Cost-Efficient and Sustainable Deployment of Renewable Energy Sources towards the 20% Target by 2020, and beyond

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Synthesis Report on Possible Valleys of Opportunity for Cooperation Mechanisms in Europe, Based on Wind, Biomass and Solar Energy Technologies

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PREFACE/ACKNOWLEDGMENTS

This document reports activities and results of Task 2.6 of the Intelligent Energy Europe supported project RES 4 Less. In this report the main outcomes of the analyses carried out in Tasks 2.1 through 2.5 are summarized and discussed. Therefore special thanks go to all the people that contributed in the realization of the aforementioned analyses.

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EXECUTIVE SUMMARY

This document concludes the work carried out within Work Package 2 of the RES 4 Les project with a synthesis of the main results. The aim of WP2 is to identify so called *Valleys of Opportunity* (VoO) for an enhanced deployment of Renewable Energy Sources (RES) across Europe, based on cooperation among Member States (MS). The general expectation is that Valleys of Opportunity will be located in areas where RES resources are more abundant. Specifically, Northern countries could exploit their large wind potential, especially within the North Sea basin. Eastern countries could benefit from the presence of large and to some extent untapped biomass resources. Southern countries could take advantage of the fact that the amount of daily sun-hours is relatively large, making the deployment of Solar-based technologies economically attractive.

In order to establish a preliminary set of *candidate* VoOs that look attractive from an economical perspective, a methodology has been developed to systematically analyze RES surpluses in EU, characterize them in terms of costs and technology composition, and determine which member states could be interested in exploiting them. The analysis has been applied to the renewable electricity (RES-E) sector using ECN model RESolve-E and its satellite model RES4Less.

The results of the modelling exercise provide a starting point towards the identification of realizable VoOs. The subsequent steps in the analysis are:

- Elaborate on the model outcomes focusing on a specific technology and a specific region;
- Conduct a "reality check" on the model outcomes against known actual plans and expected developments, and eventually complement any shortcomings by drawing information from additional sources;
- Narrow down candidate VoOs to more realistic VoOs by considering practical barriers, constraints and restrictions that are not address by the model but are very likely to come into play;
- Identify an interesting case study to bring forward for an in-depth analysis

The main conclusions can be summarized as follows.

<u>Wind energy in North Europe</u>:

There are clear opportunities for cooperation among countries in the North Sea area, based on physical transfer of RES-E from offshore wind. Denmark, Germany and Ireland have been identified as the main candidate VoO Hosts, while Benelux and the UK have been identified as the main Users. When considering practical implementation barriers such as grid constraints and maritime space availability, the role of Germany as one of the main hosts does not look very realistic. On the other hand in the Danish North Sea, suitable sites that could host (surplus) offshore wind developments have been identified in the Horns Rev area. Moreover grid-related barriers appear less severe in the case of Denmark, in particular due to the upcoming *Cobra* connection between Denmark and the Netherlands. Based on these considerations a VoO between Denmark and the Netherlands has been selected as an interesting case study to be further analyzed within Res 4 Less.

<u>Biomass energy in Eastern Europe</u>

The analysis highlights high biomass potentials in Romania, Poland and Czech Republic. Among these Romania stands as the main candidate to host a biomass-based VoO. In Poland and Czech Republic biomass potentials are expected to be used to meet the national target, and therefore no surpluses are foreseen. On the other hand, the Romanian NREAP specifies a rather low share of RES-E from biomass, and therefore a surplus potential can be expected. Possible users of the Romanian surplus are the Benelux countries, Italy and Greece. Among these the Netherlands has been championed, mainly based on the fact that Dutch policy makers already expressed their interest in looking for cooperation opportunities in Eastern Europe, as it has been pointed out during the RES 4 Less stakeholders consultation meetings in 2011. Therefore a biomass VoO between Romania and the Netherlands, based on cooperation mechanisms that do not rely on physical transfer of electricity, will be brought forward for an in-depth case study.

Solar energy in South Europe

The analysis highlights possible surpluses of RES-E from solar technologies, i.e. Photovoltaics (PV) and Concentrated Solar Power (CSP) in France, Germany and Spain. Possible users of these surpluses are the Netherlands, Greece, Poland and the UK. When considering practical barriers related technological developments, administrative issues, policy and grid connection, it appears that the following limitations apply:

- Germany can be ruled out as a major Host Country of PV VoOs
- Physical transfer of electricity from France or Spain to any of the identified User Countries is not realistic
- Specific deployment difficulties may arise, related to local administrative procedures
- Dedicated policy measures and support schemes are needed
- Further cost reductions are needed for scaling up of CSP, and therefore there is a large uncertainty as to the realistic possibilities in 2020

Based on these considerations, and taking into account the leading role of Spain in the development and deployment of concentrated solar power technologies, a CSP-based VoO with Spain as Host country seems to be the most interesting choice for an in-depth analysis. Looking at the possible users, Greece and the Netherlands figure as the main candidates. Due to the current situation of the Greece economy, it has been decided to focus on the Netherlands. The identified VoO will be based on mechanisms that do not rely on physical transfer of electricity (in order to mitigate grid limitations), and will start with a small pilot project in order to mitigate the risks related to the current uncertainties on cost reduction of CSP in the coming decade.

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1. Introduction

This document concludes the work carried out within Work Package 2 (WP2) of the Intelligent Energy Europe (IEE) funded RES 4 Less project. The main aim of WP2 is to identify so called *Valleys of Opportunity* (VoO) for an enhanced deployment of Renewable Energy Sources (RES) across Europe, based on cooperation among Member States (MS).

Countries in Europe have agreed on a set of mandatory national targets for their RES share in 2020 (European Commission, 2009). However RES potentials are distributed unevenly across EU member states. On one end of the spectrum we find countries, such as Sweden or Denmark, that, thanks to their natural resources, can easily meet their 2020 target and even produce a surplus of energy from RES at relatively low costs. On the other end of the spectrum there are countries such as the Netherlands or Luxembourg, where natural resources are scarcer, that will have to resort to deploy very expensive technologies and still struggle to meet their RES obligations. In order to compensate for this unbalance, the RES Directive 2009/28/EC allows for cross-border cooperation between member states based on one of the following mechanisms: (i) statistical transfer, (ii) joint projects, (iii) joint support schemes.

The use of the cooperation mechanisms provides MSs with the flexibility of exploiting local natural resources and trade (virtually or physically) RES energy in order to meet the 2020 targets more cost effectively compared to a situation where each MS is bound to only rely on its own RES potential.

Within this context, in WP2 of the Res 4 Less project (Dalla Longa F, Bole-Rentel T, 2011), the following two definitions have been introduced:

- *surplus potential*: potential for deployment of RES over and above what a country needs to meet its 2020 RES obligations
- *Valley of opportunity*: a fraction of this surplus potential that is readily exploitable (via a suitable cooperation mechanism) because any constraints that it is subject to can reasonably and timely be addressed.

The Work Package has been divided into several Tasks, reflecting the steps taken towards the identification of possible VoOs:

In **Task 2.1** a preliminary assessment of RES surpluses has been made based on the published National Renewable Energy Action Plans (NREAP).

In **Task 2.2** a methodology has been developed to systematically analyze RES surpluses in EU, characterize them with respect to costs and technology composition, and determine a preliminary set of *candidate VoOs* that look interesting from an economical perspective. The analysis has been applied to the renewable electricity (RES-E) sector using ECN model RESolve-E and a satellite model RES4Less.

The aim of the subsequent **Tasks 2.3, 2.4 and 2.5** is 4-folded: (i) Elaborate on the model outcomes focusing on a specific technology and a specific region; (ii) Conduct a "reality check" on the model outcomes against known actual plans and expected developments, and eventually complement any shortcomings by drawing information from additional sources; (iii) Narrow down candidate VoOs to more realistic VoOs by considering practical barriers, constraints and restrictions that are not address by the model but are very likely to come into play; (iv) Identify an interesting case study to bring forward for an in-depth analysis within Work Package 3. Specifically, Task 2.3 focused on Wind potential in North Europe, Task 2.4 focused on Biomass potential in Eastern Europe, and Task 2.5 focused on Solar potential in South Europe.

The present document (**Task 2.6**) concludes the work of WP2 by summarizing and comparing the main findings of Tasks 2.3 through 2.5. The report is organized as follows. First an overview is given of the main outcomes of Tasks 2.1 and 2.2. Then one separate chapter is dedicated to summarizing each of the Tasks 2.3, 2.4 and 2.5. Special emphasis is given to the critical factors that need to be taken into account when aspiring to make the identified VoOs a reality. Finally a comparative assessment is made, and some general conclusions are drawn.

2. Setting the Scene

In this chapter the work carried out within Tasks 2.1 and 2.2 of Work Package 2 of the RES 4 Less project is summarized.

2.1 Insights from NREAPs

In Task 2.1 a preliminary assessment of surpluses has been carried out, based on NREAPs (Beurskens L, Hekkenberg M, Vethman P, 2011). Of the 27 European Member States, 13 countries reported information on an anticipated excess or deficit of renewable energy by 2020. Two countries reported a deficit: Italy and Luxembourg, which combined amounts to 1220 ktoe. Ten countries reported an expected excess: Bulgaria, Denmark, Germany, Greece, Spain, Lithuania, Hungary, Malta, Slovakia and Sweden, totalling 7662 ktoe.

While predicting a surplus, the countries did not specify which technologies are likely to deliver it. Within Task 2.1 the predicted surpluses have been allocated to possible technologies, based on an analysis of RES-E and RES-H cost supply curves. In the case of RES-E, the cost supply curves have been produced using ECN model RESolve-E. In the case of RES-H a variety of sources has been used, as detailed in (Beurskens L, Bole-Rentel T, 2011). The result of the analysis points to *biomass heat* and *renewable energy from heat pumps* as the most promising options in terms of delivering most of the cost-effective surplus that could be developed through cooperation mechanisms to meet Italy and Luxemburg's renewable energy deficits.

Surpluses and deficits declared in the NREAPs give an indication of member states' ambitions and plans with regard to RES developments. In the following chapters we will often go back to NREAPs and use them as a starting point for "reality checks" on the outcomes of the modelling calculations.

2.2 VoO Methodology

In order to systematically analyze and characterize all possible RES-E surpluses in EU, and to produce a set of candidate Valleys of Opportunity, a methodology has been developed, based on which a modeling exercise has been carried out. The methodology consists of the following steps:

- Cost supply curves for each MS in 2010, 2015 and 2020 are produced using the ECN model *RESolve-E.*
- The NREAP targets are plotted against these curves, thereby highlighting eventual surpluses and deficits.
- The satellite model *RES4Less* is then used to compare the cost supply curves pair by pair; the two MSs being compared are considered as *User Country* (buying energy) and *Host Country* (selling energy), respectively.
- A *virtual demand* curve is created for the surplus potential of the Host Country based on the cost supply curve of the User Country.
- A demand-supply analysis is then carried out, yielding four economical indicators that characterize the candidate VoO between the two MSs: *equilibrium price*, *size of the VoO*, *User Country cost savings* and *Host Country gain.*
- Two sets of analyses are carried out:
    - A *pair-wise analysis* for each and every possible pair of MSs, yielding a 28x28x4 matrix of final results per each year considered; this can be further broken down into the 14 different technologies considered. The analysis is repeated for two scenarios: one in which cooperation between MSs starts in 2013 and continues until 2020 and a second one, in which cooperation is only assumed to take place in 2020.
    - A *global analysis*, for which EU-wide RES-E demand and supply curves are constructed, and an optimal allocation of surpluses is analyzed, also for both scenarios regarding cooperation timing.

A special scenario of RESolve-E has been run in order to produce the cost supply curves used in the analysis. In this scenario all country-specific policy and support schemes have been "switched off" in 2013, i.e. only the pure costs of technology (levelized production costs) are included in the cost supply curves. This approach brings several advantages, such as: (i) a clear view on technology costs in each MS, and thereby (ii) a clear view on where the relatively cheap surpluses are; (iii) the possibility for cooperating countries to come up with specific policies (joint support schemes) to promote the cooperation itself; (iv) a clear separation between energy costs and financing, giving cooperating countries the opportunity to properly share the costs of support schemes.

As mentioned above, the analysis yields four economical indicators that characterize candidate VoOs: *equilibrium price, size of the VoO, User Country cost savings* and *Host Country gain*. It is important to realize that these indicators only make sense when used to compare VoOs to one another in the context of this analysis, and should not be interpreted as absolute numbers. Actual VoO sizes will ultimately depend on the specific barriers that come into play. Similarly, actual trading prices, cost savings and profits will ultimately depend on the specific conditions of the chosen cooperation mechanism, and in particular on the support schemes in place.

2.3 Main modelling results

The results clearly highlight opportunities for surpluses from wind energy in the North of Europe (Sweden, Denmark, Finland, Germany) and from solar energy in the South-West of Europe (CSP in Spain and PV in France). The analysis shows that (a part of) these surpluses could be allocated via a suitable cooperation mechanism to countries such as Netherlands, Belgium, Portugal, Greece and Italy, which would mainly be giving up part of their wind offshore developments. This would bring economical advantages for both the User and the Host countries.

Biomass seems to play a relatively small role in the VoO analysis. This can be due to a combination of several factors: (i) electricity from certain biomass technologies is relatively cheap and therefore often results as *non-surplus* option in the cost-supply curves, (ii) biomass is an abundant resource in Eastern European countries, however only few of these countries are predicted to have a surplus, and (iii) biomass could play a big role in the RES-Heating sector which is presently not included in the analysis; (iv) RESolve-E input data currently underestimate biomass potentials[1].

In addition, the following conclusions can be drawn from the analysis:

- Timing matters: starting cooperation earlier means exploiting candidate VoO to a larger extent; however, aspiring Host countries must be careful not to sell off their cheaper potential too soon before they ensure they are on track to reaching their own targets.
- Timing affects not only the amount of RES potential developed, but also the relative importance of technologies developed under cooperation mechanisms. Most notably, offshore wind becomes less important the longer the start of cooperation is delayed.
- Choice of cooperation partners matters: in the case of bilateral cooperation, there is a very wide range of possible benefits for most User and Host countries, which depend on who they choose to cooperate with. The choice of cooperation partners matters not only for VoO size and equilibrium price, but also for the portfolio of technologies that would be developed in Host countries and given up in User countries; this needs to be aligned with the MSs' industrial policy.
- Benefits from cooperation (gains and savings) would be more evenly spread out under bilateral cooperation agreements than they would be under an EU-wide cooperation/trading scheme; in the case of the latter, only few large host countries benefit disproportionately, while many other countries with surplus potential just above the equilibrium price could be insufficiently motivated to offer it for trade. This means that while an EU-wide trading mechanism would achieve the lowest possible cumulative costs for reaching the total EU target, it would also make it

[1] At the time of writing this report an assessment of the model input data is being carried out in order to clarify this point.

uninteresting for a number of MSs to act as host countries and further develop their RES-E potentials for trade, with Spain being the most notable example of the latter.

- On the other hand, an EU-wide cooperation mechanisms could offer opportunities that would be more difficult to achieve based on bilateral cooperation (mainly due to administration costs), especially for the case of large User countries, which would then be able to meet their deficit by buying small surpluses from several countries rather than buying a large amount of RES-E from a single Host.

As an example of the model outcomes, in Fig. 2.1 a graph summarizing the results of the *global analysis* in 2020 is presented. For the set of Host Countries the bars represent the amount of Renewable Electricity that can be sold via cooperation mechanisms, broken down into the different technology components. For the set of User Countries the bars represent the amount of Renewable Electricity that should be given up because too expensive, broken down into the different technology components. The category *'Deficit'* has been added to take into account the predicted gaps between certain countries and their targets. The results highlight several cooperation opportunities; for an in-depth discussion the user is referred to (Dalla Longa F, Bole-Rentel T, 2011). Here it is interesting to notice that based on these results

- wind offshore in France, Germany, Denmark and Ireland is expected to be more economical than in Belgium, Greece, Poland and the Netherlands;
- biomass is expected to play a relatively minor role;
- CSP in Spain is expected to be too expensive to be traded via cooperation mechanisms.

In the following chapters these projections will be revised and analyzed in greater detail, also taking into account the critical factors that come into play.

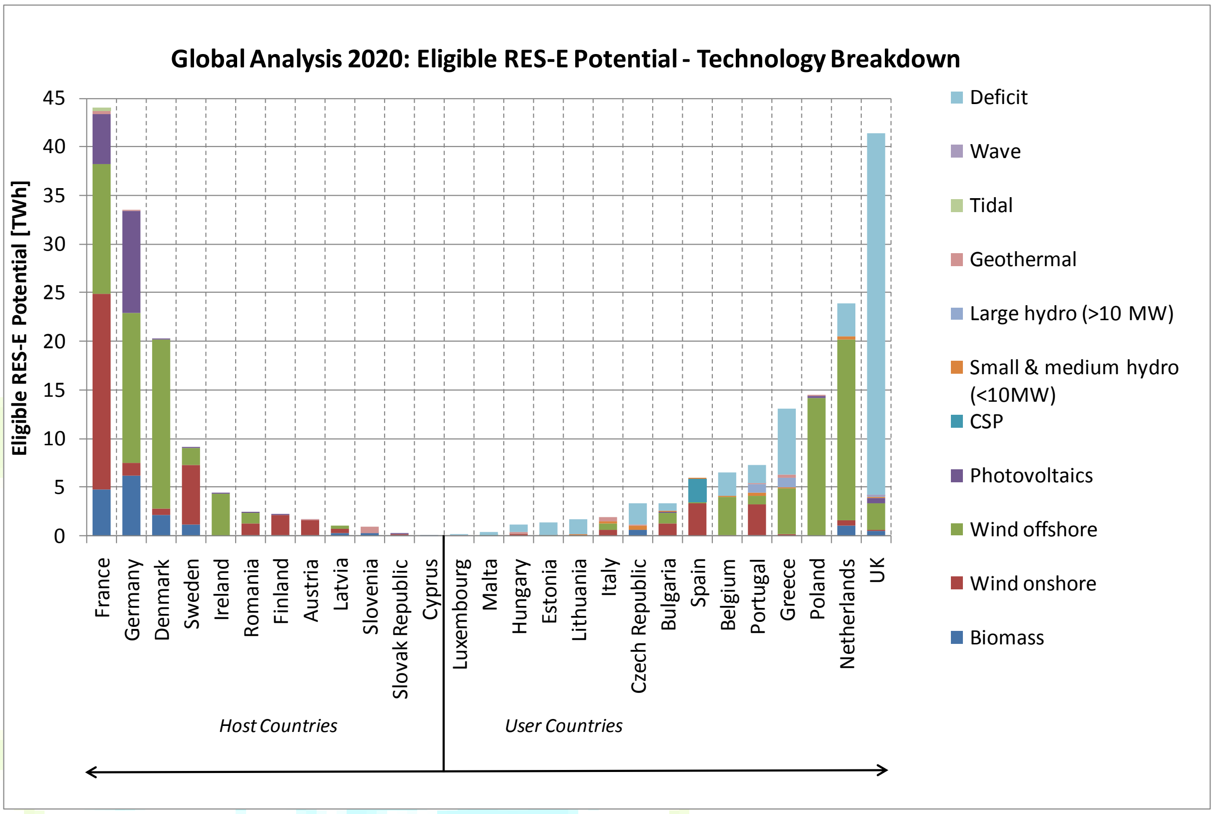

Figure 2.1 *Trading of RES-E in the Global EU27 market in 2020*

2.4 Expected valleys of opportunity

When assessing possible Valleys of Opportunity, it is reasonable to expect that their location reflect the distribution of RES resources across Europe. This is graphically represented in Fig. 2.1. Northern countries can exploit their large wind potential, especially within the North Sea basin. Eastern countries can benefit from the presence of large and to some extent untapped biomass resources. Southern countries can take advantage of the fact that the amount of daily sun-hours is relatively large, making the deployment of Solar-based technologies economically attractive.

The model outcomes are generally in line with these expectations, the main exception being the absence of sizable biomass surpluses in Eastern Europe.

In the following chapters the expectations of Fig. 2.2 are analyzed in greater detail, building on the modelling results and complementing them with additional sources, with the aim of identifying feasible VoOs for Wind, Biomass and Solar technologies.

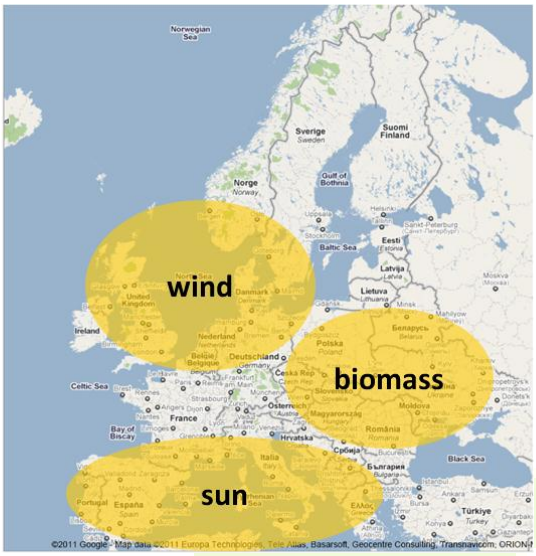

Figure 2.2 *Expected VoOs*

2.5 Discussion

When assessing possible VoOs in EU, the modelling approach summarized in this section offers a sound theoretical basis to start off with. The next chapters will move from the abstraction of a modelling exercise towards a practically realizable set of VoOs, and will therefore conduct a reality-check on the model outcomes, and complement the results with insights from other sources.

Here, some general remarks on the interpretation of the modelling results and the limitations of the approach are summarized:

- RESolve-E is calibrated to reproduce NREAP forecasts within 15%, when all current national policies are included in the model and continued up to 2020. As already mentioned above, for the purposes of RES 4 Less a special scenario has been implemented, where all national polices have been "switched off" in 2013. Obviously, this scenario does not reproduce the NREAP forecasts, as these are closely interlinked with the support schemes chosen by the different MS. In most cases this leads to an overestimation of the predicted surplus potential; for example in the case of Wind Offshore surplus in France, Denmark and Germany. Therefore steps are taken subsequently to narrow down the surpluses. For example, in the assessment of a possible VoO between Denmark and the Netherlands based on offshore wind, the initial Danish surplus of 30.9 TWh is narrowed down to 19.7 TWh after considering the actual demand from the Netherlands. This can then be further reduced when additional constraints, such as for example limitation related to maritime space planning or grid connection capacity, are taken into account, as described in Chapter 3.

- In some cases the model results underestimate the resources of certain MSs compared to what the NREAPs project. This is relevant for the current analysis in two cases, which are further elaborated in the next chapters:
  - The size of the UK deficit seems overestimated
  - Biomass does not show as one of the main resources in Eastern Europe
- Norway has been included in the modeling exercise even though no NREAP has been published for this country, and therefore no NREAP RES-E target was available. The initial idea was to include a 2020 RES-E target based on Norway's current plans. However such a target has not yet been identified, and therefore model predictions involving Norway have not been considered further in the analysis.

- The modelling exercise only includes the RES-E sector. However heat from renewable energy sources (RES-H) is becoming more and more important and is expected to become a sizable part of the RES use in the coming years (Beurskens L, Hekkenberg M, Vethman P, 2011). Therefore it is reasonable to expect that RES-H may also play a role when assessing possible cross-border cooperation, especially within biomass-related VoOs. Cost supply curves for the RES-H sector could be produced in the near future with the ECN RESolve-H model, which is currently in the calibration stage. The exclusion of renewable heat options from the analysis understates the importance of biomass-rich Eastern European countries as possible Hosts.

- The current analysis can be described as static, as it does not take into account how the cost supply curves would evolve after a certain VoO is exploited, i.e. the cost supply curves are an exogenous input to the RES4Less model. As an interesting extension, one could introduce some elements of dynamicity in the analysis. However this is outside the scope of the current modelling work.

These considerations make it clear that the model outcomes presented in Task 2.2 and herewith summarized should not be interpreted as absolute values, but rather as a starting point towards the identification of realizable VoOs.

3. Offshore wind opportunities in North Europe

In this chapter the work carried out within Work Package 2, Task 2.3, of the Res 4 Less project is summarized. The role of wind energy in North Europe is explored, and physical wind offshore Valleys of Opportunity among MSs bordering the North Sea are assessed. A VoO having the Netherlands as User Country and Denmark as Host Country is identified as an interesting and relevant case study to be further analyzed in RES 4 Less WP3.

3.1 Overview of main model outcomes

Model results indicate that wind energy accounts for 69% of the total identified surplus in EU in 2020. Offshore wind alone accounts for 45% of the total EU surplus in 2020, corresponding to 121.8 TWh. The fact that wind technologies take up a large share of the projected surpluses is not surprising, since these options are typically found on the expensive side of the national cost supply curves and hence are likely to appear beyond the national target. However, as it will be clear in the next section, when comparing the projected surpluses with actual development plans, it appears that the model typically tends to overestimate wind potentials. This is not a problem, because the projections are meant to be a starting point for further analysis, and a reality check is carried out on the model outcomes.

Focusing on offshore wind, the main player according to the model outcomes are France, Denmark, Sweden, Germany and Ireland. Their projected surpluses are summarized in Table 3.1.

Table 3.1: *Offshore wind surplus potential in France, Denmark, Sweden, Germany and Ireland (Jacobsen H K, Pade Hansen L, Bauknecht D, Heinemann C, 2011)*

	Offshore wind surplus potential [TWh]	
	2015	**2020**
France	3.2	39.5
Denmark	14.9	30.9
Sweden	6.2	17.2
Germany	0.0	15.7
Ireland	4.6	8.1

Focusing on 2020, the main users of these surpluses are expected to be Belgium, Greece, the Netherlands, Poland and the UK. The corresponding candidate VoOs are summarized in Table 3.2[2].

Table 3.2: *Size of largest wind offshore candidate VoOs in 2020 (Dalla Longa F, Bole-Rentel T, 2011)*

		User Country				
	Host Country	Belgium	Greece	Netherlands	Poland	UK
Wind offshore VoOs [TWh]	France			0.3	0.2	7.7
	Denmark	6.0	11.2	19.7	13.0	30.8
	Sweden		1.8	3.9	1.8	
	Germany	3.5	9.3	13.6	9.2	15.7
	Ireland	4.4	8.1	7.0	6.7	

[2] It is important to realize that the candidate VoOs in Table 3.1 are *mutually exclusive*, i.e. the model does not take into account the possibility of allocating a Host Country's surplus to multiple User Countries. This means that in case one of the predicted VoOs is really exploited, the others cease to exist as such. For example, if the candidate VoO of 30.8 TWh between Denmark and the UK should be exploited, this would practically exhaust the whole of Denmark's offshore wind surplus, and therefore all the other candidate VoOs (i.e. with Belgium, Greece, the Netherlands and Poland) would no longer exists.

This overview already suggest a lively and interesting scene, presenting many competing opportunities for offshore wind VoOs. However, as anticipated above, before jumping to conclusions a reality check should be carried out on the model outcomes.

First, Table 3.2 shows that VoOs involving France or Sweden as Host Countries are rather small compared to the rest. Therefore these two countries can be ruled out from the set of attractive hosts of offshore wind VoOs. This choice is also supported by the fact that the relatively large offshore surpluses in France and Sweden expected by the model are not in line with the concrete plans for offshore development in these two countries.

Second, it should be noticed that the model does not project a VoO between Ireland (as host) and the UK (as user), while on the other hand it is known that joint offshore projects between UK and Ireland are currently being discussed. The fact that the model “misses” this important candidate VoO can be attributed to the combined effect of several factors. Namely, (i) the model overestimates the RES deficit for the UK, and (ii) the *pair-wise analysis* (from which the results in Table 3.2 are produced) does not predict a VoO between two countries if the surplus potential of the Host is not enough to cover the whole deficit of the User (which is the case for the pair Ireland - UK). However, it should be mentioned that an offshore wind VoO of about 4 TWh between Ireland and the UK is fully in agreement with the results of the *global analysis*, as it can be seen in Fig. 2.1. Therefore, in this case the *global analysis* offers a more realistic picture. However, due to the uncertainty in the model projections with regards to the UK, this VoO will not be selected for further analysis.

Given these observations, the most promising candidate VoOs involve Denmark and Germany as Host Countries and the Netherlands as User Country. Here specific limitations come into play, as we will see in the next section.

Figure 3.1 offers a visual representation of the main possible fluxes of RES-E from (physical transfer of) offshore wind in the North Sea area that have been discussed in this chapter.

Figure 3.1 *Main possible fluxes of RES-E from offshore wind (physical transfer) in the North Sea area*

3.2 Practical limitations

In Task 2.3 the main barriers and constraints that one has to face when trying to realize the candidate VoOs which were identified in the model analysis have been qualitatively analyzed.

First of all, when comparing model outcomes with current national plans, it appears that:

- the presence of a wind offshore surplus in Denmark is in line with the current expectations
- the presence of a wind offshore surplus in Germany is not in line with current expectations, given that problems related to financing, grid connection and transport of electricity make even the basic national target of 10 GW offshore capacity seem too ambitious.

Moreover the following barriers can be identified:

<u>Technology related barriers</u>

From a technological perspective, the main barriers to offshore wind deployment in the North Sea are related to maritime space planning issues. In general, the costs of offshore wind installations increase with water depth and distance from shore. Therefore the most economically viable options (shallow waters, close to shore) are often competing for the use of maritime space with activities such as shipping, fishing, nature conservation and sand extraction, just to name a few. In the case of Germany, available areas for additional offshore parks above the currently authorized installations seem to be very limited. For Denmark the situation appears more positive, as part of the Danish offshore wind surplus could be accommodated in the Horns Rev area.

<u>Grid related barriers</u>

The feasibility of an offshore wind VoO in the North Sea based on physical transfer of electricity, ultimately depends on the presence and capacity of interconnections. From this point of view, the installation of the Cobra cable connecting Denmark and the Netherlands, scheduled for 2016, supports the picture of physical RES-E trade between the two countries.

<u>Conclusion</u>

In summary, it can be concluded that the role of Germany as a possible Host of offshore wind VoOs is not realistic. On the other hand, an offshore wind VoO between Denmark and the Netherlands, based on physical RES-E transfer, is in line with current developments. Therefore, this case will be further analyzed in Work Package 3 of the RES 4 Less project.

4. Biomass opportunities in Eastern Europe

In this chapter the work carried out within Work Package 2, Task 2.4, of the Res 4 Less project is summarized. The role of biomass-based electricity and heat in Central and Eastern Europe (CEE) is explored, and possible Valleys of Opportunity are assessed. A VoO having the Netherlands as User Country and Romania as Host Country is identified as an interesting and relevant case study to be further analyzed in RES 4 Less WP3.

4.1 Overview of main model outcomes

As already pointed out in chapter 2, current model outcomes do not support the expected large potentials for biomass-based energy production in Central and Eastern Europe (CEE). This is mainly due to a combination of (i) having considered too low initial raw-biomass potentials within RESolve-E, and (ii) the fact that the RES-H sector has not been included in the analysis.

For this reason, within Task 2.4 a variety of sources have been consulted in order to come up with a realistic assessment of biomass potentials in the CEE area. This has proven a challenging exercise, mainly due to the large variety of different approaches and definitions of potentials found in the sources. For sake of simplicity, in the present document we only report on the most relevant conclusions; the interested reader is referred to (Tantareanu C, Badi L, ten Donkelaar M, Harnych J, 2012) for a more detailed discussion.

The EU member states considered in the analysis are Romania, Poland, Czech Republic, Hungary, Bulgaria and Slovakia. Here only the first three countries will be considered, as they represent the most interesting cases, due to their large biomass resources coming from the presence of extensive agricultural and forestry land. According to NREAPs, both Poland and Czech Republic intend to produce a significant part of their RES-E from biomass in 2020 (44% and 53% respectively). On the contrary in the Romanian NREAP the share of RES-E from biomass is predicted to be only 9% in 2020, even if the resources are definitely comparable to those of the other two countries. This already suggests that a large potential for (surplus) RES-E production from biomass may exist in Romania.

The realistic biomass potentials for Romania, Poland and Czech Republic in 2020, determined within Task 2.4, are reported in Table 4.1, expressed in primary energy units. The main sources of these potentials are forestry, agricultural waste, dedicated energy crops and biogas. In assessing what can be considered a "realistic" potential, limiting factors such as for example land use (in the case of agriculture and energy crops) and accessibility (in the case of forestry), have been taken into account. However, due to the approximate nature of the approach, the figures reported in Table 4.1 should be considered *order of magnitude* estimates[3].

Table 4.1: *Realistic biomass potentials estimated in (Tantareanu C, Badi L, ten Donkelaar M, Harnych J, 2012), expressed in primary energy units*

	Estimated biomass realistic potential in 2020	
	[PJ]	**[TWh]**
Romania	261	73
Poland	600	167
Czech Republic	175	49

[3] Based on the thorough and systematic study on biomass potentials carried out within the IEE project Biomass Futures, a new run of the RESolve-E model is planned for the first half of 2012. The results are expected to be in line with the estimates of Table 4.1, and will provide a more systematic assessment of biomass (surplus) potentials in the rest of Europe.

Besides the aforementioned EU member states, the analysis has also been extended to include Ukraine and Republic of Moldova as possible hosts of biomass VoOs. Due to their large biomass resources, mainly from agricultural waste, both countries could be considered as suppliers of additional biomass resources for projects developed in Poland or Romania. However actual possibilities for both countries to export a higher value product, i.e. biomass-based RES-E or RES-H, within a VoO in the spirit of the RES 4 Less project seem limited.

4.2 Practical limitations

In Poland it can be expected that biomass resources will mainly be used in order to meet the national 2020 RES-E target, as possibilities of exploiting other resources are limited (for example grid restrictions largely reduce the potential for wind offshore). Similar considerations apply to Czech Republic, where current trends indicate that RES technologies that could make a significant impact such as hydro and wind are not expected to grow significantly. Therefore, despite the relatively large potentials reported in Table 4.1, Poland and Czech Republic do not appear as realistic candidates to host biomass-based VoOs.

The situation is quite different for Romania, where, as already mentioned, the low share of RES-E form biomass reported in the NREAP leaves room for potentially large deployment of biomass resources in the electricity sector above the national target. Therefore, in the following description of possible barriers to the implementation of biomass-based VoOs, the focus is primarily on Romania.

Technology related barriers

From a technological perspective the main barriers to the deployment of biomass-based energy generation are related to allocation of resources (i.e. competition with other biomass uses e.g. food, chemical products, etc.) and land availability. Another limitation comes from the competition of different biomass uses within the energy sector: often the same resources can be used for biofuels production, for heat generation and for electricity generation. It is not an easy task to allocate biomass resources in an optimal manner. In general the costs of producing heat from biomass are lower than those to produce electricity from biomass, therefore direct heating seems to face a more favorable economic situation. However, the analysis conducted in Task 2.4 concluded that in Romania specific conditions exist to secure a relevant share of biomass to electricity production. Namely, biomass demand for direct heating is not expected to increase significantly in the medium term, due to the gradual introduction of more efficient boilers to replace traditional stoves in households. This, in turn, leaves a sizable part of the estimated biomass potential to electricity production through combined heat and power (CHP) plants.

Grid related barriers

Possible User countries for the Romanian biomass surplus can be identified in the Netherlands, Belgium, Italy and Greece (as these countries also result as possible users for most other RES surpluses in the VoO analysis of Task 2.2). Due to the large distance between any of these Users and Romania, physical transfer of biomass-generated RES-E is not an option. Therefore cooperation schemes should avoid mechanisms that rely on physical transfer of electricity.

Conclusion

Summarizing, the analysis conducted in Task 2.4 highlights realistic opportunities for biomass-based VoOs, involving CHP technologies, with Romania as a host country. Fig. 2.1 offers a visual representation of the main possible fluxes of RES-E from Romanian biomass. Among the possible user countries, the Netherlands has been championed, mainly based on the fact that Dutch policy makers already expressed their interest in looking for cooperation opportunities in Eastern Europe, as it has been pointed out during the RES4 Less stakeholders consultation meetings in 2011. Therefore a biomass VoO between Romania and the Netherlands, based on cooperation mechanisms that do not rely on physical transfer of electricity, will be brought forward to Work Package 3 for an in-depth case study.

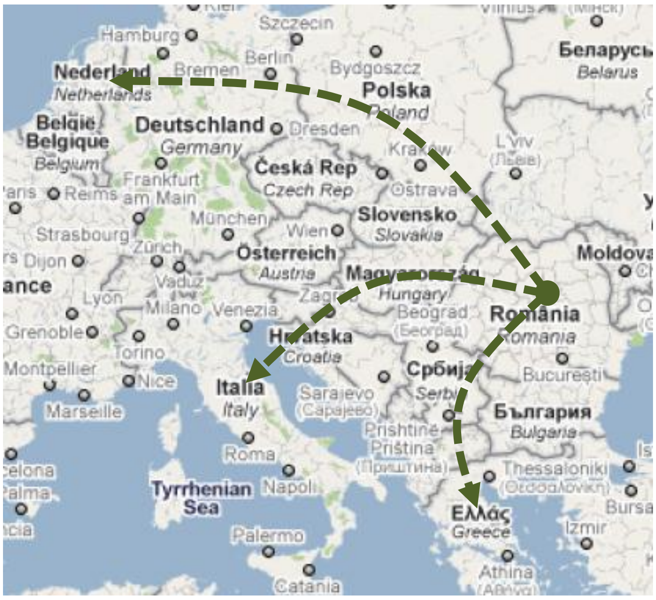

Figure 4.1 *Main possible fluxes of RES-E from Romanian biomass identified in the analysis. Dashed lines are used to indicate that cooperation should not rely on physical transfer.*

5. Solar opportunities in South Europe

In this chapter the work carried out within Work Package 2, Task 2.5, of the Res 4 Less project is summarized. The role of solar energy in South Europe is explored, and possible Valleys of Opportunity are assessed. Because of the widespread use of PV in Germany, Germany is also included in the analysis. A VoO having the Netherlands as User Country and Spain as Host Country, based on Concentrated Solar Power (CSP) is identified as an interesting and relevant case study to be further analyzed in RES 4 Less WP3.

5.1 Overview of main model outcomes

Model results indicate that solar surplus is expected to increase over time, going from 11% of total EU surplus in 2015 to 22% of EU surplus in 2020. In both cases, half of it would come from PV and the other half from CSP. From a technology perspective, PV is more cost competitive than CSP, and it is expected to reach higher cost reductions due to learning effects.

The model identifies Spain, France and Germany as the main countries presenting a surplus potential from solar energy. As summarized in Table 5.1, in 2015 PV surplus is mostly originated in Spain and France. In 2020 Spain no longer presents a PV surplus: this indicates that in practice the possibilities of Spain hosting a PV VoO are very limited, as in the long term this technology will be mainly used to meet the national target. On the other hand, PV surplus in 2020 in France grows of a factor of 5, and Germany also appears as a potentially big player. As for CSP, Spain stands as the leading country both in 2015 and 2020.

Table 5.1: *Solar surplus potential in France, Germany and Spain (Dalla Longa F, Bole-Rentel T, 2011)*

	Photovoltaics [TWh]		**CSP [TWh]**	
	2015	**2020**	**2015**	**2020**
France	1.1	5.1	0.0	0.0
Germany	0.0	12.3	0.0	0.0
Spain	3.8	0.0	7.6	17.6

Focusing mainly on 2020, the VoO analysis conducted within Task 2.2 identifies UK, the Netherlands, Greece and Poland as the main candidate Users of both PV and CSP surpluses. The predicted sizes of the corresponding candidate VoOs are shown in Table 5.2[4].

Table 5.2: Size of *largest solar candidate VoOs in 2020 (Dalla Longa F, Bole-Rentel T, 2011)*

		User Country			
	Host Country	Greece	Netherlands	Poland	UK
Photovoltaics VoOs [Twh]	France	3.5	5.1	4.4	5.1
	Germany	3.2	6.4	3.2	10.5
	Spain	0.0	0.0	0.0	0.0
CSP VoOs [TWh]	Spain	9.4	4.7	4.7	0.0

[4] When looking at Table 5.2 it is important to realize that the predicted VoOs are *mutually exclusive*, i.e. the model does not take into account the possibility of allocating a Host Country's surplus to multiple User Countries. This means that in case one of the predicted VoOs is really exploited, the others cease to exist as such. For example, if the candidate PV VoO of 5.14 TWh between France and the UK should be exploited, this would exhaust the whole of France's PV surplus, and therefore all the other candidate VoOs (i.e. with Greece, the Netherlands and Poland) would no longer exists.

5.2 Practical limitations

In (Santamaría M, Caldés N, Rodríguez I, 2012) the main barriers and constraints that one has to face when trying to make the predicted candidate VoOs a reality have been qualitatively analyzed.

Technology related barriers

From a technological perspective, PV is a much more mature technology than CSP, which is relatively new on the market. Therefore the difficulties faced by these two technologies are rather different. Focusing again on 2020, the main barriers for PV deployment in France and Germany seem to be related to administrative procedures (e.g. to building permits, site selection, grid connection), and to the eligibility for support schemes. The main consequences of these hurdles are planning issues and possible delays in project execution.

For CSP, instead, the main challenge is to reach a significant cost reduction. This is expected to come on one hand from technological developments (e.g. new storage materials, more efficient air-based cooling systems), and on the other hand from learning effects and economies of scale. The main consequence of this challenge is an uncertainty as to the realistic development potential of CSP in 2020 and beyond.

Policy related barriers

Another set of limitations comes from the role of support policies in the deployment of solar technologies. Large solar surpluses can be expected in South Europe due to the relatively high number of daily sun-hours in the southern regions, that can make investments in solar technologies more attractive than elsewhere. This argument can be applied to the case for Spain and (South) France. On the other hand, the argument does not hold for Germany, where the natural solar resource is limited. Here, large deployment of PV seems to be mostly related to the favorable feed-in tariff support scheme currently in place. In this respect the role of Germany as a major Host country for PV VoOs can be questioned, and will not be considered further.

Grid related barriers

When assessing possible cross-border physical transfer of energy, grid constraints have to be considered. France is well connected to the rest of Europe, however the capacity of existing interconnections is limited. The Iberian Peninsula is rather isolated from the rest of Europe. The currently operating interconnections between France and Spain are often congested. In this context transfer of electricity from France or Spain to any of the identified User Countries in Europe seems unrealistic; therefore possible cooperation mechanisms based on Solar technologies should concentrate on schemes that do not rely physical transfer.

Conclusion

In summary, after considering (some of) the main foreseeable barriers to the deployment and the cross-border trade of solar-based electricity, one can conclude that:

- Germany can be ruled out as a major Host Country of PV VoOs
- Physical transfer of electricity from France or Spain to any of the identified User Countries is not realistic
- Specific deployment difficulties may arise, related to local administrative procedures
- Dedicated policy measures and support schemes are needed
- Further cost reductions are needed for scaling up of CSP, and therefore there is a large uncertainty as to the realistic possibilities in 2020

These observations effectively narrow down the potential for solar Valleys of Opportunity (although it is difficult to quantify precisely to what extent), and highlight a set of specific challenges:

- On the supply side, a strong motivation of the Host country to become a leader in (one of the) solar technologies is needed. In this case the Host country should be able to overcome the administrative hurdles by providing a platform to facilitate the deployment of Solar technologies. In this respect Spain presents itself as the preferred candidate, as it is taking the leadership in EU on CSP development and deployment.
- A solar VoO should rely on mechanisms different from physical transfer. Statistical transfer is an obvious candidate, but more innovative schemes based joint developments should also be considered. In this case the main challenges would involve:
  - how to share costs and benefits between host and user
  - come up with a suitable policy framework
- Due to the uncertainty on the cost reduction achievable on CSP by 2020, countries participating in a CSP-based VoO should be willing to start with a small pilot project, and update their strategy depending on the actual developments.

Based on these considerations, a CSP-based VoO with Spain as Host country seems to be the most interesting choice for an in-depth analysis. Looking at the possible users, Greece and the Netherlands figure as the main candidates, as can be seen in Table 5.2. Due to the current situation of the Greece economy, it has been decided to focus on the Netherlands. Therefore an interesting case-study involving a CSP-based VoO between Spain and the Netherlands has been identified, and will be analyzed in Work Package 3 of the RES 4 Less project.

A visual representation of the CSP-based RES-E fluxes identified in this chapter is presented in Fig. 3.1.

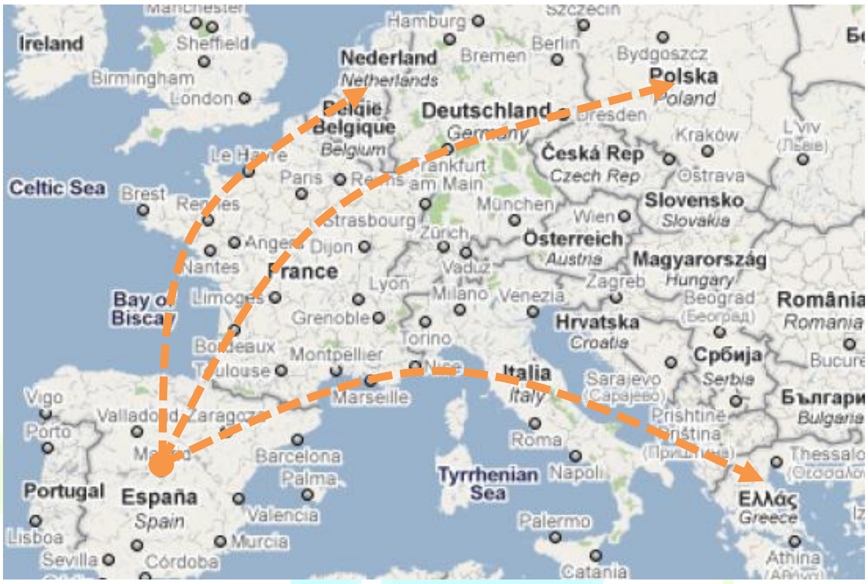

Figure 5.1 *Main possible RES-E fluxes from CSP in Spain discussed in the text. Dashed lines are used to indicate that cooperation should not rely on physical transfer.*

6. Conclusions

In this document the main findings of Work Package 2 of the RES 4 Les project are summarized and discussed. The main aim of WP2 is to identify so called *Valleys of Opportunity* (VoO) for an enhanced deployment of Renewable Energy Sources (RES) across Europe, based on cooperation among Member States (MS). The general expectation is that Valleys of Opportunity will be located in areas where RES resources are more abundant. Specifically, Northern countries could exploit their large wind potential, especially within the North Sea basin. Eastern countries could benefit from the presence of large and to some extent untapped biomass resources. Southern countries could take advantage of the fact that the amount of daily sun-hours is relatively large, making the deployment of Solar-based technologies economically attractive.

The main conclusions of the analysis can be summarized as follows.

Wind energy in North Europe:

There are clear opportunities for cooperation among countries in the North Sea area, based on physical transfer of RES-E from offshore wind. Denmark, Germany and Ireland have been identified as the main candidate VoO Hosts, while Benelux and the UK have been identified as the main Users. When considering practical implementation barriers such as grid constraints and maritime space availability, the role of Germany as one of the main hosts does not look very realistic. On the other hand in the Danish North Sea, suitable sites that could host (surplus) offshore wind developments have been identified in the Horns Rev area. Moreover grid-related barriers appear less severe in the case of Denmark, in particular due to the upcoming *Cobra* connection between Denmark and the Netherlands. Based on these considerations a VoO between Denmark and the Netherlands has been selected as an interesting case study to be further analyzed in WP3.

Biomass energy in Eastern Europe

The analysis highlights high biomass potentials in Romania, Poland and Czech Republic. Among these Romania stands as the main candidate to host a biomass-based VoO. In Poland and Czech Republic biomass potentials are expected to be used to meet the national target, and therefore no surpluses are foreseen. On the other hand, the Romanian NREAP specifies a rather low share of RES-E from biomass, and therefore a surplus potential can be expected. Possible users of the Romanian surplus are the Benelux countries, Italy and Greece. Among these the Netherlands has been championed, mainly based on the fact that Dutch policy makers already expressed their interest in looking for cooperation opportunities in Eastern Europe, as it has been pointed out during the RES4 Less stakeholders consultation meetings in 2011. Therefore a biomass VoO between Romania and the Netherlands, based on cooperation mechanisms that do not rely on physical transfer of electricity, will be brought forward to Work Package 3 for an in-depth case study.

Solar energy in South Europe

The analysis highlights possible surpluses of RES-E from solar technologies, i.e. Photovoltaics (PV) and Concentrated Solar Power (CSP) in France, Germany and Spain. Possible users of these surpluses are the Netherlands, Greece, Poland and the UK. When considering practical barriers related technological developments, administrative issues, policy and grid connection, it appears that the following limitations apply:

- Germany can be ruled out as a major Host Country of PV VoOs
- Physical transfer of electricity from France or Spain to any of the identified User Countries is not realistic
- Specific deployment difficulties may arise, related to local administrative procedures
- Dedicated policy measures and support schemes are needed

- Further cost reductions are needed for scaling up of CSP, and therefore there is a large uncertainty as to the realistic possibilities in 2020

Based on these considerations, and taking into account the leading role of Spain in the development and deployment of concentrated solar power technologies, a CSP-based VoO with Spain as Host country seems to be the most interesting choice for an in-depth analysis. Looking at the possible users, Greece and the Netherlands figure as the main candidates. Due to the current situation of the Greece economy, it has been decided to focus on the Netherlands. The identified VoO will be based on mechanisms that do not rely on physical transfer of electricity (in order to mitigate grid limitations), and will start with a small pilot project in order to mitigate the risks related to the current uncertainties on cost reduction of CSP in the coming decade.

As a final remark, it is interesting to notice that having the same user country in all three case studies resembles the real situation of a country looking for a partner to cooperate with, and assessing all the competing possibilities.

A pictorial representation of the three identified case studies is presented in Fig. 6.1.

Figure 6.1 *Three interesting case studies of VoOs. In particular: an offshore wind VoO between Denmark and the Netherlands (blue arrow), a biomass VoO between Romania and the Netherlands (green arrow), and solar VoO between Spain and the Netherlands (orange arrow). Dashed contour lines are used in the case of biomass and solar VoOs to indicate that cooperation should not rely on physical transfer.*

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