessary to valorise the flexibility. More details about flexibility are explained in the paper T1.4.1 “Improvement of system stability/flexibility for matching energy demand and supply”.

3.5 FINANCING

3.5.1 Financing schemes

The way how to finance investments in new RES is very much depending on the scale, risk exposure and who is the owner/operator of the asset. For example, financing a private investment in solar panels is completely different from investing in an immense hydro power plant. In general, every investor wants reliable technique, assured long term purchase and a committed owner/operator resulting in optimum Levelized Cost of Electricity.

Typically for RES projects, are the large upfront capital needs for project development and low operating/working capital. This does not help in obtaining the required capital against reasonable costs. Guarantees and also grants might help to overcome this.

In general, like with any other capital investment, usually there is private equity (20% to 30%) and the remainder of the sum (70% to 80%) is provided through a bank loan from a commercial or public bank (like World Bank, European Investment Bank) or private institutions, like pension funds and insurance companies. For loans in RES, there are commercial banks that have funds available dedicated for investments in green assets. As they are specialized in these assets and are familiar with the market, it might be easier to get a loan with favourable conditions.

For the equity part, this might be available capital in a company (utility, developer), but for many smaller RES projects, additional funding to raise the required capital is necessary. This could be done by for example crowdfunding or issuing certificates of a loan (participation). This is often used in Cooperatives that have an aim to raise and invest in local RES like solar roofs and wind farms.

For all these project-based investments, reducing risks is crucial to have reasonable conditions of a loan. In general, this means a stable investment climate (government policy around stimulating RES), a long-term certainty on the price of generated electricity and high availability of the assets (means good design and operation). In chapter 5 the types of risk are further elaborated.

3.5.2 Subsidy schemes available

For almost all RES the cost of the generated electricity is higher than the market price of fossil fuel-based generation. It is therefore that in European countries that have the policy to increase the portfolio of RES generation, incentives in the form of subsidy schemes are available. Energy subsidies may be direct cash transfers to producers, consumers, or related bodies, as well as indirect support mechanisms, such as tax exemptions and rebates. They may also include energy conservation subsidies. The development of today's major modern energy industries has all relied on substantial subsidy support.

Most subsidy schemes available are based on (a combination of) following incentives:

- Tax reducing measures (energy tax, real estate tax, income tax)
- Loans with favorable conditions (green loans)
- Fixed feed-in tariff
- Compensation of difference between market price and cost price
- Investment subsidy
- Guaranteed network access
- Favored dispatch of generated RES electricity

Depending on the size of the installation, the way of obtaining the subsidy might differ. Subsidies may be rather easy to apply for when it concerns local (municipality or province) investment-based incentives on residential PV or energy saving measures, or, for professional parties, national tendering schemes where the win-criterium is the lowest applied subsidy per generated kWh over a period of time (e.g. 15 years).

An important factor though for developers and investors is a stable government with a long-term view on support schemes for RES. Like in Germany, where this has contributed to the “Energiewende”. In the Netherlands however, it turned out that there was a changing policy per governmental period. This was not negative for some individual projects (they were granted longer term subsidy) but it did not stimulate a continuity of new initiatives.

A detailed overview of available subsidy schemes and policy throughout Europe can be found on http://www.res-legal.eu/.

3.6 PROCUREMENT PROCESS

3.6.1 Specifications/quality requirements

Starting the procurement process for RES is similar to those of “normal” goods or services. There are normally 7 steps to go through a procurement process:

1. Qualification of suppliers
2. Request for Proposal
3. Additional information
4. Evaluation of proposals
5. Negotiation
6. Selection of supplier
7. Contracting

In this paragraph, considerations are given with respect to criteria/specifications and quality requirements for the selection of suppliers and the installation itself.

For the selection of suppliers, a list of criteria, both soft and hard, must be made in order to select from a long list a number of suppliers that can reasonably be managed. In standard procedures, this number may be between 3 to maximum 5 potential suppliers. The first step could be to approach a number of potential suppliers to verify if they are interested. Then, after having them filled in a qualification form, a reduction in numbers is made. Criteria for this first selection could among others be:

- Experience
- Expertise
- Size and financial health
- Quality standards: ISO 9001, ISO 14001

If a European procurement process is required (depending on the size of project and type of procuring organization), this is also a necessary step to select the potential suppliers, and this evaluation must be well substantiated.

For the technical specifications and requirements, it might be necessary to make use of a specialized engineering firm for larger and riskier projects. In general, a technical specification contains the following elements:

- General description concerning the project

- Scope of supply
- Technical specifications
- Documents that need to be part of the quotation and supply
- Guarantees and quality management

The technical requirements are of course very much depending on the type of RES that is procured. In general, there are RES specific norms and standards, e.g. for windmills and PV panels, for PV- inverters, for biomass and the electrical installation and grid connection. These might be country dependent, hence it is essential to have an overview of the national requirements. National norms and standards are very often based on IEC.

Guarantees are both for the supplied components as well on a system level. The latter could be on e.g. a minimum guaranteed energy yield (wind, solar) and degradation level (solar) or plant availability percentage (wind). For PV inverters a longer guarantee period (e.g. 10 years) can be required. These guarantees are important to have reduced financial risks and provide comfort for a (bankable) business case. After commissioning the asset, an (independent) performance evidence should be part of the process (and contract).

For quality management, additional requirements can be sought at the supplier to have a documented and available project quality program. There could be “hold- and witness points” in the design, manufacturing, assembly, installation and commissioning phase. It could be made possible that independent external quality inspections can take place when the contracting party doesn't have the necessary expertise in-house available. Often this is a requirement of the financing party. After the contractor has reported “installation ready for takeover”, a complete (independent) final test and inspection report must be made and signed from both sides including a “punch-list” for the eventually remaining issues to be solved.

3.6.2 Possibilities for joint procurement

As RES projects, like most other capital investment projects, benefit from larger scales (economy of scale), it is recommended to investigate if a procurement process including investment could be executed jointly with other parties working on similar projects. In that case costs for e.g. project management and engineering could be shared, and suppliers normally offer better prices if they can deliver larger quantities. Some examples for this are:

- Buying solar panels not just for your own house but also jointly with neighbors or whole street.
- Joining a larger collective from a regional or national wide initiative (united consumers).
- As a cooperative, offering a project to the market consisting of several independent available roofs to create an attractive opportunity for suppliers.
- Work together with other cooperatives in selecting some “preferred suppliers” that can benefit from a larger scale and less marketing costs.

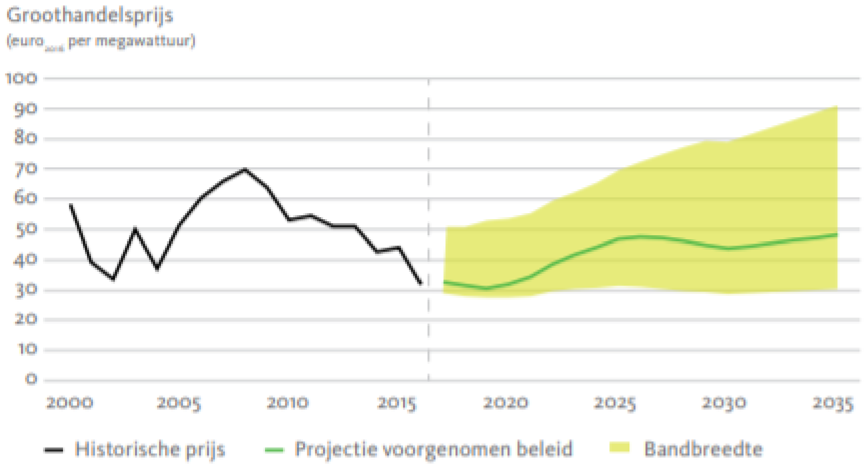
In general, it is essential to have an open view and put an effort in exploring if there are these kinds of possibilities. This could well be part of a cVPP. It will generally have a good chance to pay-out.

4 ELECTRICITY PRICES

In this chapter, the price developments of renewable energy generation and possible scenarios are described that currently arise in the energy transition. Finally, the feasibility of various Renewable Energy Sources, Grid Parity and Technology Readiness Level are explained.

4.1 PRICE DEVELOPMENTS

Price developments in the field of electricity are difficult to predict based on historical trends shown in the graph below. A downward trend in the price of electricity can be observed until 2016, but this trend is not likely to continue according to the Dutch "National Energy Exploration 2017". The given reasons for this are the low fuel prices, a possible change in law and regulations, subsidy schemes, overcapacity and growth of the production of renewable energy generation in the Netherlands and surrounding countries like Germany.



Source: ECN - Nationale energie verkenning (NEV) 2017

To get some guidance in the electricity price developments in the future, a number of scenarios could be used to foresee and hedge the price developments. The following chapter describes a number of possible scenarios, their impact on the electricity prices and other effects such as CO2 reduction and cost savings for the grid operator and (therefore) society.

4.2 SCENARIO THINKING / SENSITIVITY ANALYSIS

Due to the energy transition, the following scenarios are broadly conceivable at this moment:

- Decentralized Renewable energy

- Energy Diversity
- Economical focus
- Stagnant transition

Within these scenarios, numerous determinants are of significant influence, such as:

- Tax on CO2 emissions
- Flexible energy rates, intraday & day-ahead
- Nuclear power plant construction
- subsidy schemes changes
- Changes in law and regulations of the energy market.

Please note that the mentioned scenarios are dependent on economic, social, political/institutional, environmental and technical factors and are time- and region- or country-specific. The following descriptions should, therefore, be considered as examples.

4.2.1 Decentralized Renewable Energy

The scenario “Decentralized Renewable Energy” comprises the following preconditions:

- A society which is locally oriented, with very proactive, enterprising citizens, supported by subsidy schemes.
- Policy focuses on maximal regional self-sufficiency and decentralized techniques.
- Financial incentives for a selected set of developed technologies lead to local applications to a large extent, but are applied in various ways by community or neighborhood.

This scenario could lead to the following impact:

- Energy import is limited so internal, local energy market can flourish
- Major investment task in infrastructure and production resources: Despite the local focus, heavier electricity networks are required at all levels to maintain grid balance and ensure sufficient capacity of energy
- Partial adjustment of the natural gas network to networks for the transport and distribution of hydrogen and heat.
- Both limited energy imports and investments made in the network infrastructure will be likely to cause an increase in electricity prices and network costs.

4.2.2 Energy Diversity

Scenario Energy diversity with the following preconditions:

- Citizens and companies who want to decide for themselves
- No acceptance of targeted government control, energy is an entirely free market
- Fair, transparent, solid and binding generic tools (including CO2 tax)

- The energy transition is an organic change process in small steps.

This scenario could lead to the following impact:

- Few commitments due to deregulation and high personal responsibility. Part of society consciously chooses for sustainable energy
- Many energy sources through market forces provide a wide range of solutions fragmented across the energy system
- Clear and strong generic instruments that focus on CO2 reduction
- Limited adaptation of the natural gas network to networks for transport and distribution of hydrogen and bio syngas, with a major role for green gas
- Carbon Capture and Storage (CCS) is part of the solution
- Large share of variable costs in the total energy system
- The deregulations and described policy tools (as CO2-tax) are likely to increase a boost in renewable electric sources (such as wind & PV), both central as decentral. Together with green gas & CCS to provide heat, this will likely prevent electricity prices from increasing and remaining stable instead.

4.2.3 Economical focus

Scenario Economical focus with the following preconditions:

- Central government which can strongly manage and develop large projects
- The national government directs national energy autonomy through a mix of decentralized, but mainly central energy sources
- Regulation aimed at forced savings on energy use, through the decrease of access to primary fossil energy sources
- Central control by, for example, a further load of gas compared to electricity, addition for electric cars, etc.

This scenario could lead to the following impact:

- Major investment challenge in offshore wind energy and the associated infrastructure and storage systems
- Electrification of large parts of the energy demand
- Heavier electricity networks at all levels
- Partial adjustment of the natural gas network to networks for the transport and distribution of hydrogen
- Many conversion and storage systems: hydrogen electrolysis, gas buffers
- Due to the firm governmental control and governmental investments made in energy production, conversion and distribution, electricity prices could remain stable or increase due to fiscal taxes to finance the investments.

4.2.4 Stagnant transition

Scenario stagnant transition with the following preconditions:

- Focus on international trade; free trade increases prosperity.
- Government strongly focuses on innovative economy based on international biomass and renewable energy flows.
- No acceptance of self-sufficiency on a national level.

This scenario could lead to the following impact:

- International market for sustainable energy raw materials
- Partial adjustment of the natural gas network to networks for the transport and distribution of hydrogen and bio-synthon, in addition to green gas.
- Electrification of transport, industry and low temperature heat (hybrid heat pumps).
- Heavier electricity networks at all levels to facilitate electrification.
- Large share of variable costs in the total energy system.
- In this scenario, electricity prices will likely to be more volatile, as it will depend on international intra-day and day-ahead markets. This could both result in an increase and preservation of electricity prices.

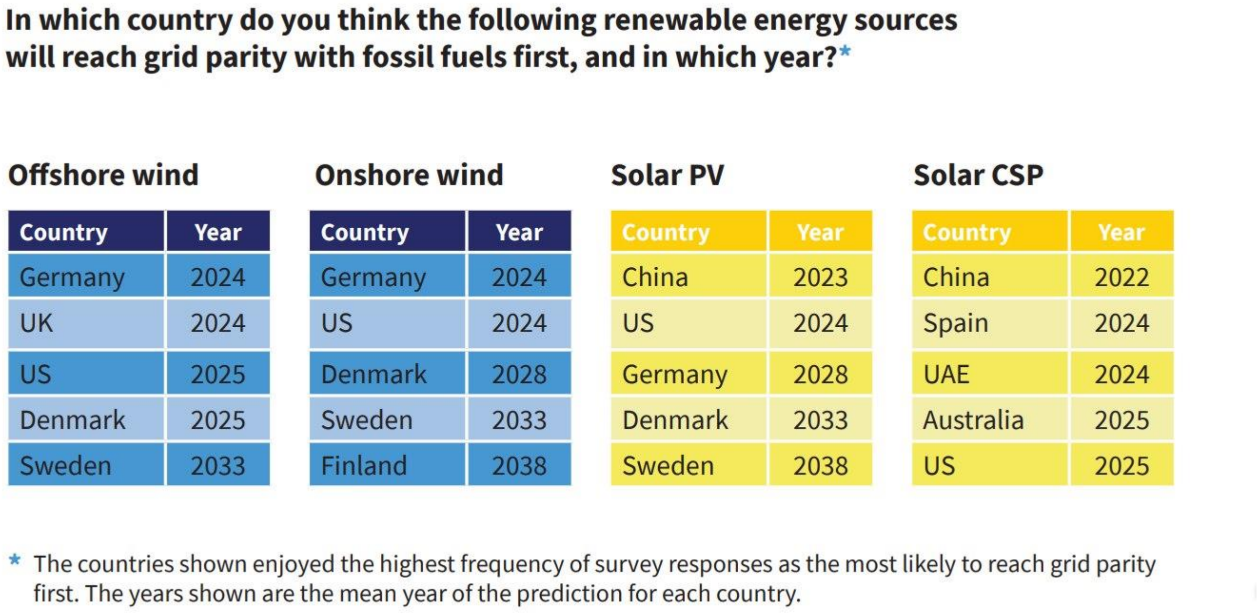
4.3 FEASIBILITY OF TYPES OF RENEWABLE ENERGY SOURCES (RES)

It is expected that the feasibility of various Renewable Energy Sources (RES), as described in chapter 2 of this document, will keep improving. For cVPP applications, onshore wind, PV and biomass are the likely technologies of choice.

In this particular case, an example of the developments of solar energy systems is given. Over the past years, the efficiency of the panels and components have improved, and the prices are dropping. There are also improvements in the design concerning the installation and maintenance so that the overall costs have significantly decreased.

It is expected, that due to these developments (Technology Readiness Level), the feasibility of solar energy systems has greatly improved, improvements in efficiency will continue, as shown in chapter 2.1.1.1 of this document.

Costs of RES will still decrease, but not as fast as the past years. It is therefore that the so-called “grid parity” will still need some time to be reached. Grid parity (or socket parity) occurs when an alternative energy source can generate power at a levelized cost of electricity (LCOE) that is less than or equal to the price of purchasing power from the electricity grid (Wikipedia). In the overview below, the results of a survey among 800 experts and influencers around the world, conducted by Lloyd’s Register for their Technology Radar 2018 show that for wind and solar RES. Overall, most technologies are expected to reach grid parity in their respective countries, by the mid-20-ies, with a few exceptions.



In which country do you think the following renewable energy sources will reach grid parity with fossil fuels first, and in which year?*

Offshore wind

Country	Year
Germany	2024
UK	2024
US	2025
Denmark	2025
Sweden	2033

Onshore wind

Country	Year
Germany	2024
US	2024
Denmark	2028
Sweden	2033
Finland	2038

Solar PV

Country	Year
China	2023
US	2024
Germany	2028
Denmark	2033
Sweden	2038

Solar CSP

Country	Year
China	2022
Spain	2024
UAE	2024
Australia	2025
US	2025

* The countries shown enjoyed the highest frequency of survey responses as the most likely to reach grid parity first. The years shown are the mean year of the prediction for each country.

The conclusion is that RES still needs incentives to be feasible, but this should be still decreasing to zero when the grid parity moment is reached. In 2018 in the Netherlands and Germany, off-shore wind parks were announced for prices which suggest no need for subsidies. In Germany, in early 2019 a 175 PV park was announced and predicted to be economical without subsidies.

However, we have to keep in mind that grid-parity is only looking at the production costs, not at total system costs. If enormous amounts of PV and wind will be added to the system, without proper energy management, the network costs (transmission and distribution) may increase total cost significantly.

5 RISKS

5.1 TYPES OF RISKS

Like all capital investments in assets, there are risks associated with investment in RES. These risks are in many countries still perceived as high (and in many cases they are indeed), which is not helping in financing the huge potential of RES that could be realized based on the enormous cost reduction of many of the RES techniques.

Risk = Probability x Impact.

In literature risks associated with RES are widely described (Ecofys (2008), Justice (2009), Waissbein, et al. (2013), Ragwitz, et al. (2007), IEA-RETD (2010) and EU project Diacore (2016)).

Based on these there can be 9 types of risk categories in RES development identified:

country risk, social acceptance risk, administrative risk, financing risk, technical & management risk, grid access risk, policy design risk, market design & regulatory risk and sudden policy change risk.

The identified risks occur during the different phases of a project (simplified: Planning, Construction, Operation) and can occur in all RES projects.

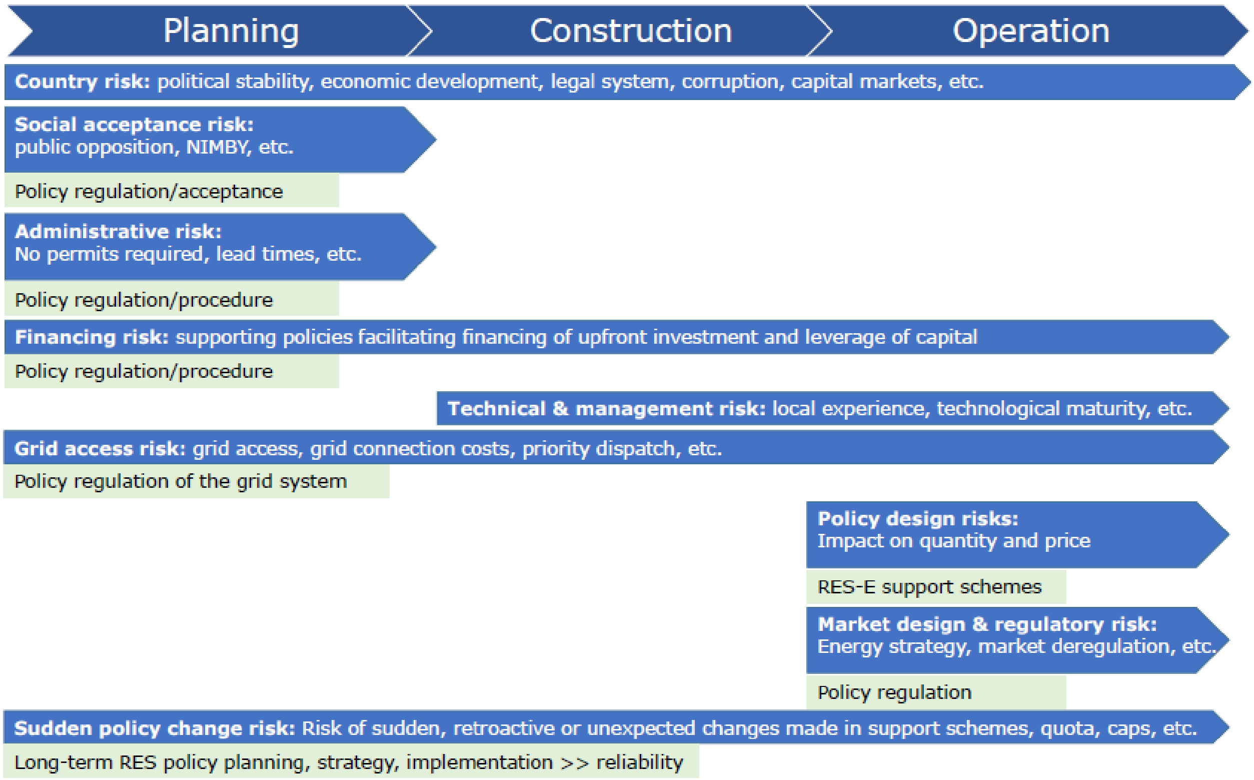


Figure: Risks related to RES project phases (Diacore)

In below table, the risk types are further elaborated:

Risk category	*Description*
Social acceptance risk	Lack of social acceptability of renewable energy investments can cause investment risks. Mostly, this is related to negative impacts on RES installations from NIMBY (Not-In-My-Backyard) effects, but it can also depend on whether local communities' benefit from the project or the lack of awareness on the positive effects of renewable energy. This can be contradictory as well: while local communities could be in favor of the benefits derived from sustainable energy, they are opposed to wind farm installations close to their residence. Moreover, resistance could arise due to increasing costs of RES paid by final consumers. Overall, social acceptance risks are defined as risks of refusal of RES installations by (a part of) civil society.
Administrative risk	In order to construct and operate a RES asset, developers must in most cases obtain several permits. The total time required to obtain these is referred to as administrative lead time. Amon countries in the EU, administrative procedures can vary depending on the complexity and time required to get permits and licences8. For instance, as reported by EWEA (2010) administrative lead times to obtain permits can vary significantly, depending on the country and the project, ranging from 2 to 154 months. Increased lead times could be due to the absence of clear, structured procedures and mechanisms, but also to corruption. Administrative risks are defined as investment risks related to approval needed from the authorities.
Financing risks	The infrastructure required to generate power from renewable sources is capital intensive. For renewable energy, almost all investments take place in the first stage of development. This requires the availability of capital such as equity, but also public financing support such as grants and soft

	loans enabling investments. If this is not available, this can lead to capital scarcity. Main reasons for capital scarcity are under-developed and unhealthy local financial sector or global financial distress. Furthermore, limited experience with renewable energy projects combined with tighter bank regulations (Basel III) could result in the inability of developers to finance their projects. Risks that arise from the scarcity of available capital are called financing risks.
Technical & management risks	Technical & management risks refer to the availability of local knowledge and experience and the maturity of the used technology. Uncertainties arise due to the lack of adequate resource assessment for future potential or the use of new technologies. The probability that a loss will incur due to insufficient local expertise, inability to operate, inadequate maintenance of the plants, lack of suitable industrial presence, and limitation of infrastructure are parameters that are included in technical & management risks.
Grid access risk	To become operational, the RES projects should be connected to the electricity grid. This process includes the procedure to grant grid access, connection, operation and curtailment. The convenience of connecting is influenced by different factors, such as the capacity of the current grid, the possibilities for expansion, planned reinforcements and whether the connection regime allows for RES priority. If this is all well-regulated, new RES projects can be connected to the grid at low risk. However, in the case that the conditions are less convenient and grid connection lead times are long and the connection procedure is unclear, grid access risks can seriously affect the project. Often, these risks are due to an inadequate grid infrastructure for RES, suboptimal grid operation, lack of experience of the operator, and the legal relationship between the grid operator and plant operator.
Policy design risk	Support mechanisms are needed for renewable sources to be competitive, as there is still a cost gap between renewable and conventional energy technologies. Each country individually decides on its support mechanism. Policies aim to mitigate risks mainly related to electricity price and demand. The design characteristics of policy indicate the degree of effectiveness of this risk mitigation. Uncertainties arise when the policy design does not account for all revenue risks, such as wind yield, demand and price fluctuations.
Market design & regulatory risk	Market design & regulatory risks refer to the uncertainty regarding governmental energy strategy and power market deregulation and liberalization. Fair and independent regulation implies that electricity market regulation safeguards that RES-producers have non-discriminatory access to the market. Examples of risk-increasing barriers are legislation hindering participation of independent power producers (IPPs), incomplete unbundling, and a lack of an independent regulatory body.
Sudden policy change risk	Sudden policy change risks refer to risks associated with drastic and sudden changes in the RES strategy and the support scheme itself. In the worst case, this could imply a complete change or abandon of the present RES support scheme or retroactive changes in the RES support scheme. Sudden policy change risks are defined as risks of unexpected, sudden or even retrospective changes to policies or policy design features.
Country risk	Country risks refer to a set of factors that can adversely affect the profits of all investments in a country. These factors include political stability, level of corruption, economic development, legal system and exchange rate fluctuations. Although it constitutes an important risk factor, there is no uniform way to quantify it. Therefore, we use sovereign debt rating to reflect country risks and compare countries with each other.

Table: Overview and description of risk categories (Diacore)

Risks levels influence the willingness of investors financing the project. Therefore, for project developers, it is needed that they are aware of them and prepare mitigating measures upfront to reduce them. Good risk management increases the chance on a successful project in all aspects and for all stakeholders.

5.2 IMPACTS OF RISK

From an investor's point of view, the main goal of investing is to maximise the return. In general, investors strive to minimise risks, but are willing to accept risks if these are compensated with a higher return rate.

Investments and risks are inextricably linked to each other. Investment risks refer to the probability of factors occurring that can influence the return on investment. The probability of these factors occurring and their impact determine the scale of risk. These two aspects form the basis of risk perception. Prior to their decision, investors estimate the factors that can influence their investments. However, not all factors are known upfront, or it might not be possible to estimate their probability. This will add uncertainty to the investment decision. If uncertainty grows, investors will become more reluctant to invest. The second aspect relates to the impact of risks. For some risks, it is quite certain that they will occur, but as long as the impact is not substantial, it will not have a significant effect on the investors. It is therefore the combination of probability/uncertainty and effect/impact that will determine how much risk is perceived by investors.

To estimate whether an investment is financially viable, investors will calculate the Net Present Value (NPV) based on the estimated future income and expenses of the investments. An important factor in this calculation is the Internal Rate of Return (IRR). In order to be profitable, the NPV should be positive. The IRR that is needed to obtain this positive NPV reflects the return investors will receive on their investment. To decide whether the investment is financially interesting, the resulting IRR is compared to a hurdle rate or discount rate. If the IRR exceeds the discount rate, investments are regarded as financially viable. This trade-off between risk and return is the basic framework for financial decision making. Additionally, the size of the losses is an essential aspect in the decision making. The discount rate is determined by the investor upfront and varies depending on the type of investment and the associated risk. A high discount means that investors aim to receiver a high return on their investment to compensate for the risk of investing in the project.

Investors, depending on their risk preferences, will choose to invest in riskier or safer projects. As explained above, investors estimate these risks by setting discount rates. The height of these discount rates is important in the investment decision. With a high discount rate, only projects with a high IRR will be eligible for investments. This increases the costs for attracting capital, and thus the costs for renewable energy projects. If the discount rate is set too high, the chances are that the IRR of renewable energy projects will not meet the discount rate, meaning that there will be no investments at all and renewable energy development will come to a standstill. Understanding how the risk of projects are determined and how they can be influenced is therefore essential for successful financing of RES projects.

6 CONCLUSIONS

In this document, the technical and economical aspects of Renewable Energy Sources (RES) are described. The focus has been put on the likely most favourable RES for applications for the scale of this project, a c-VPP. These are wind energy, solar-PV and biomass.

Conclusions are:

- The techniques have developed rapidly in the past decade and are still improving. Wind and PV are mature enough for Local Energy Communities to invest in. Biomass is feasible but needs extra considerations.
- Prices per kW installed capacity and subsequently per kWh have steadily decreased over the past decade. Wind and biomass are cheapest per kWh but not decreasing much further, while solar PV is more expensive but still on a decreasing curve (though flattening out).
- Trends are mostly in the direction of decreasing production costs for existing technology and less in improving the energy yield technique.
- Operation and maintenance differ very much: solar-PV normally only needs some cleaning, on the other end of the spectrum is biomass. The latter needs process operation and fuel handling and thus skilled workers and in-depth knowledge of the technology.
- Levelized Cost of Electricity (LCOE) approach is the method of choice to compare various electricity generation techniques on the basis of an integral price per kWh. In (especially energy) project development, economies of scale are beneficial to the business case. Joint procurement can be a way to increase scale.
- Pricing of grid connection and grid transportation costs are an integral part of a RES project and should thus be taken into account.
- Future (mid to long term) electricity price developments are important to consider as RES projects normally have long payback with associated risks.
- Procurement of RES must be professional when sizes of the project and related financial requirements increase. Good specifications, vendor selection and quality control are important.
- Risks can be financial, technical, political, social and regulatory and have to be part of the business plan including mitigating actions. Risks of PV and wind are very manageable, due to good subsidy schemes (10-15 years of guaranteed subsidy). Biomass is trickier, as technology, sourcing of fuel and waste management are less predictable. However, biomass has the big advantage of being dispatchable, hence stabilizing the system.
- This all must lead to a sound business case that gives banks enough security to facilitate a loan. Together with the equity (typically 20% to 30%) this is necessary to finance the project.

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