European Commission

Study on Research needs on the use of Earth observation data for the benefit of renewable energy exploitation and deployment

Final Report

PP-06201-2017

Written by Carlo Strazza, Nicolo Olivieri

Final version May – 2019

Research and Innovation

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Manuscript completed in May 2019.

Luxembourg: Publications Office of the European Union, 2019

PDF ISBN 978-92-76-04109-2 doi: 10.2777/16968 KI-02-19-378-EN-N

EUROPEAN COMMISSION

Study on Research needs on the use of Earth observation data for the benefit of renewable energy exploitation and deployment

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Directorate-General for Research and Innovation
Secure, Clean and Efficient Energy

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List of abbreviations

Abbreviations	
CBA	Cost Benefits Analysis
DG RTD	Directorate-General for Research and Innovation
EC	European Commission
EO	Earth Observation
ESA	European Space Agency
EU	European Union
GEOSS	Global Earth Observation System of Systems
GMES	Global Monitoring for Environment and Security programme
H&C	Heating and Cooling
IT	Information Technology
R&D	Research and Development
RE	Renewable Energy
RET	Renewable Energy Technology
TRL	Technology Readiness Level
SoA	State of the Art
SW	Software
SWOT	Strength Weakness Opportunities and Threats

1. ABSTRACT

As the EU's Earth Observation programme, Copernicus, is entering its operational phase, the European Commission with the European Space Agency has launched a number of initiatives to promote and to increase the use of Copernicus data and information.
This study was meant to perform an in-depth analysis of how EO data are being used in the six RE sectors identified (Solar energy, Geothermal energy, Wind energy, Bioenergy, Ocean energy, Hydropower), to identify possible research and development paths that would significantly improve EO and to finally provide a cost-benefit analysis of introducing such R&D outcomes associated to EO in the RE sector.
Crucial to the achievement of the project's purposes was the multidisciplinary approach, combining expertise both in the RE sector and in the field of EO and the involvement of key stakeholders in each of the two workshops, to provide support and feedback to the project team and ensure that the final outcome of the study is commonly agreed and not biased by personal interpretations.
The implementation of the study is articulated around the following main activities: evaluation of the State of Play, assessment of the R&D needs and finally provision of a cost / benefits analysis.

Alors que Copernicus, le programme européen de Surveillance de la Terre, entre dans sa phase opérationnelle, la Commission européenne et l'Agence spatiale européenne ont lancé un certain nombre d'initiatives visant à promouvoir et développer l'utilisation des données et informations collectées par Copernicus.
L'objectif était de procéder à une analyse approfondie de la manière dont les données issues de l'Observation de la Terre sont utilisées dans six secteurs d'énergies renouvelables (énergie solaire, géothermique, éolienne, océanique, hydraulique et bioénergie), afin d'identifier des pistes de Recherche et Développement susceptibles d'améliorer significativement l'Observation de la Terre et de fournir une analyse coûts-avantages résultant de l'introduction de tels résultats.
L'approche multidisciplinaire associant des compétences du secteur des énergies renouvelables et de celui de l'Observation de la Terre, et la participation des principaux acteurs à chacun des séminaires, fournissant ainsi soutien et compte-rendu à l'équipe de projet et veillant à ce que le résultat final de l'étude soit communément accepté et non biaisé par des interprétations personnelles, ont été déterminants pour la détermination des objectifs du projet.
L'exécution de l'étude s'articule autour des activités suivantes: évaluation de l'état des lieux, évaluation des besoins en R & D et, fourniture d'une analyse coûts / avantages.

2. EXECUTIVE SUMMARY

The present document constitutes the final report of the Study 'Research needs on the use of Earth observation data for the benefit of renewable energy exploitation and deployment', issued by the European Commission (EC) through a framework contract intended to support its research and innovation policy in the areas of renewable energy, carbon capture and storage and clean coal.

The report is aimed to introduce the scope and purpose of the project, describe the methodological approach proposed by the Consultant and present the overall findings and conclusions from the work. It is therefore articulated around 5 main sections:

- Introduction to the study;
- Results from Task 1 – State of Play
- Results from Task 2 – Research and development needs
- Results from Task 3 – Cost / Benefit analysis
- Conclusive remarks.

Introduction to the study

The context.
As the EU's Earth Observation programme, Copernicus, is entering its operational phase, the European Commission (EC) with the European Space Agency (ESA) has launched a number of initiatives to promote and to increase the use of Copernicus data and information. Its strength is based on its accurate, timely and easily accessible information to improve the management of the environment, understand and mitigate the effects of climate change and ensure civil security.

Copernicus is served by a set of dedicated satellites (the Sentinel families) and contributing missions (existing commercial and public satellites). The 7 Sentinel satellites are specifically designed to meet the needs of the Copernicus services and their users. Copernicus also collects information from in situ systems (ground stations, waterborne or airborne) which deliver data acquired by a multitude of sensors.

In the context of Renewable Energy (RE) generation and exploitation, increased energy efficiency, EU energy security and renewable energy system integration, Copernicus and EO data and services are expected to play an important role towards energy resource assessments, production plant siting, operations (including safety) and various decision-making processes.

The approach proposed to meet the study's objectives.
The overall objective of the study is to perform an in-depth analysis of how EO data are being used in the six RE sectors identified (Solar energy, Geothermal energy, On- and offshore wind, Bioenergy, Ocean energy (wave and tide), Hydropower). It will also identify possible research and development paths that would significantly improve EO and provide a cost-benefit analysis of introducing such R&D outcomes associated to EO in the RE sector.

The scope of the study requires a multidisciplinary approach, combining expertise both in the RE sector and in the field of EO.

Crucial to the achievement of the project's purposes will also be the involvement of key stakeholders in each of the two foreseen workshops, to provide support and feedback to the project team and ensure that the final outcome of the study is commonly agreed and not biased by personal interpretations.

The implementation of this study is be articulated around the following main activities:

1. evaluation of the State of Play: analysis and mapping of the RE sectors, analysis of the state of the art in the use of EO data in general and in the six energy sectors identified;
2. assessment of the R&D needs: identification of R&D needs and actors, organisation of the first consultative workshop, elaboration and consolidation of the results for the next phase;
3. cost / benefits analysis: cost / benefit analysis of the actions' implementation, organisation of the validation workshop, validation of the results and finalisation of the study.

Task 1

Task 1 is divided in two sub-tasks with the overall objective to establish the current state of play in the RE sectors selected in the use of EO data and information, in particular in the use of data and information from the Copernicus programme.

From one side, the six renewable energy sectors have been analysed in order to extract information about the value chain: detailed steps, involved actors, their relationships in the three main phases (exploration/resource assessment/siting, design, operation) and, equally important, the sectorial data useful for the cost benefit analysis.

For each of the six energy sectors identified (solar energy, geothermal energy, on- and off-shore wind, bioenergy, ocean energy (wave and tide), hydropower) the following activities were performed:

- identification and description of the steps of the RE technology sector value chain;
- clustering of the steps in the three macro-phases (exploration/resource assessment/siting, design, operation);
- identification of the actors involved (typology of main players);
- refining of the market related data already present in the proposal document;
- enriching the list of stakeholders to be invited to participate in the consultation.

For each energy sector, a table reports the description of the main steps of the sector value chain and the indication of the different actors associated to each of them. Moreover a picture represents the logical sequence of the sector value chain, grouping the steps in the three main macro-phases.

On the other hand, there are three types of information analysed:

- EO data use and their scope, connection with in-situ data, tools and SW;
- research and innovation developments;
- degree of awareness of Copernicus and EO data uses within the renewable energy sectors selected.

The main findings are:

- The list of EO data and Information products used in each energy sector;
- The list of software, tools or models allowing the use of EO data or information products for each energy sector;
- The list of potential in-situ sensors integrated with EO data for each energy sector;
- The list of gaps identified or confirmed for each energy sector;
- The SWOT analysis tables, sector by sector. They represent a resume of the overall findings of the desk analysis and of the discussion with the Energy sectorial experts, updated with the results of the survey and the phone/e-mail interviews.

Task 2

The identification and assessment of the R&D needs was performed mainly through desk research, and notably reviewing literature, communications, conference proceedings, workshops minutes and EU, national and regional activities or projects.

The identification of these R&D Needs was naturally supported by the results of Task 1. R&D needs are organised within the different RE sectors, plus one additional "Cross-cutting" sector, which collects all the relevant transversal issues, covering more or less all of the sectors.

Actors needed to implement the R&D identified have been found cross-linking the value chain of the specific RE sector, the value chain of the EO framework and the input received during the workshop.

The main outcome of the analysis is the list of the preliminary R&D Needs to be submitted to the stakeholders for preliminary desk consultation, and workshop interactions.

In accordance to the results of the desk analysis and of the workshop, a final prioritisation of actions has been made for each energy sector plus the cross-cutting area.

The rationale behind the final prioritisation is the following: firstly R&D Needs and Actions evaluated as "frontrunner", in terms of Impact and Technical feasibility, are deemed as worthy of being selected

for the Cost Benefit analysis (CBA). "Frontrunner" Needs are then ranked with respect to Timeframe and Estimated cost for implementation. In the Marine energy case, since no frontrunner Needs were identified (nor in the 2nd group), the selection was performed starting from 3rd group.

In particular, for cross cutting issues, in accordance to the comments received from the experts during the validation workshop, an additional refinement is made, clustering R&D needs related to the same general topic e.g. training and awareness).

It is interesting to point out the Workshop validation allowed to consolidate the outcomes of the survey and desk study without any major area of dissent but providing also some additional refinements and specific inputs.

In total, 34 prioritised needs are identified, split as per the following: 7 for solar energy, 2 for geothermal energy, 6 for wind energy, 5 for bioenergy, 1 for marine energy, 6 for hydropower and 7 for the cross-cutting area.

As final note, it is possible to see within the bioenergy field that some actions were differently evaluated by the experts whether considering implementation at EU level or global level.

Task 3

Task 3 is divided in three sub-tasks with the overall objective to perform a simple cost/benefit analysis on the implementation of actions aiming to meet the R&D needs already identified.

The analysis is divided in five phases.

1. Identification of the main costs incurring when fulfilling a need through the identification of R&D activities to be done.

2. Evaluation of the benefits deriving from the introduction of the new technologies/knowledge/information according to three different parameters, as per the Terms of References: exploitation efficiency, operation cost saved, extended exploitation potential thanks to enhanced siting or exploration.

3. Evaluation of the value of the Benefit provided by the action fulfilling each R&D Need against the created scenarios.

4. Evaluation of the magnitude of the impact.

5. Finalisation of the input through a validation workshop.

As output of the workshop, for each of the six energy sectors identified (solar energy, geothermal energy, on- and off-shore wind, bioenergy, marine energy (wave and tide), hydropower) and the cross cutting area, the cost/benefit analysis is validated by the stakeholders which laready provided their own overall prioritisation.

Conclusive remarks

As final outcome of the project, each one of the 34 prioritised R&D needs is presented in a dedicated fiche, which contains the following information:

- Need description;
- Actions necessary to fulfil the need;
- Actors involved;
- Range of the cost for action implementation;
- Share between public and private funding;
- Benefits derived in terms of increase of energy generation and decrease of energy production cost;
- Final prioritisation.

In total, 34 prioritised needs are identified, split as per the following: 7 for solar energy, 2 for geothermal energy, 6 for wind energy, 5 for bioenergy, 1 for marine energy, 6 for hydropower and 7 for the cross-cutting area.

Ce document constitue le rapport final de l'étude « Besoins de recherche sur l'utilisation des données d'observation de la terre en bénéfice de l'exploitation et le déploiement des énergies renouvelables », publié par la Commission européenne (CE) dans un contrat-cadre destiné à soutenir sa politique de recherche et d'innovation dans les domaines des énergies renouvelables, du captage et du stockage du carbone et du charbon propre.

Le rapport vise à introduire la portée et l'objet du projet, à décrire l'approche méthodologique proposée par le consultant et à présenter les constatations et conclusions générales du travail. Il est donc articulé dans 5 sections principales :

- introduction à l'étude ;
- résultats de la tâche 1 – État de situation
- résultats de la tâche 2 – Besoins en recherche et développement
- résultats de la tâche 3 – Analyse des coûts / avantages
- remarques conclusives.

Introduction à l'étude

Le contexte.
Étant donné que le programme d'observation de la terre (OT) de l'UE, Copernicus, entre dans sa phase opérationnelle, la Commission européenne (CE) de concert avec la Agence spatiale européenne (ESA) a entrepris un certain nombre d'initiatives dans le but de promouvoir et d'accroître l'utilisation des informations et données de Copernicus. Sa force repose sur ses informations précises, opportunes et facilement accessibles, qui permettent d'améliorer la gestion de l'environnement, de comprendre et d'atténuer les effets du changement climatique et de garantir la sécurité civile.

Copernicus est desservi par un ensemble de satellites dédiés (les familles Sentinel) et par des missions contributrices (des satellites commerciaux et publics existants). Les 7 satellites Sentinel ont été spécialement conçus pour répondre aux besoins des services Copernicus et de leurs utilisateurs. Copernicus collecte également des informations à partir des systèmes in situ (stations terrestres, aéroportées ou flottantes) qui fournissent des données acquises par une multitude de capteurs.

Dans le contexte de la production et de l'exploitation des énergies renouvelables (ER), de l'efficacité énergétique accrue, de la sécurité énergétique de l'UE et de l'intégration de systèmes d'énergie renouvelable, les données et les services Copernicus et d'OT devraient jouer un rôle important dans les évaluations des ressources énergétiques, dans la localisation des installations de production, leur fonctionnement (y compris la sécurité) et les divers processus de prise de décision.

L'approche proposée pour atteindre les objectifs de l'étude.
L'objectif général de l'étude est de réaliser une analyse approfondie de la manière dont les données de l'OT sont utilisées dans les six secteurs d'énergies renouvelables identifiés (énergie solaire, énergie géothermique, énergie éolienne onshore et offshore, bioénergie, énergie marine -vagues et marées-, énergie hydraulique). Elle identifiera également des chemins de recherche et de développement susceptibles d'améliorer considérablement l'OT et fournira une analyse des coûts-avantages de l'introduction de tels résultats de R&D associés à l'OT dans le secteur des ER.

La portée de l'étude nécessite une approche multidisciplinaire, combinant une expertise à la fois dans le secteur des ER et dans le domaine de l'OT.

La participation des principales parties prenantes à chacun des deux séminaires prévus est essentielle à la réalisation des objectifs du projet, afin de fournir un soutien et des informations en retour à l'équipe du projet et de garantir que le résultat final de l'étude soit accepté d'un commun accord et ne soit pas tergiversé par des interprétations personnelles.

La mise en œuvre de cette étude s'articule autour des activités principales suivantes :

1. évaluation de l'état de situation : analyse et cartographie des secteurs des énergies renouvelables, analyse de l'état de la technique dans l'utilisation des données d'OT en général et dans les six secteurs de l'énergie identifiés ;
2. évaluation des besoins en R&D : identification des besoins en R&D et des acteurs, organisation du premier séminaire consultatif, élaboration et consolidation des résultats pour la prochaine phase ;
3. analyse des coûts-avantages : analyse des coûts-avantages de la mise en œuvre des actions, organisation de séminaire de validation, validation des résultats et finalisation de l'étude.

Tâche 1

La tâche 1 est divisée en deux sous-tâches avec l'objectif général d'établir l'état de situation actuelle dans l'utilisation des données et informations de l'OT dans les secteurs d'ER sélectionnés, en particulier dans l'utilisation des données et informations du programme Copernicus.

D'un côté, les six secteurs des énergies renouvelables ont été analysés afin d'extraire des informations sur la chaîne de valeur : étapes détaillées, acteurs impliqués, leurs relations dans les trois phases principales (exploration / évaluation des ressources / sélection de site, conception, exploitation) et, ce qui est tout aussi important, les données sectorielles utiles à l'analyse des coûts-avantages.

Les activités détaillées ci-dessous ont été réalisées pour chacun des six secteurs énergétiques identifiés (énergie solaire, énergie géothermique, énergie éolienne, bioénergie, énergie marine, énergie hydraulique) :

- identification et description des étapes de la chaîne de valeur du secteur technologique des énergies renouvelables ;
- regroupement des étapes dans les trois phases macro (exploration / évaluation des ressources / sélection de site, conception, exploitation) ;
- identification des acteurs impliqués (typologie des principaux acteurs) ;
- raffinage des données relatives au marché déjà présentes dans le document de proposition ;
- enrichissement de la liste des parties prenantes invitées à participer à la consultation.

Pour chaque secteur d'énergie, un tableau consigne la description des étapes principales de la chaîne de valeur du secteur et l'indication des différents acteurs associés à chacun d'eux. De plus, une image représente la séquence logique de la chaîne de valeur du secteur, regroupant les étapes dans les trois phases macro principales.

D'un autre côté, trois types d'information sont analysés :

- utilisation des données d'OT et leur portée, connexion avec les données in-situ, outils et logiciels ;
- recherche et développements innovants ;
- degré de sensibilisation à l'utilisation des données de Copernicus et d'OT dans les secteurs d'énergie renouvelable sélectionnés.

Les principaux résultats sont :

- la liste des données et des produits d'information d'OT utilisés dans chaque secteur d'énergie ;
- la liste de logiciels, outils ou modèles permettant l'utilisation des données ou des produits d'information d'OT pour chaque secteur de l'énergie ;
- la liste des capteurs in-situ potentiels intégrés aux données d'OT pour chaque secteur de l'énergie ;
- la liste des lacunes identifiées ou confirmées pour chaque secteur de l'énergie ;
- les tableaux d'analyse SWOT, secteur par secteur. Ils représentent un résumé des conclusions générales de l'analyse documentaire et de la discussion avec les spécialistes du secteur de l'énergie, mises à jour avec les résultats de l'enquête et des entretiens téléphoniques ou par courrier électronique.

Tâche 2

L'identification et l'évaluation des besoins en R&D ont été réalisées principalement au moyen de recherches documentaires, notamment dans les publications existantes, dans les communications, les actes de conférences, les rapports des séminaires et les activités ou projets européens, nationaux et régionaux.

L'identification de ces besoins en R&D a naturellement été soutenue par les résultats de la tâche 1. Les besoins en R&D sont organisés dans les différents secteurs des ER, plus un secteur « transversal » supplémentaire, qui rassemble toutes les questions transversales pertinentes, couvrant plus ou moins tous les secteurs.

Les acteurs nécessaires à la mise en œuvre des R&D identifiés ont été trouvés en mettant en corrélation croisée la chaîne de valeur du secteur spécifique des ER, la chaîne de valeur du cadre d'OT et les informations reçues au cours du séminaire.

Le résultat principal de l'analyse est la liste des besoins préliminaires en R&D à soumettre aux parties prenantes pour une consultation préliminaire et des interactions en séminaire.

Conformément aux résultats de l'analyse documentaire et du séminaire, une hiérarchisation finale des actions a été effectuée pour chaque secteur de l'énergie ainsi que pour le secteur transversal.

La justification de la hiérarchisation finale est la suivante : tout d'abord, les actions et les besoins en R&D évalués comme « favoris » en termes d'impact et de faisabilité technique sont jugés dignes d'être sélectionnés pour l'analyse des coûts-avantages (CBA par ses sigles en anglais). Les besoins « favoris » sont ensuite classés en fonction du calendrier et du coût estimé de mise en œuvre. Dans le cas de l'énergie marine, du fait qu'aucun besoin favori n'a été identifié (ni dans le 2e groupe), la sélection a été effectuée à partir du 3e groupe.

En particulier, pour les questions transversales, conformément aux commentaires reçus des experts lors du séminaire de validation, un raffinement supplémentaire est apporté, regroupant les besoins en R&D liés au même sujet général, par exemple formation et sensibilisation.

Il est intéressant de souligner que la validation en séminaire a permis de consolider les résultats de l'enquête et de l'étude théorique sans aucun point de désaccord majeur, mais en produisant également quelques améliorations supplémentaires et des apports spécifiques.

Au total, 34 besoins hiérarchisés sont identifiés, répartis comme suit : 7 pour l'énergie solaire, 2 pour l'énergie géothermique, 6 pour l'énergie éolienne, 5 pour la bioénergie, 1 pour l'énergie marine, 6 pour l'énergie hydraulique et 7 pour le secteur transversal.

En guise de note finale, il est possible de voir dans le domaine de la bioénergie que certaines actions ont été évaluées différemment par les experts, selon qu'ils envisagent une mise en œuvre au niveau européen ou mondial.

Tâche 3

La tâche 3 est divisée en trois sous-tâches avec l'objectif général de réaliser une simple analyse des coûts-avantages de la mise en œuvre des actions visant à répondre aux besoins en R&D déjà identifiés.

L'analyse est divisée en cinq phases.

1. Identification des principaux coûts liés à la satisfaction d'un besoin grâce à l'identification des activités de R&D à réaliser.

2. Évaluation des avantages découlant de l'introduction de nouvelles technologies / connaissances / informations selon trois paramètres différents, conformément aux termes de référence : efficacité de l'exploitation, économies de coûts d'exploitation, potentiel d'exploitation étendu grâce à un meilleur choix de site ou à une exploration améliorée.

3. Évaluation de la valeur du bénéfice fourni par l'action répondant à chaque besoin en R&D par rapport aux scénarios créés.

4. Évaluation de l'ampleur de l'impact.

5. Finalisation de l'entrée par un séminaire de validation.

En tant que résultat du séminaire, pour chacun des six secteurs énergétiques identifiés (énergie solaire, énergie géothermique, énergie éolienne, bioénergie, énergie marine, énergie hydraulique) et le secteur transversal, l'analyse des coûts-avantages est validée par les parties prenantes qui ont déjà fourni leur propre hiérarchisation globale.

Remarques conclusives

En tant que résultat final du projet, chacun des 34 besoins en R&D hiérarchisés est présenté dans une fiche dédiée contenant les informations suivantes :

- description du besoin ;

- actions nécessaires pour satisfaire le besoin ;
- acteurs impliqués ;
- gamme des coûts pour la mise en œuvre de l'action ;
- partage entre financement public et privé ;
- avantages dérivés en termes d'augmentation de la production d'énergie et de diminution du coût de production d'énergie ;
- hiérarchisation finale.

Au total, 34 besoins hiérarchisés sont identifiés, répartis comme suit : 7 pour l'énergie solaire, 2 pour l'énergie géothermique, 6 pour l'énergie éolienne, 5 pour la bioénergie, 1 pour l'énergie marine, 6 pour l'énergie hydraulique et 7 pour le secteur transversal.

3. INTRODUCTION TO THE STUDY

This study, entitled '*Research needs on the use of Earth observation data for the benefit of renewable energy exploitation and deployment'* has been issued by the European Commission (EC) through a framework contract intended to support its research and innovation policy in the areas of renewable energy, carbon capture and storage and clean coal.

The project started in May 2018, with an expected duration of 10 months.

RINA was the leading partner for the implementation of this project, acting in a consortium with EY in charge of the revision and quality check of the reports.

3.1. Background and context

As the EU's Earth Observation programme, Copernicus, is entering its operational phase, the European Commission (EC) with the European Space Agency (ESA) has launched a number of initiatives to promote and to increase the use of Copernicus data and information.

Copernicus is involved in the Group on Earth Observations' Global Earth Observation System of Systems (GEOSS) that aims to strengthen the monitoring of the state of the Earth.

The Copernicus programme covers the activities previously provided by the Global Monitoring for Environment and Security programme, GMES. Its strength is based on its accurate, timely and easily accessible information to improve the management of the environment, understand and mitigate the effects of climate change and ensure civil security.

Copernicus is served by a set of dedicated satellites (the Sentinel families) and contributing missions (existing commercial and public satellites). The 7 Sentinel satellites are specifically designed to meet the needs of the Copernicus services and their users.

Copernicus also collects information from in situ systems (ground stations, waterborne or airborne) which deliver data acquired by a multitude of sensors.

In the context of Renewable Energy (RE) generation and exploitation, increased energy efficiency, EU energy security and renewable energy system integration, Copernicus and EO data and services are expected to play an important role towards energy resource assessments, production plant siting, operations (including safety) and various decision-making processes.

3.2. General objectives

The overall objective of the study is to perform an in-depth analysis of how EO data are being used in the six RE sectors identified (Solar energy, Geothermal energy, On- and offshore wind, Bioenergy, Ocean energy (wave and tide), Hydropower). It will also identify possible research and development paths that would significantly improve EO and provide a cost-benefit analysis of introducing such R&D outcomes associated to EO in the RE sector.

3.3. Overview of the services required

The scope of the study mentioned above requires a multidisciplinary approach, combining expertise both in the RE sector and in the field of EO.

Crucial to the achievement of the project's purposes will also be the involvement of key stakeholders in each of the two foreseen workshops, to provide support and feedback to the project team and ensure that the final outcome of the study is commonly agreed and not biased by personal interpretations.

The implementation of this study is be articulated around the following main activities:

4. evaluation of the State of Play:
    - analysis and mapping of the RE sectors,
    - analysis of the state of the art in the use of EO data in general and in the six energy sectors identified;
5. assessment of the R&D needs:
    - identification of R&D needs and actors,
    - organization of the first consultative workshop,

- elaboration and consolidation of the results for the next phase;

6. cost / benefits analysis:
   - cost / benefit analysis of the actions' implementation,
   - organization of the validation workshop,
   - validation of the results and finalization of the study.

The following picture shows how the services required by the Terms of Reference were translated into a process flowchart, so as to ensure the maximization of any interaction between the different tasks.

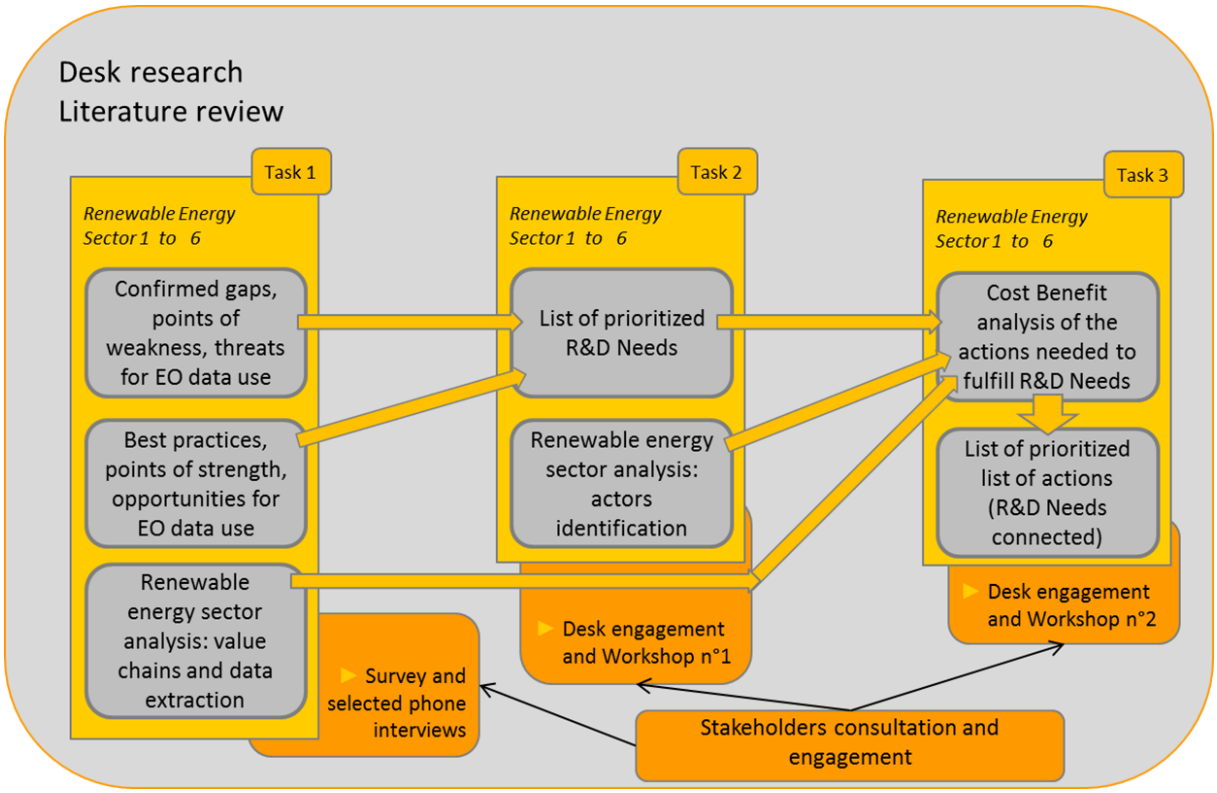


Figure 1 Our overall approach to the project

4. STAKEHOLDERS ENGAGEMENT PROCESS

A wide community of stakeholders (technological experts and non-technological experts) was addressed to and consulted at an early stage, to complement the results of the desk research in Task 1 and to participate in the workshop held in Task 2. They were also involved in Task 3 for the validation final workshop.

This involvement was achieved through an online survey and by selected telephone interviews. Statistics resulting from interviews and survey provided an overview of the different positions and allowed our project team to classify stakeholders and ensure all views are taken into account while asking for a feedback on the draft documents.

Stakeholders were then selected and invited to the first of the two workshops so as to ensure a good balance between different categories. Such representativeness is a key to ensure the guidance documents are as consistent and complete as possible and receive a broad acceptance and buy-in.

Selection of stakeholders for the second workshop were made giving priority for first workshop participants.

The following Figure 2 depicts the stakeholders' engagement process, and the type of stakeholders needed for this study.

The list of stakeholders participating in the first workshop is reported in Appendix A, while the list of stakeholders participating in the second workshop is reported in Appendix B.

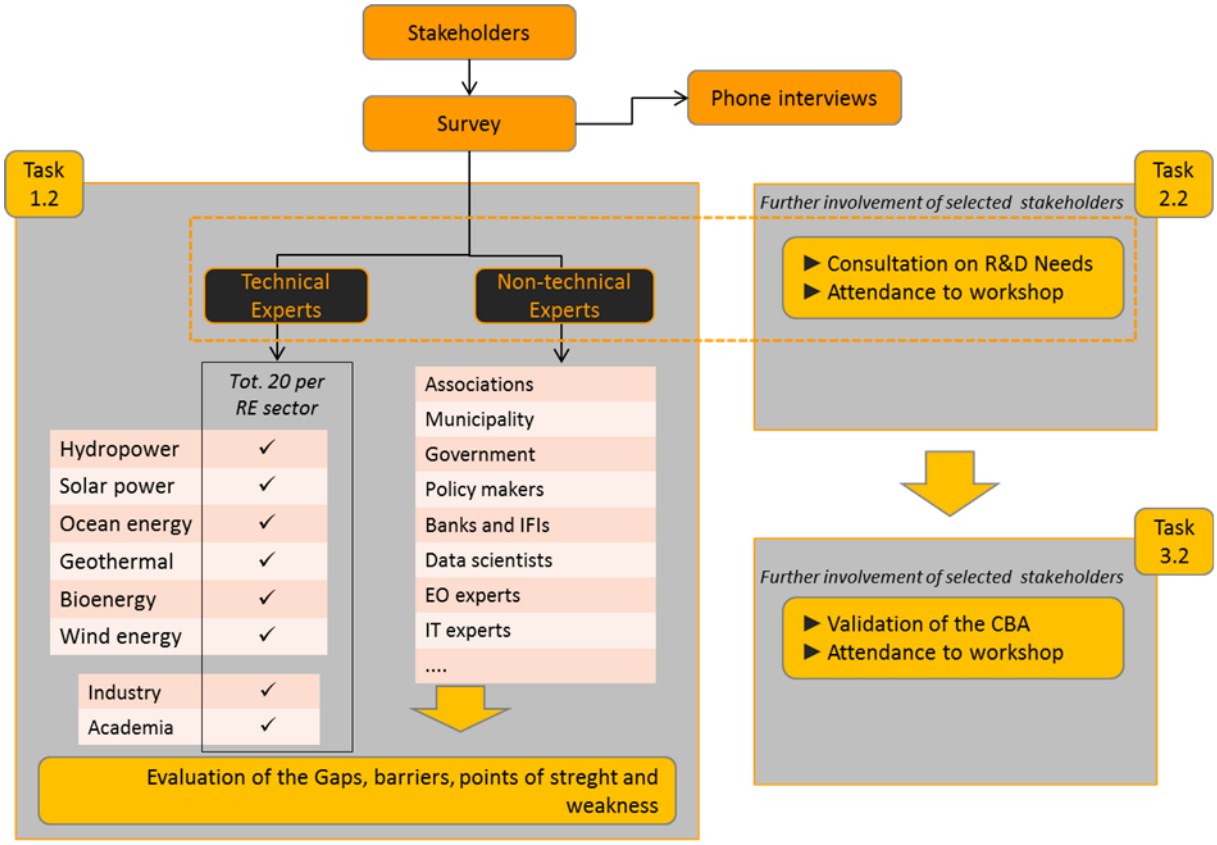


Figure 2 Stakeholders engagement process

5. TASK 1 – STATE OF PLAY

5.1.Overall methodological approach

Task 1 is divided in two sub-tasks with the overall objective to establish the current state of play in the RE sectors selected in the use of EO data and information, in particular in the use of data and information from the Copernicus programme.

From one side (Task 1.1), the six renewable energy sectors have been analysed in order to extract information about the value chain: detailed steps, involved actors, their relationships in the three main phases (exploration/resource assessment/siting, design, operation) and, equally important, the sectorial data useful for Task 3.

On the other hand, in Task 1.2, there are three types of information analysed:

- EO data use and their scope, connection with in-situ data, tools and SW;
- research and innovation developments;
- degree of awareness of Copernicus and EO data uses within the renewable energy sectors selected.

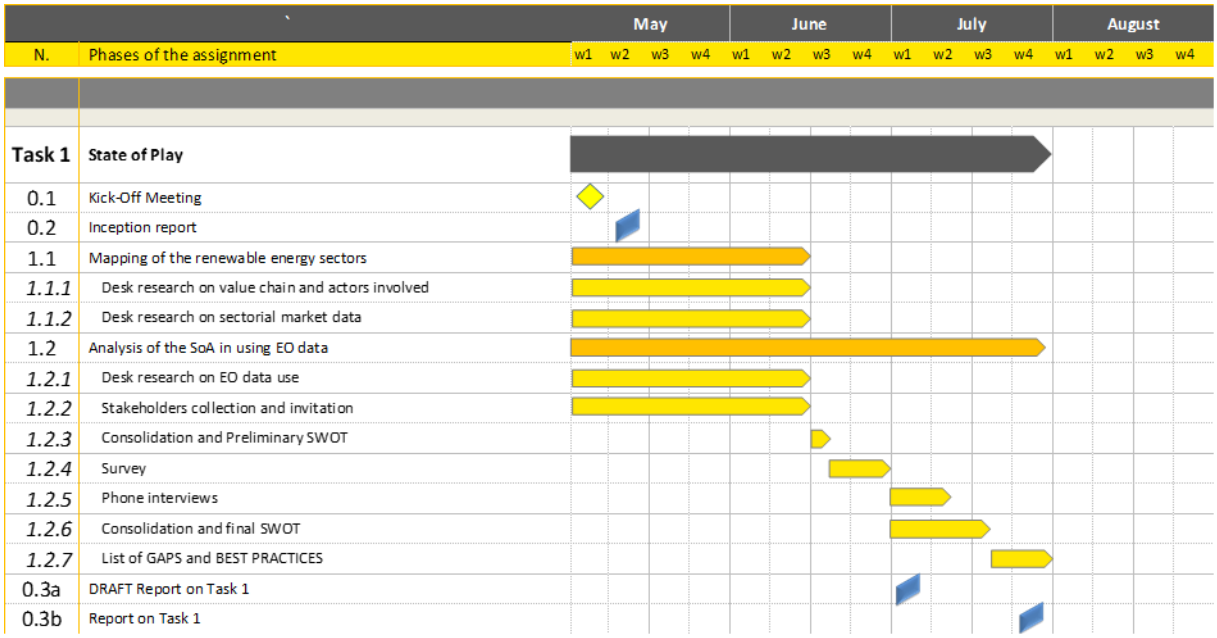


Figure 3 Timeline for Task 1 implementation

5.2.Sub-task 1.1: Mapping of the renewable energy sectors

For each of the six energy sectors identified (solar energy, geothermal energy, on- and off-shore wind, bioenergy, ocean energy (wave and tide), hydropower) the following activities were performed:

- identification and description of the steps of the RE technology sector value chain;
- clustering of the steps in the three macro-phases (exploration/resource assessment/siting, design, operation);
- identification of the actors involved (typology of main players);
- refining of the market related data already present in the proposal document;
- enriching the list of stakeholders to be invited to participate in the consultation.

For the collection of the data, a word template was prepared and distributed to the sectorial Expert, altogether with a Power Point template for the graphical description of the value chain.

The sectorial experts, with the support of the EO expert, compiled the appropriate template with the retrieved information.

For each energy sector, a table reports the description of the main steps of the sector value chain and the indication of the different actors associated to each of them. Moreover a picture represents the logical sequence of the sector value chain, grouping the steps in the three main macro-phases.

The amount of data available from the analysis for the 6 energy sectors is too large to include in the present progress report. The reader is redirected to the more appropriate "Report on Task 1".

Indicatively, for the format of the presentation of results, we present below the headline of the table (Table 1) for energy sectors value chain description available in the "Report for Task 1" is presented, along with an example of the picture (Figure 4), extracted from the Hydropower chapter.

Table 1 Headline for Task 1.1 table

#	Value Chain Step [title and description]	Macro Phase associated	Type(s) of actors involved in the associated step
1		Exploration/siting, Design, Operation	

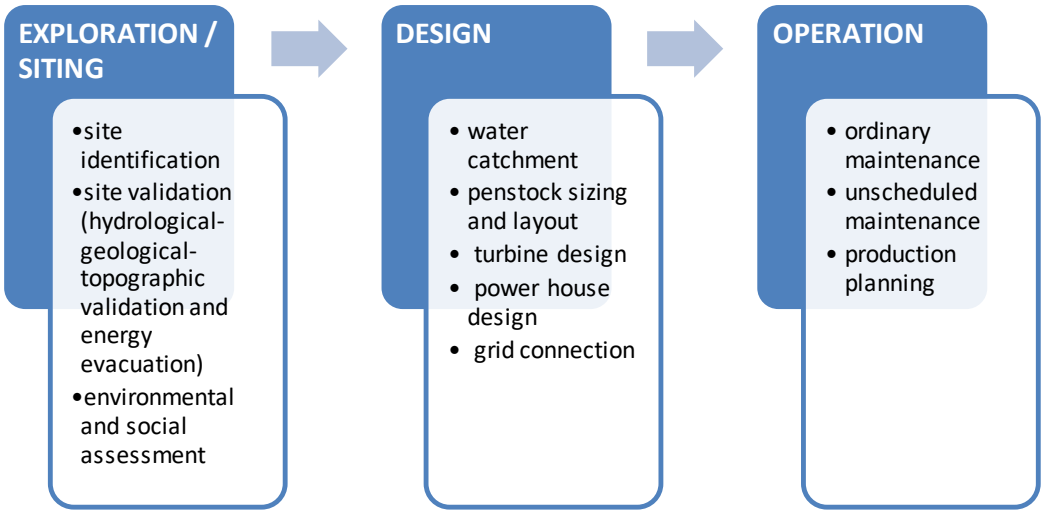


Figure 4 Example of the hydropower value chain

5.3. Sub-task 1.2: Analysis of the state of the art in using Earth observation data

For each of the six energy sectors identified (solar energy, geothermal energy, on- and off-shore wind, bioenergy, ocean energy (wave and tide), hydropower) the following activities are completed:

- desk research (literature review) on:
  - use of EO data and scope of the usage, their connection with in-situ data, tools and SW,
  - research and innovation developments.

The analysis was focussed in order to answer to the following aspects:

- which EO data are used?
- in which macro-phase of the value chain is it used?
- for which kind of services?
- are there R&D activities in place?
- are there connections or integrations with SW or Tools used for exploration, design or operation of the technology?
- which can be a preliminary list of gaps and weaknesses?

A word template for the collection of the data for Task 1.2 was prepared by RINA and sent to the sectorial experts for completion.

The headlines of the five template tables are reported here below for, respectively, use of EO data analysis (Table 2), development activities (Table 3), integration with SW, tools or models (Table 4), integration with in-situ sensors (Table 5) and gaps and weaknesses identification (Table 6).

Table 2 Template table for collection of use of EO data

Which data/information product is currently used in the sector? Description [lines to be added when needed]	Which service the data/info products offer to the sector?	Which macro phase(s) covers / can be associated?	Source
		Exploration/siting, Design, Operation	

Table 3 Template table for collection of developments activities

Which data/information product is currently under developments (project, research, idea, …) in the sector? Description [lines to be added when needed]	Which service the data/info products can offer to the sector?	Which macro phase(s) covers?	Source
		Exploration/siting, Design, Operation	

Table 4 Template table for integration with SW, tools or models

Are there in the sector SW / tools / models which allow integrating data / information products coming from EO? Description [lines to be added when needed]	Which data/information product can be added?	Which macro phase(s) covers?	Source
		Exploration/siting, Design, Operation	

Table 5 Template table for integration with in-situ sensors

Which data/information product is currently integrated with in situ sensors (land, water, air) in the sector? Description [lines to be added when needed]	List here the sensor(s) integrated	Which service the data/info products offer to the sector?	Which macro phase(s) covers?	Source
			Exploration/siting, Design, Operation	

Table 6 Template table for gaps and weaknesses identification

Are there Gaps or weaknesses already highlighted in the docs?	Which actions can cover these gaps?	Which macro phase(s) covers?	Source
		Exploration/siting, Design, Operation	

On this basis, RINA aggregated the contributions and performed a preliminary SWOT analysis for each one of the energy sectors. The SWOT analysis, the list of gaps and best practices were used as basis for the survey for external stakeholders.

Survey run initially for two weeks and was extended for two additional weeks in order to catch the majority of the possible answers. At the end of the consultation process, 32 stakeholders - out of 305 invitations sent - answered to the survey. It means 10,5% that is in line with the usual expectation of a generic survey. Out of 32 stakeholders, 27 provide availability to participate to the first workshop.

The files provided by the experts resumed and homogenised were used by the energy stakeholders as basis for filling the survey.

The main findings of sub-task 1.2 are:

- The list of EO data and Information products used in each energy sector;
- The list of software, tools or models allowing the use of EO data or information products for each energy sector;
- The list of potential in-situ sensors integrated with EO data for each energy sector;
- The list of gaps identified or confirmed for each energy sector;
- The SWOT analysis tables, sector by sector. They represent a resume of the overall findings of the desk analysis and of the discussion with the Energy sectorial experts, updated with the results of the survey and the phone/e-mail interviews.

The amount of data available from the analysis, for the 6 energy sectors and the Cross-cutting area is too large to include in the present progress report. The reader is redirected to the more appropriate "Report on Task 1".

Here below we present an example of SWOT analysis for the Solar energy sector (Figure 5) is reported.

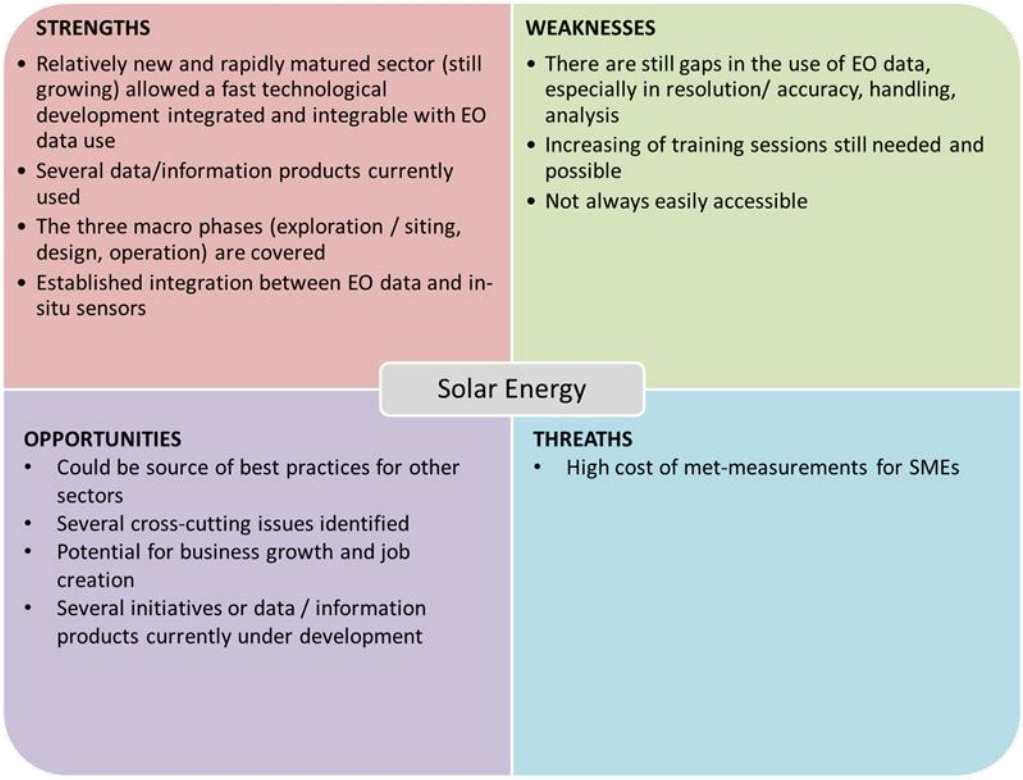


Figure 5 SWOT Analysis for Solar energy

5.4.Overall conclusions

A number of relevant outstanding issues arose from the developed research at this stage, in addition to the several findings reported in the previous sections along the structure of the study. Such general considerations are summarized and reported below, as a list of relevant hints for successive in-depth analysis:

- Presently, the source of EO data that can actually approach the requirements in both space and time needed by the energy sector is through remote sensing. Thus, the tools to analyse such kind of data are mostly designed to manage big raster data files from many kind of radiometers and radiosignals. There are two generic wide-purpose tools to do that: SEADAS from NASA and SNAP from ESA;
- Additionally, in order to carry more quantitative analysis, to combine such tools with some kind of GIS software is expected. QGIS is considered a useful tool because it is open source, powerful to carry most of the GIS manipulations and flexible enough to allow the integration of new specific capabilities designed by users;
- EO data and information products can be integrated with current Design/Energy SW or Tools depending basically on the macro phase(s) of the value chain that wants to be covered. Thus for a general resource exploration phase EO data, as for example on wind, wave and ocean currents, can be used from climatologist coming from reanalysis, which result from combining numerical models an in situ historical observations;
- For a design phase, much more detailed EO information (mostly in space) should be needed and here, historical as well as remote sensing data could be used. Although detailed observational campaigns with in-situ instruments during relative short time periods are often devised;
- For the operation phase, the direct use of remote sensing data could be of great help, but normally what is more important is to get information on accurate forecasting. The EO data enters in this activity through assimilation techniques of data into operational forecasting models;
- Product and information could be provided as Open Standard Web Services (eg. OGC) and can easily be included into desktop tools with Internet connexion. QGIS can load various Web Services based resources (eg. WMS, WFS, NetCDF);
- EO data and information products can be integrated with current energy System models. Energy system models require to deal with high resolution both in space and in time of the resource availability, namely wind, wave, etc. In such sectors weather and ocean forecasting systems are needed to foresee the levels of power that could be available in real time. All these forecasting systems incorporate in an essential way (through data assimilation) EO data to get good forecasts. For the solar energy sector is less critical because insolation is more predictable and only temperature and cloud coverage may affect its performance;
- In-situ sensors are integrated with EO data in two ways. Firstly, they are used as the ground truth of remote sensing products just to calibrate and correct biases of remote sensors. Secondly, they are directly integrated into numerical models to build reanalysis and to provide forecasting systems. An example is a network of met-ocean buoys at sea to measure atmospheric and oceanic parameters of the ocean-atmosphere interface (wind, wave, sea currents, water and air temperatures, etc.). These networks are used as reference systems for remote sensing calibration and are regularly integrated in weather and ocean forecasting tools.
- In-situ measurements are crucial for calibration / validation of EO derived solar radiation measurements. All existing Satelitte based database (e.g. SoDa http://soda-pro.com/ and CAMS Radiation http://www.soda-pro.com/webservices/radiation/cams-radiation-service) extensively use in-situ measurements for calibration and validation. Incomplete time series can be completed as well with satellite-based data.

6. TASK 2 – RESEARCH AND DEVELOPMENT (R&D) NEEDS

6.1.Overall methodological approach

The identification and assessment of the R&D needs was performed mainly through desk research, and notably reviewing literature, communications, conference proceedings, workshops minutes and EU, national and regional activities or projects.

The identification of these R&D Needs was naturally supported by the results of Task 1. R&D needs are organized within the different RE sectors, plus one additional "Cross-cutting" sector, which collects all the relevant transversal issues, covering more or less all of the sectors.

Actors needed to implement the R&D identified have been found cross-linking the value chain of the specific RE sector, the value chain of the EO framework and the input received during the workshop.

The main outcome of the analysis is the list of the preliminary R&D Needs to be submitted to the stakeholders for preliminary desk consultation and workshop interactions. Workshop homework document preparation and preparatory actions were done during September, including the consolidation of the homework results.

The objective of the workshop was to validate the findings of the first subtask of Task 2.

The outcome of the workshop will serve as input to the following Task 3.

The actual timeline of activities for the present task is depicted in the following Figure 6.

The following dates for meetings or deadlines for deliverable have been drafted:

- first consultative workshop: 2nd October 2018
- draft report on Task 2: 1st December
- progress meeting: between 3rd and 14th December
- report on Task 2: before 14th December
- progress Report: 1st December

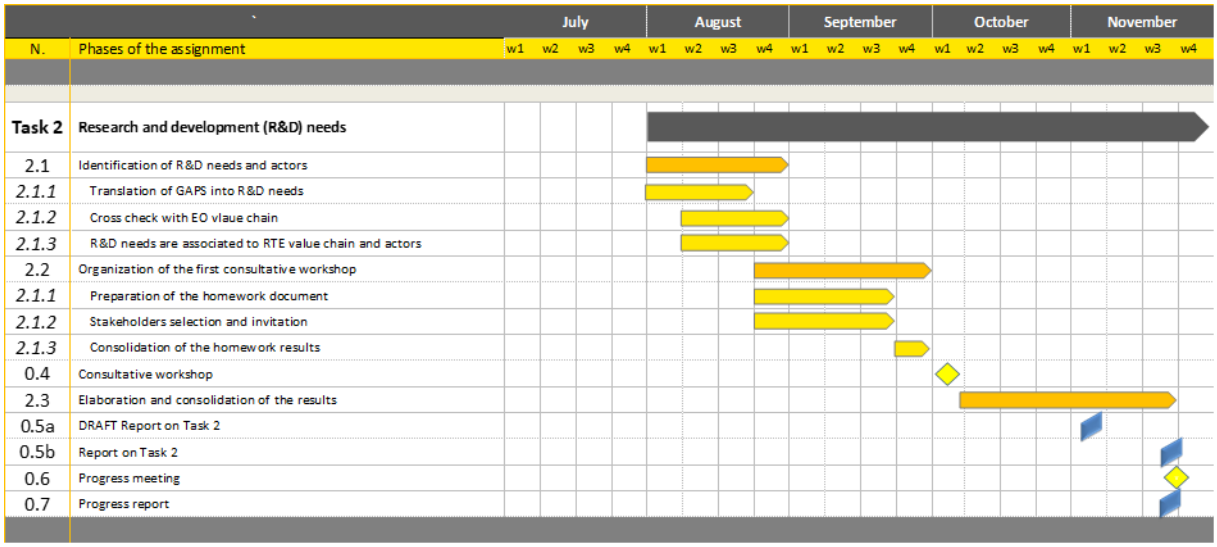


Figure 6 Detailed timeline for Task 2

6.2.Sub-Task 2.1: Identification of R&D needs and actors

For each of the six energy sectors identified (solar energy, geothermal energy, on- and off-shore wind, bioenergy, marine energy (wave and tide), hydropower) the following activities are completed:

- identification of the R&D needs associated to gaps found in Task 1;
- identification of the associated actions for implementation;
- association of the potential actors potentially involved;
- provision of the preliminary scores to the R&D needs for four main parameters;
- consolidation of the input.

Activities 3 and 4 above mentioned are actually related to subtask 2.2 but for practical issue (logical flow of actions performed) they are reported here.

For the collection of the data, a word template was prepared and distributed to the sectorial Expert.

Starting from the gap analysis and the SWOT analysis performed in Task 1 and through the means of an additional desk research, the gaps, the weaknesses, the threats are transformed into R&D needs and associated actions for implementation by the sectorial experts.

The R&D NEEDS (and correlated ACTIONS for the implementation) were then evaluated against 4 main parameters (see below), in accordance to stakeholders' view and expertise. Stakeholders filled in the energy sector of own expertise and tried to evaluate also the other sectors in accordance to their critical thinking, considering that the ACTIONS are more related on the use of EO data rather than on specific sectorial technologies.

Stakeholders also evaluated an additional cross-cutting sector, which collects common issues to be evaluated.

Stakeholders were asked to write down the numerical vote and a short explanation of the choice made. They could also decide to introduce (and evaluate) additional R&D needs if it would have been the case.

Final objective of the workshop was to find consensus among the participants on the evaluation given and to prioritize the actions for the future steps of the study.

The four parameters used to prioritize the R&D needs are:

- Impact: the impact in terms of "size" of the needs. It will impact just a small portion of the energy sector? More than one energy sector? Just a restricted geographical area (and as a consequence, population or community) or it is more world spread?
- Technical feasibility: are the actions/techniques needed to cover the needs mature? Research is on-going? Just an idea? Which is the TRL of the actions?
- Timeframe to implementation: which is the time frame needed to implement the actions: 2020 or 2030? And despite the technical feasibility, there are other factors hampering the adoption (non-technological barriers), i.e. policies, training, knowledge, need of capacity building …?
- Estimated Cost for implementation: which is the expected cost for implementing the actions needed to fulfill the need?

Points are given in order to reward the higher scores and allow the prioritization. In **Error! Reference source not found.** the scoring system is reported for each parameter.

Table 7 Description of the scoring system

Points	Value	Description
		IMPACT
7	Very high	Most of the communities or topics will be impacted
4	High	More than one community or topic will be impacted

2	Medium	A community or topic is identified
1	Low	A small community or topic is identified
0	None	Not able to identify a community of topic
FEASIBILITY		
7	Very high	There is a mature technique (TRL 8-9)
4	High	The technique is entering or is in its demonstration phase (TRL 6-7)
2	Medium	There was already research and maturing the technique is need (TRL 4-5)
1	Low	There is an idea to fill the gap that needs research (TRL 1 -3)
0	None	There is not technology foreseen to fill the gap
TIMEFRAME TO IMPLEMENTATION (non tech. barriers)		
7	Very short	Horizon 2020, basically there are no non-technical barriers
4	Short	Within 5 years
2	Medium	Within 10 years
1	Long	More than 10 years
0	Very Long	More than 15 years
ESTIMATED COST FOR IMPLEMENTATION		
7	Very low	Less than 0,5 M€
4	Low	Between 0,5 M€ and 2M€
2	Medium	Between 2 M€ and 5M€
1	High	Between 5 and 20 M€
0	Very high	More than 20 M€

The headlines of the two template tables are reported here below for, respectively, R&D needs and Actions definition and actors identification (Table 8) and scoring definition (Table 9).

Table 8 Template for R&D needs and Actions definition and actors identification

Preliminary list of R&D needs	Actions	Macro phase(s) of the value chain	Actors associated
		Exploration/siting Design Operation	

Table 9 Template for scores assignment

Preliminary list of R&D needs	Actions	Impact	Technical feasibility	Timeframe to implementation	Estimated Cost for implementation

The sectorial experts, with the support of the EO expert, compiled the template with Table 8 with the retrieved information.

The files provided by the experts, resumed and homogenised was transferred to Table 9 and the new file was then sent to the stakeholders participating at the workshop asking them to provide the right information, as explained above.

The contractor collected the scores from the stakeholders and calculated an average score for each R&D needs as starting point for the workshop discussion.

Due to the high amount of data available from the analysis, every one of the two tables is repeated for the 6 energy sectors plus the Cross-cutting area, all the results are available in the "Report on Task 2".

6.3.Sub-Task 2.2: Organization of the first consultative workshop

Two workshops are foreseen by the study to be held in Brussels. The first one is described in the present chapter.

The Contractor identified and selected participants in agreement with DG RTD, developed a draft agenda and suggested the speakers. Also, it took care of all practical matters concerning the organization of the workshops (logistics, secretarial services for registration, administrative costs, travel and subsistence costs for participants). Venue and catering were as well provided by the Consortium. The list of stakeholders participating in the first workshop is reported in Appendix A.

The workshop was organized at EY premises, in Diegem, Belgium, the 2nd of October 2018;

Stakeholders invited and participating to the workshop and Stakeholders interested in contributing but not able to join were preliminary engaged and received the preparatory material, in order to optimize the available time during the workshops (this document is described in the previous chapter related to sub-Task 2.1).

The agenda proposed is reported here below in Table 10.

Table 10 Workshop Agenda

Time	Action
8.30	Registration of the participants
9.00	Welcome, tour de table and study presentation
9.20	Presentation of the work to be done during the day, workshop goal and scope
9.30	4 Sectorial session with smart games (45 mins each energy sector) (Coffee break included) – 2 in parallel
	Session A1: Solar Energy Session A2: Hydropower
	Session B1: Bio-energy Session B2: Marine energy
12.45	Lunch break
13.30	3 Sectorial session with smart games (45 mins each energy sector) (Coffee break included)
	Session C1: Geothermal energy Session C2: Wind energy
	Session D: Cross cutting issues
16.45	Summary and consolidation of the work done, next steps
17.00	End of the workshop

In respect to the original planning, it was decided prior to the workshop to perform parallel sessions to allow more time available for the discussion. Stakeholders decided in which of the two sessions would have provided their direct contribution.

Main objective of the workshop was to present and receive feedback on the draft R&D needs identified through the desk research:

- what are the critical areas of major dissent?
- what are the proposed routes to converge?
- what is the impact (in terms of size) of the needs identified?
- what is the technical feasibility of the solution for the needs identified?
- what is the timeframe of implementation of the solution for the needs identified?

During the workshop, the consensus on the input sent was driven by a smart game, explained below.

Prior to the workshop, the contractor prepared two sets of "playing" cards (two cards for each R&D need), and two A0 posters for each sector.

The two sets of cards contain:

- First set of cards: each card of this set contains on the front the R&D need identified, and on the back the results of the Impact and Technical feasibility evaluations. These cards contain the total score and the split for each level.
- Second set of cards: each card of this set contains on the front the R&D Need identified, on the back the results of the Timeframe to implementation and Estimated Cost evaluations. The card contains the total score and the split for each level.

The first set is used in the first part of the session, while the second set in the second part. For this reason, the parameters are described separately in the two sets of cards in order to avoid stakeholders to be biased when they are agreeing on only two of them during first session.

Here below, an example of both type of cards related to cross-cutting issues (front on the left, rear on the right) is shown.

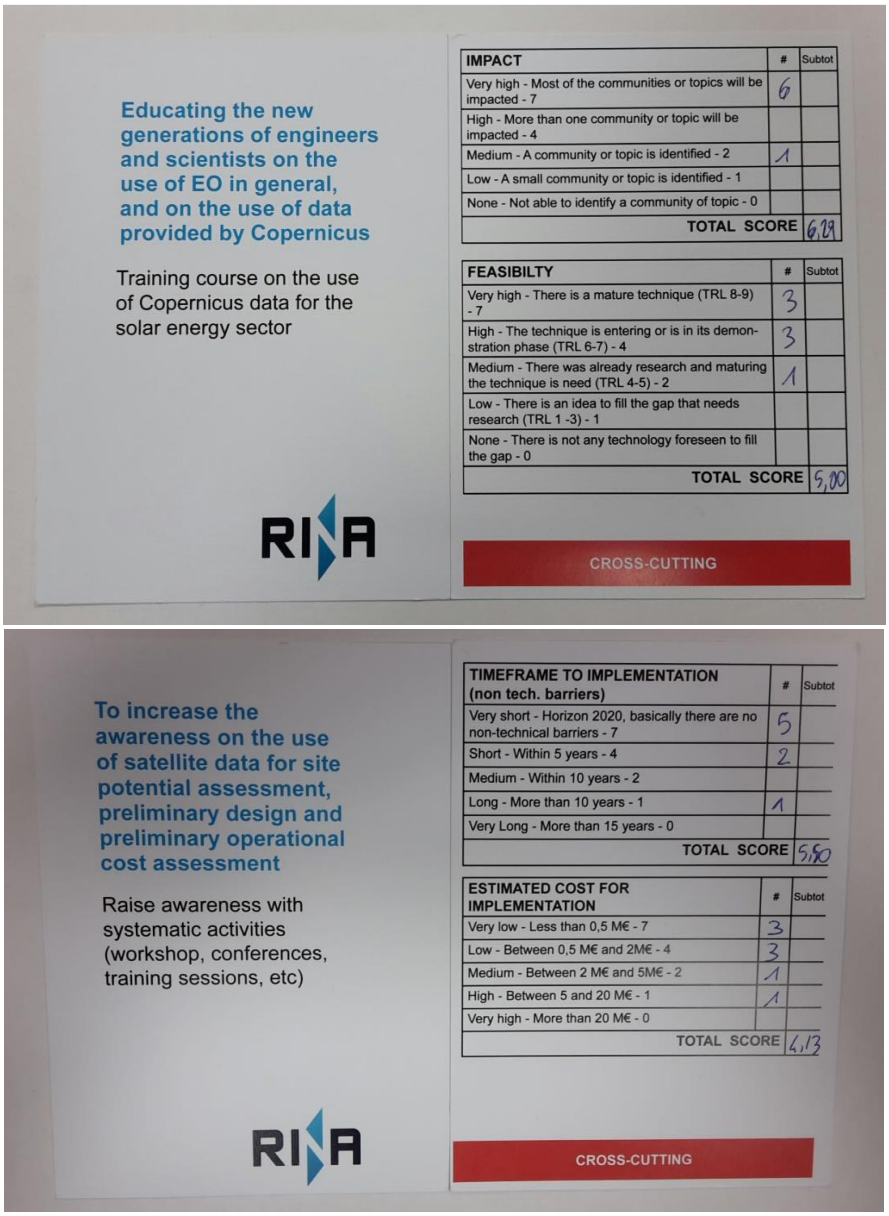


Figure 7 Card examples

The cards have a color code in accordance to the energy sector in order to ease the individuation.

Table 11 Color code for energy sector

Category	Color code
Wind energy	
Solar energy	
Geothermal energy	
Bioenergy	
Marine energy	
Hydropower	
Cross-cutting	

First poster contains a Cartesian graph, having in abscissa the Technical feasibility and in ordinate the Impact.

Stakeholders are provided with the first set of cards and an handout containing the whole set of the R&D needs identified and their desk evaluation is always available on the pc.

They must find an agreement on the scores assigned to the first two parameters (Impact and Feasibility) and place the cards in the graph (**Error! Reference source not found.** on the left p resents a possible cards' positioning).

At the end of the first phase of the session, it is possible to identify (Figure 8 on the right) the Frontrunners (high impact, high feasibility), the second group and the third group. The R&D Needs positioned to the 4th quarter (low impact, low feasibility) are discharged.

For the following prioritisation phase, the Frontrunners R&D Needs are taken into account. In case Frontrunners are less than 10, the whole set of the R&D needs of the second group is considered. Third group is considered for the next phase only if the sum of Frontrunners and second group is less than 10. As it is possible to understand, priority for the selection is given to the expected Impact of the R&D Needs.

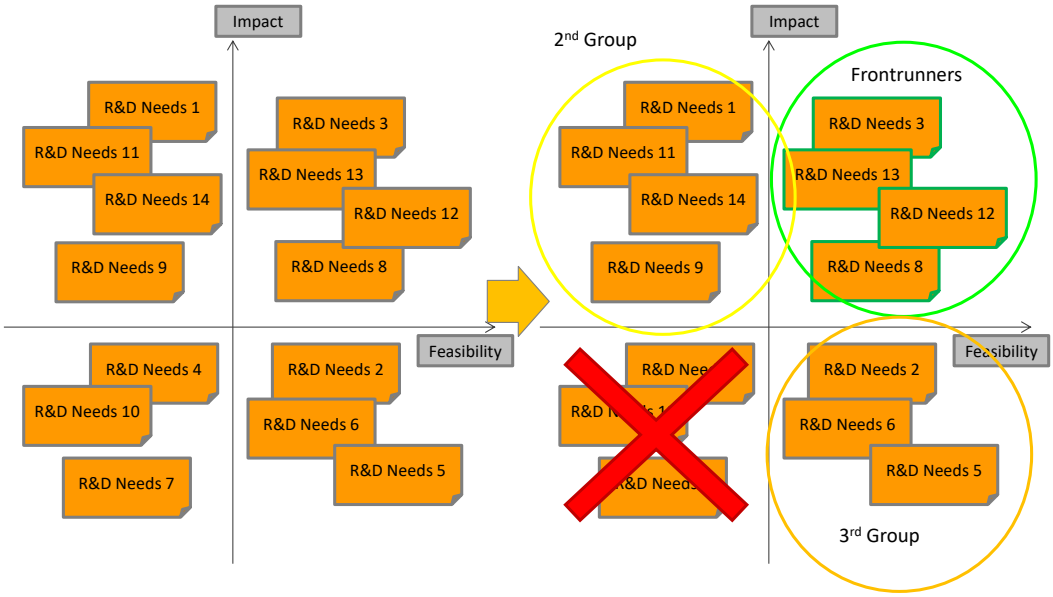


Figure 8 Smart game: first phase

In the second prioritisation phase, stakeholders are provided with the second set of cards, containing only the R&D needs that passed the first phase. Stakeholders must find an agreement on the scores assigned to the second two parameters (Timeframe and Cost for implementation) and place the cards in a second Cartesian graph, having in abscissa the Estimated Cost and in ordinate the Time of

implementation (Figure 9 on the left presents a possible cards' positioning). The ideal prioritisation is shown in Figure 9 on the right. According to what reported in the parameters explanation above higher score is given to lower time for implementation and lower estimated cost for implementation.

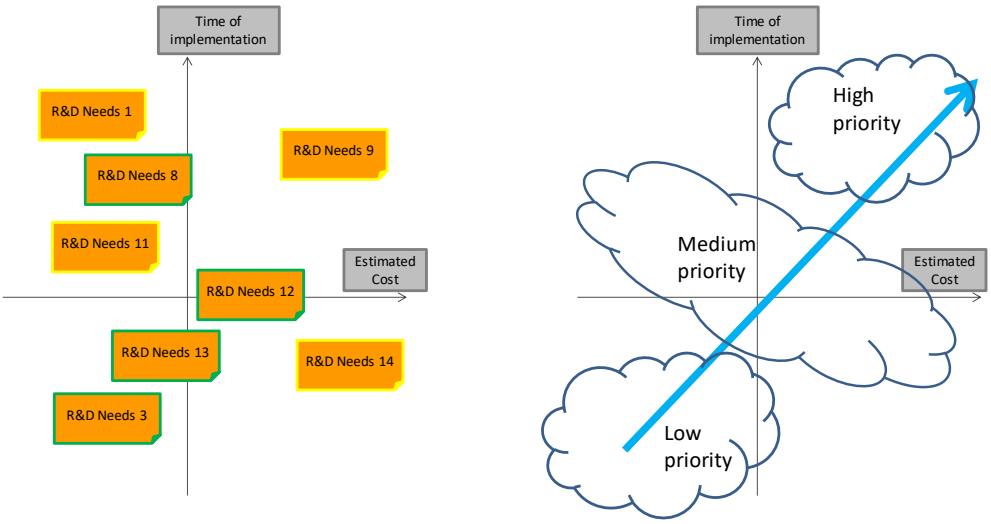


Figure 9 Smart game: second phase

Some picture here below (Figure 10, Figure 11 and Figure 12) shows the interaction between the participants.

Figure 10 Discussion among the participants during the parallel sessions

Figure 11 Common session on cross-cutting issues

Figure 12 Placing the cards on the graph

6.4.Sub-Task 2.3: Elaboration and consolidation of the results

In accordance to the results of the desk analysis and the results of the workshop, a final prioritization of actions has been derived and summarized for each energy sector plus the cross-cutting area, from Table 12 to Table 18. These tables are the starting point for the work to be performed in Task 3, which is presented in the following Chapter 7.

The rationale behind the final prioritization, applied for each of the seven sectors and after workshop validation process, is the following: firstly R&D Needs and Actions evaluated as "frontrunner", in terms of Impact and Technical feasibility, are deemed as worthy of being selected for the Cost Benefit analysis (CBA). "Frontrunner" Needs are then ranked with respect to Timeframe and Estimated cost for implementation. In the Marine energy case, since no frontrunner Needs were identified (nor in the 2nd group), the selection was performed starting from 3rd group.

In particular, for cross cutting issues, in accordance to the comments received from the experts during the validation workshop, an additional refinement is made, clustering R&D needs related to the same general topic e.g. training and awareness).

It is interesting to point out the Workshop validation allowed to consolidate the outcomes of the survey and desk study without any major area of dissent but providing also some additional refinements and specific inputs.

In total, 34 prioritized needs are identified, split as per the following: 7 for solar energy, 2 for geothermal energy, 6 for wind energy, 5 for bioenergy, 1 for marine energy, 6 for hydropower and 7 for the cross-cutting area.

As final note, it is possible to see within the bioenergy table (Table 15) that some actions were differently evaluated by the experts whether considering implementation at EU level or global level.

In the following table, under the "Evaluation" column, the previous ranking extrapolated from the previous tables is reported. The current ranking (under the column "Ranking") reports the potential priority up to the current status of the R&D needs and associated actions. Frontrunner and High bring to a "1", Frontrunner and Medium to "2" and Frontrunner and Low to "3". In case of Marine energy the only R&D need identified in ranked as "3".

Table 12 Prioritized R&D Needs and Actions for Solar energy

R&D needs	Actions	Evaluation	Ranking
To improve the detection of aerosols (using the Sentinels) to obtain a better clear sky irradiation – especially over bright surfaces (deserts)	Identify the correct data to be transformed in this new information product	FRONTRUNNER HIGH	1
To increase accurate in situ measurements in most of the world. Large networks measuring radiation, such as GAW, BSRN have a limited coverage. National meteo networks are by definition limited and in addition, many of them do not measure radiation, except sunshine duration. More in-situ observations, higher level of networking	Meta-Network: Opportunities exist to get access to in-situ measurements coming from numerous PV plant operators all over Europe. PV plant operators do hold in-situ measurements for their daily work. An extra effort is needed to identify, convince, access and connect their data. As a result one could create a Meta-Network of private providers using open, standard and interoperable technologies. This Meta-Network would complement existing well known meteo networks (GAW, BSRN).	FRONTRUNNER HIGH	1
To create long term satellite data and how to measure spectral irradiance at acceptable costs.	Develop applicable (cheap, simple, sufficiently accurate) measurement methods that improve models and validate them	FRONTRUNNER HIGH	1

R&D needs	Actions	Evaluation	Ranking
To extend the coverages of solar irradiances and cloud statistics outside the traditional Meteosat coverage	Investigate the possibility to integrate new data to the actual available sources	FRONTRUNNER MEDIUM	2
To continue Meteosat-East services – rather at 60°East than only 40° for better coverage of Asian countries	To understand the possibility to vary the satellite trajectories		
To improve retrieval accuracy of irradiances for conditions of sunrise, multi-layered clouds and thin cirrus clouds	Identify the correct data to be transformed in this new information product	FRONTRUNNER MEDIUM	2
To increase spatial and temporal resolution at different scales, from intra-day to multi-decennial time horizons: improved spatial accuracy and quality, High-Resolution (HR) and Very-High Spatial Resolution (VHR) data needed (for solar cadastres and better solar resource assessment at urban scale)	Investigate how the spatial and temporal resolution of the satellite measurements can be refined for future satellites.	FRONTRUNNER LOW	3
To validate satellite-retrieved solar irradiance results on a global scale with many more measurement stations for ground truth especially in tropical and subtropical areas	Better integration with in-situ sensors and data integration within existing information products	FRONTRUNNER LOW	3

Table 13 Prioritized R&D Needs and Actions for Geothermal energy

R&D needs	Actions	Evaluation	Ranking
To monitor temperature anomalies as indicator of potential geothermal sites	New sensing technologies More economic in situ sensors	FRONTRUNNER MEDIUM	2
To enhance the monitoring of the ground subsidence	New sensing technologies, More economic in situ sensors, coupled with satellite imagery	FRONTRUNNER MEDIUM	2

Table 14 Prioritized R&D Needs and Actions for Wind energy

R&D needs	Actions	Evaluation	Ranking
To improve wind resource maps particularly for offshore, for improved long term wind resource assessments	Creating a common database	FRONTRUNNER MEDIUM	2
To increase the resolution of the meteorological numerical models, according to the requirements for wind projects development	Increase horizontal resolution for lower atmosphere parameters, and provide them at different heights above ground instead of pressure levels. If reanalysis data could reliably predict ground conditions, then that would be a huge step forward in wind assessment as it could dispense with/reduce the need for costly on-site wind measurements.	FRONTRUNNER MEDIUM	2

R&D needs	Actions	Evaluation	Ranking
To connect and uniform the existing databases on historical microwave data	Creating a global climatology of offshore winds	FRONTRUNNER MEDIUM	2
To obtain high resolution surface data for improvement to short term forecasts and long term energy assessments	Creating a common database	FRONTRUNNER MEDIUM	2
To exploit Sentinel-1 for ocean winds. in modelling the lifting of winds, e.g. from 10 m to 100 m (hub height)	New or improved SW releases and training of operators	FRONTRUNNER MEDIUM	2
To monitor sea state monitoring both for planning and operation of wind farms with respect to the likely wave loading characteristics	Creating a common database and more accurate statistical info	FRONTRUNNER LOW	3

Table 15 Prioritized R&D Needs and Actions for Bioenergy

R&D needs	Actions	Evaluation	Ranking
To estimate average biomass production per area unit of a particular crop type, and map the crop types in the agricultural fields of the area of interest	Providing easy use of radar (SAR) satellite data for identification of crop types and estimation of the current biomass	FRONTRUNNER HIGH	1
To develop a network on forest-related reference data.	Developing inventories of data records for existing forest-related reference data.	FRONTRUNNER HIGH EU LOW global	1
To improve the retrieval/modelling of vegetation water content	Developing inventories of data records for several years to identify if the lands are permanently abandoned and thus available for energy/non-food crops cultivation	FRONTRUNNER HIGH EU LOW global	1
To obtain inventories of unused, abandoned and marginal land, suitable for energy crops.	Developing inventories of data records for several years to identify if the lands are permanently abandoned and thus available for energy/non-food crops cultivation	FRONTRUNNER HIGH EU LOW global	1
To use existing biomass terrestrial data (agricultural, forest) from various sources. To use available algorithms to estimate standing forest biomass from remote sensing and terrestrial data. For agricultural biomass crop area estimation and yield are often supported by modelling including meteorological, pedological data and phonological information as well.	Retrieving terrestrial data for ground truthing and the calibration of the regressions between biomass and EO data for biomass potential assessment. E.g. to be integrated with k-nearest neighbours (k-NN) and multiple regressions	FRONTRUNNER MEDIUM	2

Table 16 Prioritized R&D Needs and Actions for Marine energy

R&D needs	Actions	Evaluation	Ranking
To increase accurate in situ measurements in coastal areas for marine renewable energies: bathymetry, type of floor, tides, swell, currents.	More in-situ observations: For bathymetry and type of floor, exploit SAR images or images in visible- NIR range together with computer models.	3RD GROUP MEDIUM	3

Table 17 Prioritized R&D Needs and Actions for Hydropower

R&D needs	Actions	Evaluation	Ranking
To develop downscaling procedure and validation techniques at local (watershed) scale	Development of low-cost sensor networks	FRONTRUNNER HIGH	1
To estimate hydropower potential from snow and ice	To use EO data about snow and ice run-off in order to create models for estimation of energy potential stored in snow and ice	FRONTRUNNER HIGH	1
To improve spatial resolution for land topography assessment. Detection and quantitative evaluation of high-potential areas (in terms of head availability).	Development of EO data processing in order to highlight high-drop areas, which could be developed into high-head penstock installations	FRONTRUNNER MEDIUM	2
To enable 3D monitoring of landslide faces for statistical processing of sudden collapse probability and for scheduling maintenance / corrective actions	Spatial and time data resolution to allow near real-time monitoring	FRONTRUNNER LOW	3
To improve detection of areas affected by landslide phenomena	Image processing for landslide area recognition		
To allow the (at least) qualitative assessment of water flows of rivers	Development of algorithms for the calculation of water depth from EO data	FRONTRUNNER LOW	3
To improve the environmental mapping and characterization of rivers and river disturbances and/or modifications.	Development of algorithms for the qualitative characterisation of the health status of rivers from EO data and on-site sensors	FRONTRUNNER LOW	3

Table 18 Prioritized R&D Needs and Actions for Cross-cutting area

R&D needs	Actions	Evaluation	Ranking
Data that combine high spatial and temporal resolution Combination of multisource EO data	Implementation of schemes for operationally fusing multi source data	FRONTRUNNER HIGH	1
To harmonize the existing databases related to earthquake and seismic hazards	Creation of a common database	FRONTRUNNER HIGH	1

R&D needs	Actions	Evaluation	Ranking
To provide easy and affordable access to SMEs to meteorological measurements	Open access: it is likely a networking activity to demonstrate to governments supporting met-offices that providing easy access at very limited costs to companies will foster the development of renewable energy projects and will support their international commitments in climate and environment	FRONTRUNNER HIGH	1
To provide easy and affordable access to SMEs and local authorities to EO data	Open access and data processing: providing easy access to data and to processing software at very limited costs to companies and/or local authorities will foster the development of renewable energy projects and will support local authorities commitment to promote the projects with higher added value		
Comprehensive documentation and guides of best practices.	Central repository for training	FRONTRUNNER HIGH	1
Educating the new generations of engineers and scientists on the use of EO in general, and on the use of data provided by Copernicus	training course on the use of Copernicus data for the specific energy sector		
To increase the awareness on the use of satellite data for the site potential assessment, to support the preliminary design and preliminary operational cost assessment	Raise awareness: systematic activities (workshop, conferences, training sessions, etc) aimed at raising awareness on the scope and quality of satellite data database, freely on not freely available, and how to use them.		
Awareness of end-users on the potential of EO for renewable energies	Professional trainings and education of stakeholders		
To improve handling of large amounts of data from MTG and Sentinels, especially in nowcasting scenarios	New or improved SW releases able to process this large amount of data	FRONTRUNNER MEDIUM	2
To set up fixed standards for EO data processing	The scientific community have to fix standards for the EO data processing in order to make possible the validation of the results coming from the processing of raw data	FRONTRUNNER MEDIUM	2
To improve spatial and temporal resolution for the assessment of the resources and preliminary design.	Investigate how the spatial and temporal resolution of the satellite measurements can be refined. Part of the solution, already adopted but that can be reinforced, is the integration with local measurement systems. (Altimeter measurements by satellite tracks should be often interpolated, since)	FRONTRUNNER LOW	3

7. TASK 3 – COST BENEFIT ANALYSIS

7.1. Overall methodological approach

Task 3 is divided in three sub-tasks with the overall objective to perform a simple cost/benefit analysis on the implementation of actions aiming to meet the R&D needs identified in the already finished Task 2.

The analysis is divided in five phases.

6. Identification of the main costs incurring when fulfilling a need through the identification of R&D activities to be done.

For each prioritized and selected R&D need, identified actions have an impact in terms of costs to be sustained by both private and public entities. The potential share of public funding is also investigated, based on past initiatives, according to the energy sector, TRL of the actions and type of entity potentially funding the activity.

7. Evaluation of the benefits deriving from the introduction of the new technologies/knowledge/information according to three different parameters, as per the Terms of References:

   - exploitation efficiency (such as more energy produced with the same resource),
   - operation cost saved (such as less cost to produce the same amount of energy),
   - extended exploitation potential thanks to enhanced siting or exploration (such as more opportunities for RE systems).

Cross checking the three parameters with the three main phases of project implementation (Exploration and siting, Design, Operation), the preliminary result was the following matrix (Table 19), where the "X" identifies a match.

Table 19 Phases and parameters for CBA

	Exploration / Siting	Design	Operation
Exploitation efficiency		X	X
Operation cost saved	X	X	X
Extended exploitation potential	X		
Timeframe of impact	Future installations	Future installations	Actual plants Future installations

As a consequence, six scenarios, where the satisfied need is impacting, can be identified. Details on this table are reported in the description of the Task 3.1.

8. Evaluation of the value of the Benefit provided by the action fulfilling each R&D Need against the six scenarios.

The quantification of the four categories of benefit in terms of: a) percentage of cost reduction b) increased production of energy can be quantified only according to the type of need and, especially, according to the energy sector considered. Percentages of improvement were matter of discussion during the workshop with stakeholders in Task 3.2.

9. Evaluation of the magnitude of the impact.

Two other types of data area analysed, derived from previous tasks: size of the impact, i.e. applicability and type of technology installations affected (new and/or already in place installations). Again, this information was matter of discussion during the workshop with stakeholders in Task 3.2.

10. Finalisation of the input through a validation workshop.

The main objective of the validation workshop is to present and receive feedback on the draft Actions needed to cover the R&D needs identified through Task 2, and accompanied by information derived from the Cost Benefit Analysis run in sub-task 3.1.

GANTT Chart (Figure 13) is reported here below.

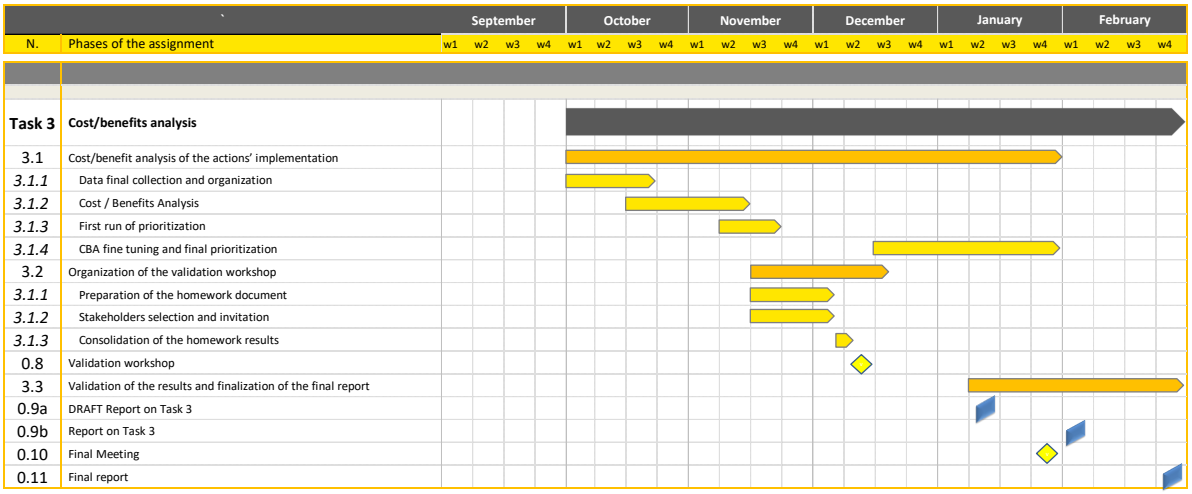


Figure 13 Timeline for Task 3 implementation

7.2.TASK 3.1: COST/BENEFIT ANALYSIS OF THE ACTIONS' IMPLEMENTATION

In accordance to the results of the desk analysis and the results of the workshop of Task 2, a first run of prioritization of actions has been derived and summarized for each energy sector plus the cross-cutting area.

In total, 34 prioritised needs are identified, split as per the following:

1. 7 for solar energy
2. 2 for geothermal energy
3. 6 for wind energy
4. 5 for bioenergy
5. 1 for marine energy
6. 6 for hydropower and
7. 7 for the cross-cutting area.

The tables reported in the previous report, with prioritised R&D needs and correlated actions were the starting point for the work to be performed in Task 3.

Task 3 foresee to perform a series of different activities including an estimation of cost's ranges and an estimation of the possible benefits.

For each prioritised and selected R&D need, a set of actions fulfilling the needs are associated. These main actions will have an impact in terms of costs to be sustained for the fulfillment of these needs. These costs are borne by the actors involved (private and/or public entities) and can be publicly financed. The cost range has been preliminary drafted during the previous phase and validated by external stakeholders.

The energy sector experts, altogether with the EO data expert, were asked to provide their expertise in defining, for the first set of tables (see template reported in Table 21):

- The final list of the main actions;
- A better estimation of the cost range already provided;
- The possible need of public funding (Yes/No);
- The estimation of the possible share of funding (%).

According to the Tender's Terms of Reference the evaluation of the benefits, resulting from the introduction of the new technologies/knowledge/information (derived from the R&D needs fulfillment), must be done according to three different objectives/frameworks:

- exploitation efficiency (more energy produced with the same resource),
- operation cost saved (less cost to produce the same amount of energy),
- extended exploitation potential thanks to enhanced siting or exploration (more opportunities for RE systems).

On the other hand, covering the R&D Needs identified in the three main phases of project implementation (Exploration and siting, Design, Operation) means to affect positively already built (in-place) technology installations and/or new (still to be built) technology installations.

The following matrix (Table 20) is the result of the combination of what said above. The present table was already discussed and validated with the EC.

Table 20 Creation of the scenarios

Objective	Parameters	Phase	Impact on technology installations
Exploitation efficiency (more energy produced with the same resource)	Production of energy	Design	New installations
		Operation	Already in-place installations
			New installations
Operation cost saved (less cost to produce the same amount of energy)	Energy cost reduction	Design	New installations
		Operation	Already in-place installations
			New installations
Extended exploitation potential thanks to enhanced siting or exploration (more opportunities for RE systems)	Production of energy Energy cost reduction	Exploration / Siting	New installations

As well for the second set of tables (see template provided in Table 22), the energy experts with the support of the EO data expert, defined the order of magnitude (O.of M.) of improvement for the 2 parameters reported above.

For the definition of the order of magnitude energy experts took into account the worldwide applicability. Here below an example of information flow is reported.

E.g. Fulfilling R&D Need n°1 can bring a 10% improvement in the Production of energy. It can be applied to the 30% (in terms of energy produced) of (already in place and new) installations. Values to be inserted in the table: 10% and 30%. Globally the improvement provided will be of the 10% * 30% = 3%.

Table 21 R&D Needs and Actions cost range and public financing definition

R&D needs	Actions	Cost range	Need of Public Financing	Percentage of Public Financing

Table 22 R&D Needs and Actions impact and applicability

R&D Need	Actions	Parameters	O. of M. for improvement(%)	O. of M. for applicability (%)
		Production of energy Energy cost reduction		

The sectorial experts, with the support of the EO expert, compiled the template within Table 21 and Table 22 with the retrieved information.

The files provided by the experts were resumed, homogenised and sent to the stakeholders participating in the workshop. The stakeholders were asked to confirm or modify the assumptions made, and to provide any additional information, if relevant.

Due to the high amount of data available from the analysis, every one of the two tables is repeated for the 6 energy sectors plus the Cross-cutting area, all the results are available in the "Report on Task 3".

7.3.TASK 3.2: ORGANIZATION OF THE FINAL VALIDATION WORKSHOP

For the second workshop as well, the Consortium identified and selected participants in agreement with DG RTD and developed a draft agenda with suggested speakers. Also, RINA took care of all practical matters concerning the organization of the workshops (logistics, secretarial services for registration, administrative costs, travel and subsistence costs for participants). Venue and catering were provided by the EC.

The second workshop was held in Brussels, at EC - DG RTD premises, the 16th January 2019.

Stakeholders that were invited and participated in the workshop as well as stakeholders interested in contributing, but not able to join, were preliminary engaged and received preparatory material, to optimise the available time during the workshop.

The agenda proposed for the second workshop (and reported afterwards, Table 23) is similar to the previous one: 7 sectorial sessions of 45 minutes, one for each of the six energy sectors plus one additional "Cross-cutting" session, collecting all the transversal issues.

Stakeholders were asked to participate in group to seven sessions, free to intervene in the discussion according to their own expertise.

This second workshop has the main objective of presenting and receiving feedback on the Cost Benefit Analysis, by answering the following questions:

- what are the critical areas of major dissent?
- what are the proposed routes to converge?
- is the cost range associated to the actions correct?
- are the actors correctly identified?
- are the percentages of improvement correctly assigned?
- is the share between public and private funding sustainable?

Stakeholders were asked to read a draft document of the cost benefit analysis and the assumptions made. The different pieces of information listed above, i.e. actions, cost associated, actors identified, percentages of improvement, share between public and private funding, were highlighted in the document and stakeholders were preliminary asked to provide comments, in a closed and guided way.

The documents sent to the stakeholders were collected and analysed by RINA, aggregated and elaborated prior to the workshop.

The final objective of the workshop was to build real time consensus regarding the input sent and to provide a final prioritisation, driven by a smart game.

The smart game proposed was a method of prioritisation in which participants were asked to assign a relative value to a list of items by spending an imaginary €100. By using the concept of cash, the exercise captured more attention and kept participants more engaged than an arbitrary point or a ranking system.

To set up the game, two posters were prepared containing the whole list of R&D needs.

The euros represent the importance of items, and stakeholders must decide as a single person or as a group on the allocation of the euros across the list, based on the cost/benefit analysis already done.

While assigning their values, stakeholders were asked also to write a brief explanation for the amount, if necessary.

The agenda proposed is reported here below in Table 23.

Table 23 Workshop Agenda

Time	Action
8.30	Registration of the participants
9.00	Welcome, tour de table and study presentation

9.20	Presentation of the work to be done during the day, workshop goal and scope
9.30	4 Sectorial session (45 mins each energy sector) (Coffee break included)
	Session 1: Solar Energy Session 2: Marine energy Session 3: Wind energy Session 4: Bio-energy
13.00	Lunch break
14.00	3 Sectorial session (45 mins each energy sector) (Coffee break included)
	Session 5: Geothermal energy Session 6: Hydropower Session 7: Cross cutting issues
16.30	Smart game for final prioritization, consolidation of the work done
17.00	End of the workshop

Some picture here below (Figure 14, Figure 15) shows the interaction between the participants.

Figure 14 Discussion among the participants during the plenary session

Figure 15 Prioritisation Smart Game, placing the "euros" on the panels

7.4.Task 3.3: Validation of the results and finalisation of the final report

As output of the workshop, for each of the six energy sectors identified (solar energy, geothermal energy, on- and off-shore wind, bioenergy, marine energy (wave and tide), hydropower) and the cross cutting area, the cost/benefit analysis is validated by the stakeholders that provided the whole amount of information necessary to conclude the project. The final prioritisation is given as well, thanks to the smart game made.

The Table 24 presents the final prioritisation. Some of the R&D needs reported resulted as ex aequo, thus they have the same position number.

Table 24 R&D Needs and Actions final prioritisation, based on smart game

Position (out of 34)	R&D Need	Sector
1	To monitor sea state monitoring both for planning and operation of wind farms with respect to the likely wave loading characteristics	WIND ENERGY
2	To increase the accuracy of the in situ measurements in coastal areas for marine renewable energies: bathymetry, seabed geotechnics, tides, swell, currents.	MARINE ENERGY
3	Need of standardisation (format, practices, …) for EO data processing	CROSS CUTTING
3	To improve wind resource maps particularly for offshore, for improved long term wind resource assessments	WIND ENERGY
5	To provide easy and affordable access to SMEs and local authorities to meteorological measurements and EO data	CROSS CUTTING
6	To use existing biomass terrestrial data (agricultural, forest) from various sources. To use available algorithms to estimate standing forest biomass from remote sensing and terrestrial data. For agricultural biomass crop area estimation and yield are often supported by modelling including meteorological, pedological data and phenological information as well.	BIOENERGY
6	To obtain high resolution surface data for improvement to short term forecasts and long term energy assessments	WIND ENERGY
8	Data that combine high spatial and temporal resolution and combination of multisource EO data	CROSS CUTTING
8	To increase the awareness and the level of education on the use of EO data for site potential assessment, to support the preliminary design and preliminary operational cost assessment and decision making for end-users.	CROSS CUTTING
10	To improve spatial resolution for land topography assessment. Detection and quantitative evaluation of high-potential areas (in terms of head availability).	HYDROPOWER
11	To improve the detection of aerosols (using the Sentinels) to obtain a better clear sky irradiation – especially over bright surfaces (deserts)	SOLAR ENERGY
11	To extend the coverages of solar irradiances and cloud statistics outside the traditional Meteosat coverage To continue Meteosat-East services – rather at 60°East than only 40° for better coverage of Asian countries	SOLAR ENERGY
11	To increase spatial and temporal resolution at different scales, from intra-day to multi-decennial time horizons: improved spatial accuracy and quality, High-Resolution (HR) and Very-High Spatial Resolution (VHR) data needed (for solar cadastres and better solar resource assessment at urban scale)	SOLAR ENERGY
11	To obtain inventories of unused, abandoned and marginal land, suitable for energy crops.	BIOENERGY
11	To estimate average biomass production per area unit of a particular crop type, and map the crop types in the agricultural fields of the area of interest	BIOENERGY
16	To enhance the monitoring of the ground subsidence	GEOTHERMAL ENERGY

Position (out of 34)	R&D Need	Sector
16	To increase the resolution of the meteorological numerical models, according to the requirements for wind projects development	WIND ENERGY
16	To validate satellite-retrieved solar irradiance results on a global scale with many more measurement stations for ground truth especially in tropical and subtropical areas	SOLAR ENERGY
19	To exploit Sentinel-1 for ocean winds. in modelling the lifting of winds, e.g. from 10 m to 100 m (hub height)	WIND ENERGY
19	To enable 3D monitoring of landslide faces for statistical processing of sudden collapse probability and for scheduling maintenance / corrective actions. To improve detection of areas affected by landslide phenomena	HYDROPOWER
19	To create long-term satellite data and how to measure spectral irradiance at acceptable costs.	SOLAR ENERGY
19	To develop a network on forest-related reference data.	BIOENERGY
19	To develop downscaling procedure and validation techniques at local (watershed) scale	HYDROPOWER
19	To improve spatial and temporal resolution for the assessment of the resources and preliminary design.	CROSS CUTTING
25	To connect and uniform the existing databases on historical microwave data	WIND ENERGY
25	To improve retrieval accuracy of irradiances for conditions of sunrise, multi-layered clouds and thin cirrus clouds	SOLAR ENERGY
25	To monitor temperature anomalies as indicator of potential geothermal sites	GEOTHERMAL ENERGY
25	To allow the (at least) qualitative assessment of water flows of rivers	HYDROPOWER
25	To increase accurate in situ measurements in most of the world, increase the current level of networking Large networks measuring radiation, such as GAW, BSRN have a limited coverage. National meteo networks are by definition limited and in addition, many of them do not measure radiation, except sunshine duration.	SOLAR ENERGY
30	To improve the retrieval/modelling of vegetation water content	BIOENERGY
30	To estimate hydropower potential from snow and ice	HYDROPOWER
30	To improve the environmental mapping and characterisation of rivers and river disturbances and/or modifications.	HYDROPOWER
30	To harmonise the existing databases related to earthquake and seismic hazards	CROSS CUTTING
30	To improve handling of large amounts of data from MTG and Sentinels, especially in nowcasting scenarios	CROSS CUTTING

8. CONCLUSIONS

As final outcome of the project, each one of the 34 prioritised above mentioned R&D needs is presented in a dedicated fiche, which contains the following information:

- Need description;
- Actions necessary to fulfil the need;
- Actors involved;
- Range of the cost for action implementation;
- Share between public and private funding;
- Benefits derived in terms of increase of energy generation and decrease of energy production cost;
- Final prioritisation.

In total, 34 prioritised needs are identified, split as per the following: 7 for solar energy, 2 for geothermal energy, 6 for wind energy, 5 for bioenergy, 1 for marine energy, 6 for hydropower and 7 for the cross-cutting area.

Fiches are reported in Annex C.

Here below the template of the fiche is reported. The template contains the number of the R&D needs within the sector, the short description, the associated actions and the energy sector associated. In case more than one sector is affected by the R&D need, the secondary ones can be reported below. Sectors are reported along with the colour code.

Then the project phase(s) in which the R&D need can intervene is reported together with the actors potentially involved. This information is extracted from the previous reports.

Evaluation of the impacts for the 4 indicators is provided deriving from the first workshop (cost is also evaluated following the final workshop) and the related graph is reported. For bioenergy the graph sometimes presents also a dashed line, which represents the impact at global level.

Furthermore, the cost range (very high, high, medium, low and very low) is reported with the range of possible investments, coupled with the need of public financing and related average percentage expected of public financing.

In addition, the potential impact of the fulfillment of the R&D needs is evaluated in relation to type of technology installations affected (new and/or already in place installations), potential applicability (order of magnitude, expressed in percentage) and expected improvement (order of magnitude, expressed in percentage) in terms of increased production of energy and reduction of the energy costs.

Finally, the fiche reports the prioritisation rank.

R&D NEED #

Short description			
Actions needed to cover the R&D need			
Main RENEWABLE ENERGY TECHNOLOGY sector associated			**SECTOR 1**
Other RET sector(s) potentially addressed		**SECTOR 2**	**SECTOR 3**
Project phase(s) associated	Exploration, resource assessment, siting	Design	Operation
Actors involved			

Impact	
Feasibility	
Timeframe	
Cost	

Cost range	Need of public financing and related average percentage expected

Impact on technology installations	Expected improvement, OoM (%)
Potential applicability, OoM (%)	Production of energy Energy cost reduction

Overall priority after the Validation Workshop

ANNEX A: LIST OF STAKEHOLDERS– 1ST WORKSHOP

Name	Affiliation	Sector expertise
Thierry Ranchin	Mines - ParisTech	Earth Observation data expert
Hermen Westerbeeke	Rhea Group	Bioenergy
Joannes Berque	Tecnalia	Wind, Solar, Ocean, Hydropower
Sismanidis Panagiotis	NOA	Earth Observation data expert
Emmanuel Mondon	Digital Globe	Earth Observation data expert
Hayati Koyuncu	JeoDijital	Earth Observation data expert
Alessandro Nilberto	Unige	Hydropower, Solar, Wind
Elsa Tejada	Meteo for Energy	Earth Observation data expert
Roberta Boscolo	WMO	Earth Observation data expert
Giacomo Negrinelli	Mott-MacDonald	Hydropower
Geoff Sawyer	EARSC	Earth Observation data expert
David Vinué Visúseh	Universitat Politècnica de València	Earth Observation data expert
Alberto Troccoli	WEM Council	Earth Observation data expert
Gabriele Palma	MP Power	Hydropower, Ocean, Wind
Zhiming Yuan	University of Strathclyde	Ocean
Abigaëlle Peterschmitt	EGEC	Geothermal

ANNEX B: LIST OF STAKEHOLDERS– 2ND WORKSHOP

Name	Affiliation	Sector(s) expertise
Joannès Berque	Tecnalia	Wind energy Solar energy Marine energy Hydropower
Emmanuel Mondon	Digital Globe	Earth Observation data expert
Geoff Sawyer	EARSC	Earth Observation data expert
Mauricio Richter	3E	Solar energy Wind energy Earth Observation data expert
Arslan Ali Nadir	Finnish Meteorological Institute	Earth Observation data expert
Bartalis Zoltan	European Space Agency	Earth Observation data expert
Francioni Elena	e-GEOS	Earth Observation data expert
Tom Waddington	Earth-i	Earth Observation data expert
Muriel Lux	NOVELTIS	Earth Observation data expert
Nilsson Stefan	SMHI	Solar energy Earth Observation data expert
Lucy Kennedy	Spottitt	Solar energy Wind energy Earth Observation data expert
Vital Teresa	GMV	Earth Observation data expert
Lizcano Gil	Vortex	Wind energy Earth Observation data expert
Thierry Ranchin	MINES ParisTech/France	Earth Observation data expert
Joan Masó	CREAF	Bioenergy Earth Observation data expert
Palma Blonda	CNR-ISSIA	Bioenergy Geothermal energy
Anthony Lewis	University College Cork	Marine energy
Jason Schofield	Green Marine (UK) Ltd	Marine energy
Elsa Tejada	Meteo for Energy	Earth Observation data expert
Giacomo Negrinelli	Mott-MacDonald	Hydropower
Abigaëlle Peterschmitt	EGEC	Geothermal energy
Eugenio Realini	GReD	Earth Observation data expert
Carlo De Michele	Polimi	Hydropower
David Bolsée	Belgian Institute for Space Aeronomy BIRA-IASB	Solar energy
Ioanna Karagali	DTU	Wind energy
Santino Diberardino	LNEG	Bioenergy
Joana Mendes	Met Office UK	Earth Observation data expert

ANNEX C: R&D NEEDS FACT SHEETS

R&D NEED #1

Short description

To improve the detection of aerosols (using the Sentinels and the coming EUMETSAT EPS//Metop SG) to obtain a better clear sky irradiation – especially over bright surfaces (e.g. deserts, cities with pollution, etc.)

Actions needed to cover the R&D need

To identify the correct data to be analysed, to create new information products

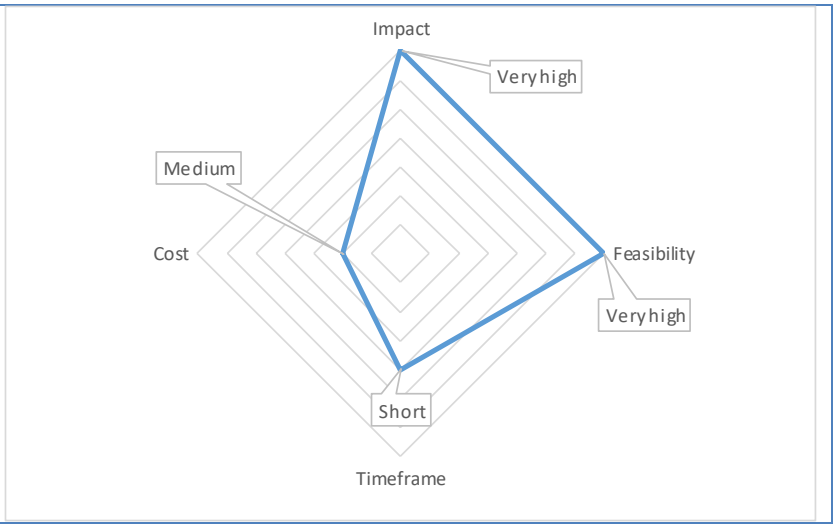
Main RENEWABLE ENERGY TECHNOLOGY sector associated

SOLAR

Other RET sector(s) potentially addressed

Project phase(s) associated	Exploration, resource assessment, siting	Design	Operation
Actors involved	Engineering company, research institute/university, IT and data analysis company		

Impact	Very high
Feasibility	Very high
Timeframe	Short
Cost	Medium



Cost range

MEDIUM
Between 2M€ and 5M€

Need of public financing and related average percentage expected

YES[1], 30%[2]

Impact on technology installations

Already in-place and New installations

Potential applicability, OoM (%)

100%

Expected improvement, OoM (%)

Production of energy	-
Energy cost reduction	1% - 15%

Overall priority after the Validation Workshop

11 out of 34

[1] Not so relevant at a "generic" R&D status – some countries with high presence of desert to host big solar plants (PV,CSP) could finance it to attract new investors and plants as they could be able thanks to this data to have a more accurate estimation of plant production.

[2] Basic Research usually provided by public/research institution, downstream by Private entities.

R&D NEED #2

Short description

To increase accurate in situ measurements in most of the world, increase the current level of networking. Large networks measuring radiation, such as GAW, BSRN have a limited coverage. National meteorological networks are limited and in addition, many of them do not measure radiation, except sunshine duration.

Actions needed to cover the R&D need

To create a Meta-Network of private providers, getting access to in-situ measurements coming from numerous PV plant operators all over Europe. PV plant operators do hold in-situ measurements for their daily work. Meta-Network uses open, standard and interoperable technologies. This Meta-Network would complement existing well known meteorological networks (GAW, BSRN).
To identify, convince, access and connect their data. To create a virtual platform for sharing data and results for the users and play holders

Main RENEWABLE ENERGY TECHNOLOGY sector associated

SOLAR

Other RET sector(s) potentially addressed

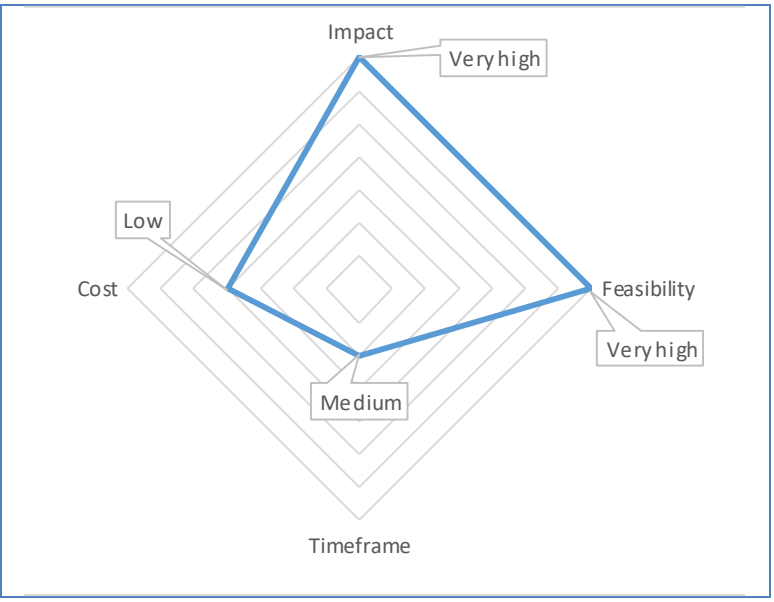
Project phase(s) associated

Exploration, resource assessment, siting | Design | Operation

Actors involved

Non-profit central entity. PV plant owner and managers.

Impact	Very high
Feasibility	Very high
Timeframe	Medium
Cost	Low



Cost range

MEDIUM
Between 2M€ and 5M

Need of public financing and related average percentage expected

YES, 70%

Impact on technology installations

Already in-place and New installations

Potential applicability, OoM (%)

100%

Expected improvement, OoM (%)

Production of energy	Up to 1%
Energy cost reduction	1% - 3%

Overall priority after the Validation Workshop

25 out of 34

R&D NEED #3

Short description

To create long-term satellite data and how to measure spectral irradiance at acceptable costs.

Actions needed to cover the R&D need

To develop applicable (cheap, simple, sufficiently accurate) measurement methods that improve models. To validate these models.

Main RENEWABLE ENERGY TECHNOLOGY sector associated

SOLAR

Other RET sector(s) potentially addressed

Project phase(s) associated

Design Operation

Actors involved

Engineering company, research institute/university, IT and data analysis company

Impact

Very high

Feasibility

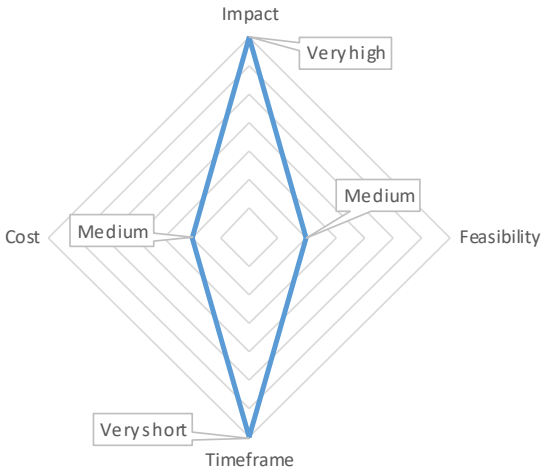
Medium

Timeframe

Very short

Cost

Medium



Cost range

MEDIUM
Between 2M€ and 5M€

Need of public financing and related average percentage expected

YES[3], 70%

Impact on technology installations

Already in-place and New installations

Potential applicability, OoM (%)

100%

Expected improvement, OoM (%)

Production of energy	-
Energy cost reduction	1% - 2%

Overall priority after the Validation Workshop

19 out of 34

[3] This kind of measurement can facilitate localized irradiance measurement via pyranometer.

R&D NEED #4

Short description

To extend the coverages of solar irradiances and cloud statistics outside the traditional Meteosat coverage. To continue Meteosat-East services – rather at 60°East than only 40° for better coverage of Asian countries.[4]

Actions needed to cover the R&D need

To investigate the possibility to integrate new satellite data to the actual available sources. To merge the different measurements derived from all meteorological satellites including Meteosat. To understand the possibility to vary the satellite trajectories

Main RENEWABLE ENERGY TECHNOLOGY sector associated

SOLAR

Other RET sector(s) potentially addressed

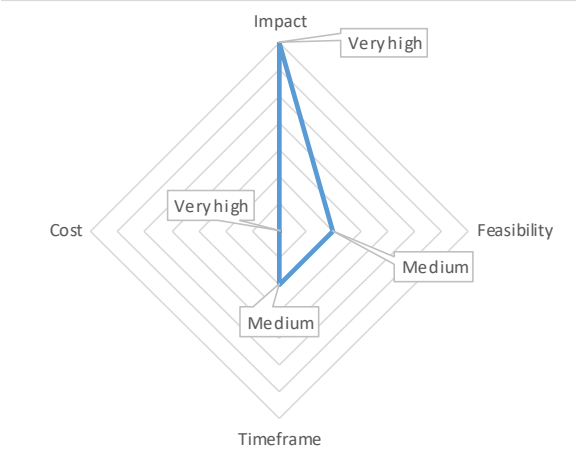
Project phase(s) associated

Exploration, resource assessment, siting | Design | Operation

Actors involved

engineering company, research institute/university, IT and data analysis company, Space Agency

Impact	Very high
Feasibility	Medium
Timeframe	Medium
Cost	Very high



Cost range

VERY HIGH
Higher than 20M€

Need of public financing and related average percentage expected

YES[5], 50%

Impact on technology installations

Already in-place and New installations

Potential applicability, OoM (%)

30%-60%[6]

Expected improvement, OoM (%)

Production of energy	-
Energy cost reduction	1%

Overall priority after the Validation Workshop

11 out of 34

[4] The EUMETSAT IODC (Indian Ocean Data Collection) service is under discussion between the Member States of EUMETSAT, but for the time being Meteosat-8 delivers the operational Indian Ocean Data Coverage Service from its position at 41.5 °E. (having it at 60 °E would be out of question). So one should rather look at other satellite operators, from China, Japan or Korea operating GEO satellites for the Asian Coverage. Moreover, it is also a problem in using Meteosat data at high latitudes.

[5] Depending on how EUMETSAT will provide this kind of Meteosat data, if totally for free or via a pay-per-view/download service

[6] Plants not covered by EUMETSAT

R&D NEED #5

Short description

To improve retrieval accuracy of irradiances for conditions of sunrise, multi-layered clouds and thin cirrus clouds

Actions needed to cover the R&D need

To identify the correct data to be analysed, to create a new information product.

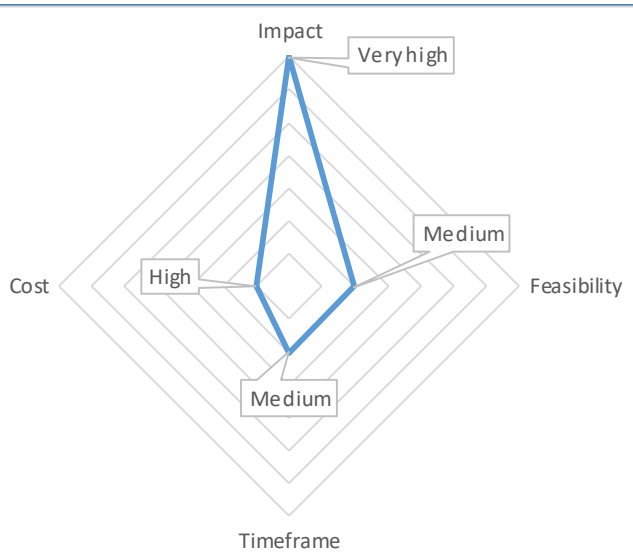
Main RENEWABLE ENERGY TECHNOLOGY sector associated

SOLAR

Other RET sector(s) potentially addressed

Project phase(s) associated	Exploration, resource assessment, siting	Design	Operation
Actors involved	Engineering company, research institute/university, IT and data analysis company		

Impact	Very high
Feasibility	Medium
Timeframe	Medium
Cost	High



Cost range

HIGH
Between 5M€ and 20M€

Need of public financing and related average percentage expected

YES[7], 50% - 70%

Impact on technology installations

Already in-place and New installations

Potential applicability, OoM (%)

100%

Expected improvement, OoM (%)

Production of energy	2%
Energy cost reduction	2%

Overall priority after the Validation Workshop

25 out of 34

[7] The opportunity to have dataset for different kind of "cloud conditions" could facilitate modelling of solar plant performances, providing more accurate "high level" data particularly when we talk about daily irradiation data

R&D NEED #6

Short description

To increase spatial and temporal resolution at different scales, from intra-day to multi-decennial time horizons: improved spatial accuracy and quality, High-Resolution (HR) and Very-High Spatial Resolution (VHR) data needed (for solar cadasters and better solar resource assessment at urban scale)

Actions needed to cover the R&D need

To investigate how the spatial and temporal resolution of the satellite measurements can be refined for future satellites launch.
To leverage Digital Surface Models at urban scale compliant with the development of solar cadastres (other potential applications linked with availability of such a dataset).

Main RENEWABLE ENERGY TECHNOLOGY sector associated

SOLAR

Other RET sector(s) potentially addressed

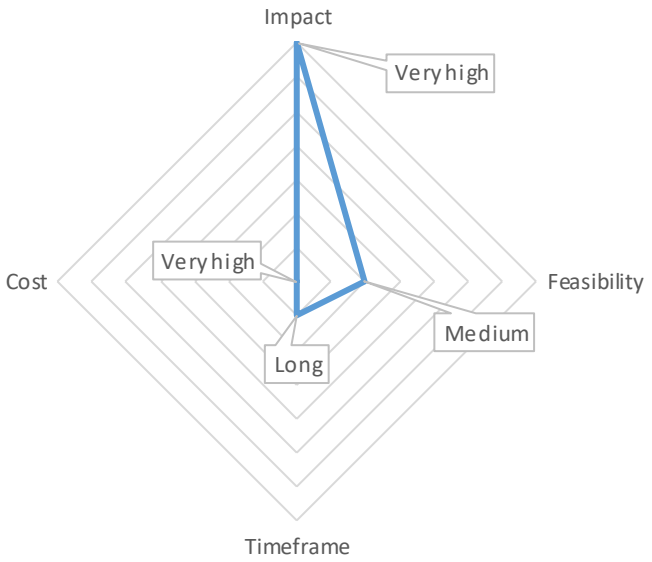
Project phase(s) associated

Exploration, resource assessment, siting | Design | Operation

Actors involved

Engineering company, research institute/university, IT and data analysis company

Impact	Very high
Feasibility	Medium
Timeframe	Long
Cost	Very high



Cost range

VERY HIGH
Higher than 20M

Need of public financing and related average percentage expected

YES[8], 50%

Impact on technology installations

Already in-place and New installations

Potential applicability, OoM (%)

100%

Expected improvement, OoM (%)

Production of energy	10% - 20%
Energy cost reduction	10% - 20%

Overall priority after the Validation Workshop

11 out of 34

[8] As stated, this kind of data are useful both at urban and bright area level – furthermore this kind of data with different time scale resolutions, if well connected with "clean sky irradiation" trends/historical dataset, can easily provide an evaluation of how smog/pollution/climate change effects are affecting solar irradiation at local level (so data useful also for medical/biological purposes)

R&D NEED #7

Short description

To validate satellite-retrieved solar irradiance results on a global scale with many more measurement stations for ground truth especially in tropical and subtropical areas

Actions needed to cover the R&D need

To integrate in a better way these data with in-situ sensors (new measurements stations). To integrate these data within existing information products

Main RENEWABLE ENERGY TECHNOLOGY sector associated

SOLAR

Other RET sector(s) potentially addressed

Project phase(s) associated

Exploration, resource assessment, siting | Design | Operation

Actors involved

Engineering company, research institute/university, IT and data analysis company

Impact

Very high

Feasibility

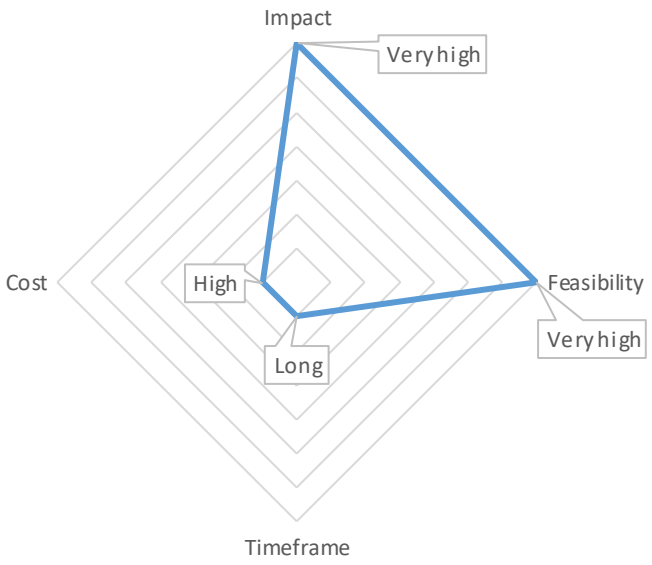
Very high

Timeframe

Long

Cost

High



Cost range

HIGH
Between 5M€ and 20M€

Need of public financing and related average percentage expected

YES[9], 50%

Impact on technology installations

Already in-place and New installations

Potential applicability, OoM (%)

60%

Expected improvement, OoM (%)

Production of energy	2%
Energy cost reduction	2%

Overall priority after the Validation Workshop

16 out of 34

[9] Public funding at regional/local level driven by different purposes – to validate this kind of model even a cheaper/higher level approach (i.e. installing as few irradiation measurements stations as possible to use few data to cross validate irradiation models) could be enough

R&D NEED #1

Short description

To monitor temperature anomalies as indicator of potential geothermal sites.

Actions needed to cover the R&D need

New sensing technologies. More economic in situ sensors.

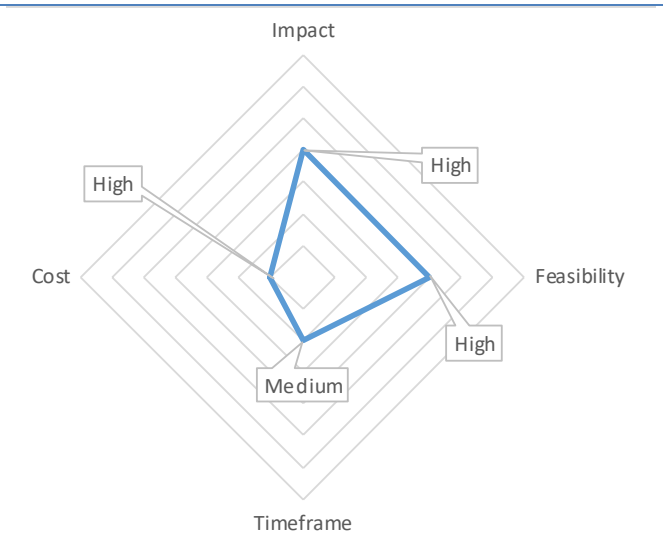
Main RENEWABLE ENERGY TECHNOLOGY sector associated

GEOTHERMAL

Other RET sector(s) potentially addressed

Project phase(s) associated	Exploration, resource assessment, siting — Design
Actors involved	Engineering company, research institute/university, IT and data analysis company

Impact	High
Feasibility	High
Timeframe	Medium
Cost	High



Cost range

HIGH
Between 5M€ and 20M€

Need of public financing and related average percentage expected

YES, 75%

Impact on technology installations

New installations

Potential applicability, OoM (%)

25%

Expected improvement, OoM (%)

Production of energy	0,1%
Energy cost reduction	5%

Overall priority after the Validation Workshop

25 out of 34

R&D NEED #2

Short description

To enhance the monitoring of the ground subsidence

Actions needed to cover the R&D need

New sensing technologies. More economic in situ sensors, coupled with satellite imagery.[10]

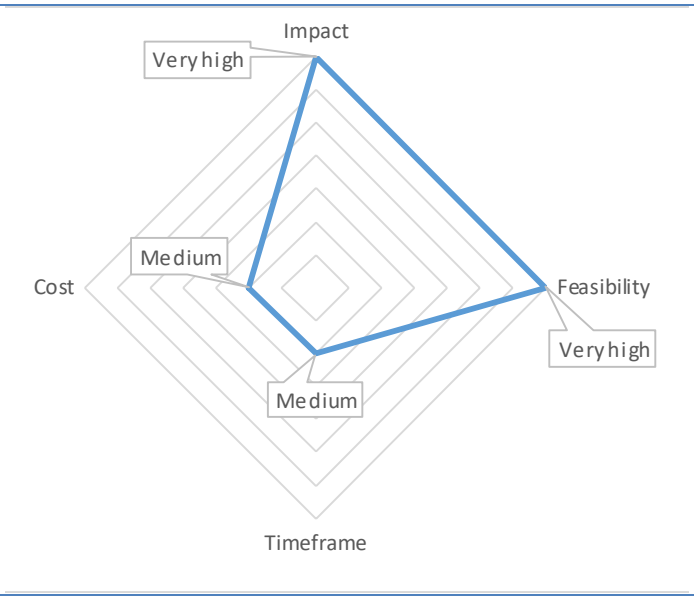
Main RENEWABLE ENERGY TECHNOLOGY sector associated

GEOTHERMAL

Other RET sector(s) potentially addressed

Project phase(s) associated	Exploration, resource assessment, siting	Design	Operation
Actors involved	Engineering company, research institute/university, IT and data analysis company		

Impact	Very high
Feasibility	Very high
Timeframe	Medium
Cost	Medium



Cost range

MEDIUM
Between 2M€ and 5M€

Need of public financing and related average percentage expected

YES, 50%

Impact on technology installations

Already in-place and New installations

Potential applicability, OoM (%)

50%

Expected improvement, OoM (%)

Production of energy	0,1%
Energy cost reduction	0,1%

Overall priority after the Validation Workshop

16 out of 34

[10] InSAR techniques using free Sentinel 1 imagery can be used to determine ground motion to cm's of accuracy BUT at least 30 scenes are needed to get decent results. With Sentinel 1's revisit cycle being 2-3 days that means 60-90 days of data collection to get a decent result. If Sentinel 1 revisit frequency can be brought to daily, then meaning full subsidence data can be updated every month. Synergies with DG-GROW are needed, a tender is to be issued.

R&D NEED #1

Short description

To improve wind resource maps particularly for offshore, for improved long-term wind resource assessments

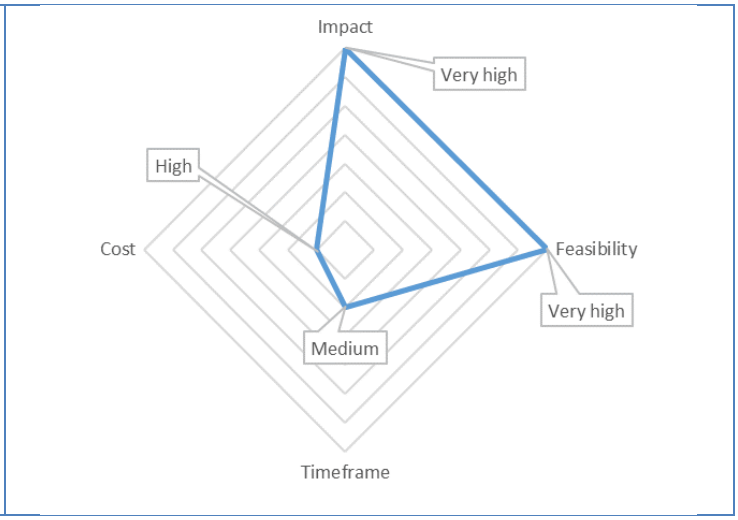
Actions needed to cover the R&D need

To create a common and freely available database.
To provide global coastal datasets to produce and maintain global offshore wind maps.
To contact owners of maritime infrastructures (e.g. oil rigs) and create partnerships to install weather stations and receive data for "global usage".

Main RENEWABLE ENERGY TECHNOLOGY sector associated	WIND
Other RET sector(s) potentially addressed	-

Project phase(s) associated	Exploration, resource assessment, siting
Actors involved	Engineering company, research institute/university, IT and data analysis company

Impact	Very high
Feasibility	Very high
Timeframe	Medium
Cost	High



Cost range

Between 5M€ and 20M€

Need of public financing and related average percentage expected

YES (70 - 100%)

Impact on technology installations

New installations

Potential applicability, OoM (%)

100%

Expected improvement, OoM (%)

Production of energy	1% - 2%
Energy cost reduction	5%

Overall priority after the Validation Workshop

3 out of 34

R&D NEED #2

Short description

To increase the resolution of the numerical weather prediction (NWP) models and data assimilation techniques, according to the requirements for wind projects development and short/long term energy production estimates.

Actions needed to cover the R&D need

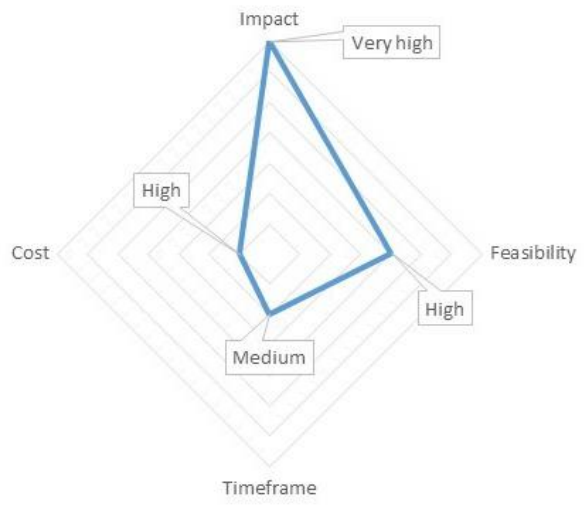
To study the applicability of the reanalysis and EO data to predict in a better way, ground conditions for wind assessment.

To Increase the use high resolution weather related satellite based products as model inputs.

Main RENEWABLE ENERGY TECHNOLOGY sector associated	**WIND**
Other RET sector(s) potentially addressed	-

Project phase(s) associated	Exploration, resource assessment, siting Design Operation
Actors involved	Engineering company, research institute/university, IT and data analysis company

Impact	Very high
Feasibility	High
Timeframe	Medium
Cost	High



Cost range

Between 5M€ and 20M€

Need of public financing and related average percentage expected

YES (50 - 100%)

Impact on technology installations

Already in-place and New installations

Potential applicability, OoM (%)

100%

Expected improvement, OoM (%)

Production of energy	5%
Energy cost reduction	5%

Overall priority after the Validation Workshop

16 out of 34

R&D NEED #3

Short description

To connect and uniform the existing databases on historical microwave data (from both passive microwave radiometer and active microwave scatter-meter) for measuring offshore winds.

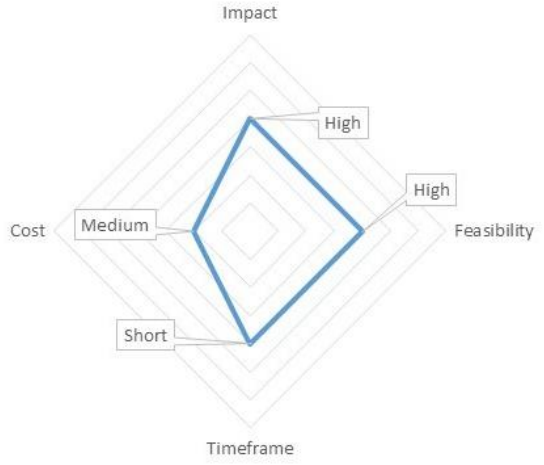
Actions needed to cover the R&D need

To create a global climatology of offshore winds.
To contact/influence major public weather institutes (research and service provider) to create uniform standards.
Possible use of data cube techniques and artificial intelligence.

Main RENEWABLE ENERGY TECHNOLOGY sector associated	**WIND**
Other RET sector(s) potentially addressed	-

Project phase(s) associated	Exploration, resource assessment, siting / Design / Operation
Actors involved	Climate companies, engineering company, research institute/university, IT and data analysis company

Impact	High
Feasibility	High
Timeframe	Short
Cost	Medium



Cost range

Between 2M€ and 5M€

Need of public financing and related average percentage expected

YES (50 - 100%)

Impact on technology installations

Already in-place and New installations

Potential applicability, OoM (%)

100% (of off-shore plants)

Expected improvement, OoM (%)

Production of energy	5%
Energy cost reduction	5%

Overall priority after the Validation Workshop

25 out of 34

R&D NEED #4

Short description

To obtain high resolution surface data (including land use and altimetry) for improvement to short term forecasts and long-term energy assessments.

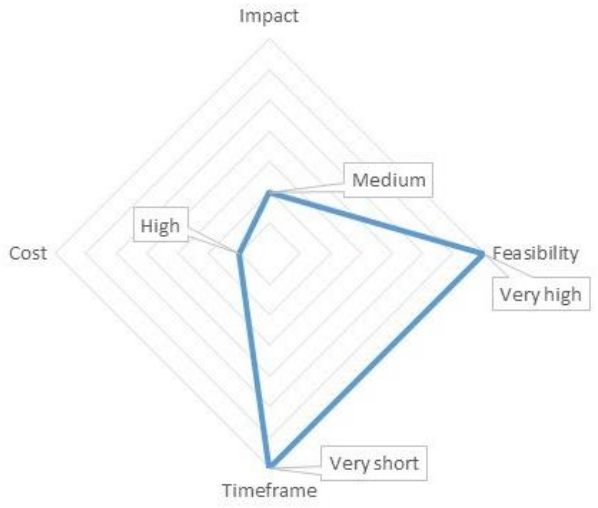
Actions needed to cover the R&D need

To create a common database; more economic in-situ sensors to measure parameters useful to improve wind forecasts.

Main RENEWABLE ENERGY TECHNOLOGY sector associated	WIND
Other RET sector(s) potentially addressed	-

Project phase(s) associated	Exploration, resource assessment, siting / Design / Operation
Actors involved	Engineering company, research institute/university, IT and data analysis company

Impact	Medium
Feasibility	Very high
Timeframe	Very short
Cost	High



Cost range

Between 5M€ and 20M€

Need of public financing and related average percentage expected

YES (30%)

Impact on technology installations

Already in-place and New installations

Potential applicability, OoM (%)

100%

Expected improvement, OoM (%)

Production of energy	5% - 10%
Energy cost reduction	5%

Overall priority after the Validation Workshop

6 out of 34

R&D NEED #5

To exploit Sentinel-1 for ocean winds, in modelling the lifting of winds, e.g. from 10 m to 150 m (hub height).

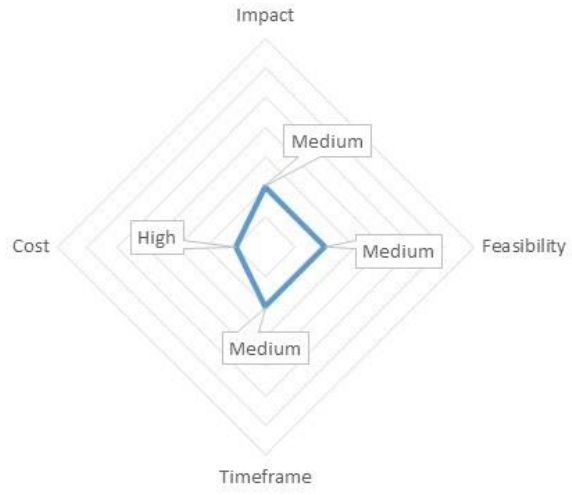
Actions needed to cover the R&D need

To release new or improved software versions. To increase training of operators.

Main RENEWABLE ENERGY TECHNOLOGY sector associated	WIND
Other RET sector(s) potentially addressed	-

Project phase(s) associated	Exploration, resource assessment, siting / Design
Actors involved	Engineering company, research institute/university, IT and data analysis company

Impact	Medium
Feasibility	Medium
Timeframe	Medium
Cost	High



Cost range

Between 5M€ and 20M€

Need of public financing and related average percentage expected

YES (100%)

Impact on technology installations

New installations

Potential applicability, OoM (%)

100%

Expected improvement, OoM (%)

Production of energy	5%
Energy cost reduction	5%

Overall priority after the Validation Workshop

19 out of 34

R&D NEED #6

Short description

To monitor the sea state both for planning and operation of wind farms with respect to the likely wave loading characteristics.

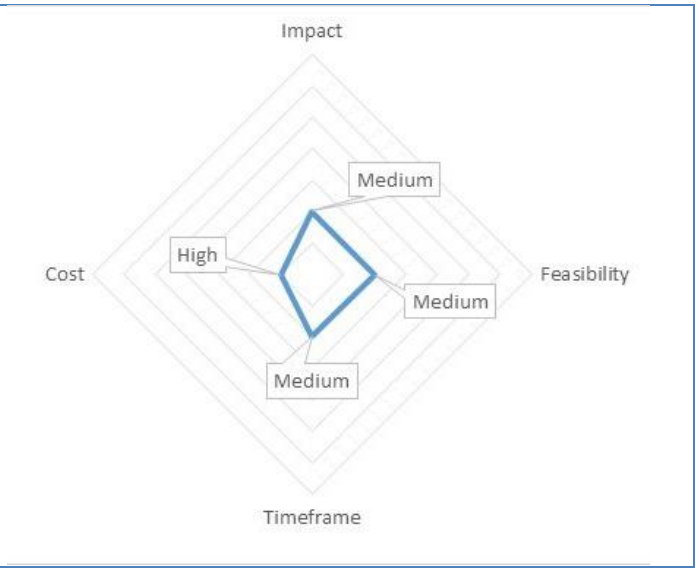
Actions needed to cover the R&D need

To create a common database which is easily accessible to vessels and operators, possibly linked to real time data such as wave buoy data, etc.
To retrieve more accurate statistical info.

Main RENEWABLE ENERGY TECHNOLOGY sector associated	WIND
Other RET sector(s) potentially addressed	MARINE

Project phase(s) associated	Exploration, resource assessment, siting / Design / Operation
Actors involved	Engineering company, research institute/university, IT and data analysis company

Impact	Medium
Feasibility	Medium
Timeframe	Medium
Cost	High



Cost range

Between 5M€ and 20M€

Need of public financing and related average percentage expected

YES (100%)

Impact on technology installations

Already in-place and New installations

Potential applicability, OoM (%)

100%

Expected improvement, OoM (%)

Production of energy	-
Energy cost reduction	20% - 30%

Overall priority after the Validation Workshop

X out of 34

R&D NEED #1

Short description

To estimate average biomass production per area unit of a particular crop type, and map the crop types in the agricultural fields of the area of interest.

Actions needed to cover the R&D need

To provide easy use of radar (SAR) satellite data for identification of crop types and estimation of the current biomass
To evaluate agrobiodiversity to adopt conservation policies.
To use HAPS (High Attitude Pseudo Satellites) to improve precision in local areas or firstly define/establish requirements and analyse HAPS usage in bioenergy area.

Main RENEWABLE ENERGY TECHNOLOGY sector associated	**BIOENERGY**
Other RET sector(s) potentially addressed	-

Project phase(s) associated	Exploration, siting	Design
Actors involved	Engineering company, research institute/university, IT and data analysis company	

Impact	High
Feasibility	Very high
Timeframe	Very short
Cost	Medium

Cost range

Between 2M€ and 5M€

Need of public financing and related average percentage expected

YES (50%)

Impact on technology installations

New installations

Potential applicability, OoM (%)

Expected improvement, OoM (%)

Production of energy	10% - 20%[12]
Energy cost reduction	15% - 20%[13]

[12] This RTD need may have only 10% improvement since this information on its own is not expected to largely affect the biomass provisions of the energy plants, because industries usually have long-term contracts with farmers. In the case we are talking about annual contracts, this percentage could raise to 20% or even more.

[13] In contrast to the previous comment, the accurate estimation of the biomass is expected to reduce energy costs due to more efficient organisation of the logistics

10%[11]

Overall priority after the Validation Workshop	11 out of 34

[11] Applicability to bioenergy installations (old and new) may not exceed the 10%, as we believe not many plants will be able to adjust their energy production lines according to the changes in biomass estimations

R&D NEED #2

Short description

To develop a network on forest-related reference data.

Actions needed to cover the R&D need[14]

To develop inventories of data records for existing forest-related reference data, including not only coverage but also conditions (distribution, abundance, quality).

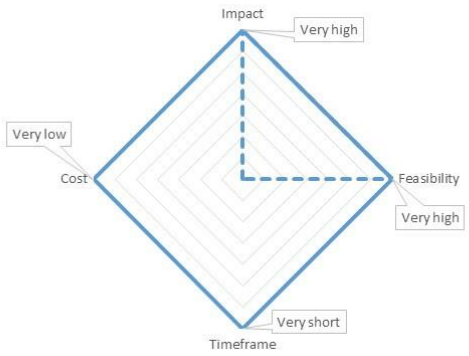
To set up a global network, with possible integration of LIDAR data, exploitation of stereo imaging from VHR for forest structure.

To create a shared virtual platform to share data, material, information, etc. between the users and scientific community.

Main RENEWABLE ENERGY TECHNOLOGY sector associated	**BIOENERGY**
Other RET sector(s) potentially addressed	-

Project phase(s) associated	Exploration, siting	Design	Operation
Actors involved	Engineering company, research institute/university, IT and data analysis company		

Impact	Very high
Feasibility	Very high
Timeframe	Very short (EU) Very long (global)
Cost	Very low (EU) Very high (global)



Cost range

Lower than 0.5M€ (EU level)
Higher than 20M€ (global level)

Need of public financing and related average percentage expected

YES (75% for EU level; 50% for global level)

Impact on technology installations

Parameters affected

Expected improvement, OoM (%)

Potential applicability, OoM (%)

Production of energy (5%)[15]
Energy cost reduction (

20%[16]

Impact on technology installations

Expected improvement, OoM (%)

Already in-place and New installations

[14] This action can be intended to cover European territory only (EU level) or worldwide (global level)

[15] All percentages here are low because forest biomass data inventories are more or less already organised.

[16] The percentage is high on the hypothesis that imports may also increase the applicability in several energy plants (of bigger scale)

Potential applicability, OoM (%) 20%[17]	Production of energy Energy cost reduction	5%[18] 5-10%[19]
Overall priority after the Validation Workshop		19 out of 34

[17] The percentage is high on the hypothesis that imports may also increase the applicability in several energy plants (of bigger scale)

[18] All percentages here are low because forest biomass data inventories are more or less already organised.

[19] Higher percentages of 10% can be applied for global applications because they involve biomass imports/exports from country to global level

R&D NEED #3

Short description

To improve the retrieval/modelling of vegetation water content.

Actions needed to cover the R&D need[20]

To develop inventories of data records for several years to identify if the lands are permanently abandoned and thus available for energy/non-food crops cultivation.

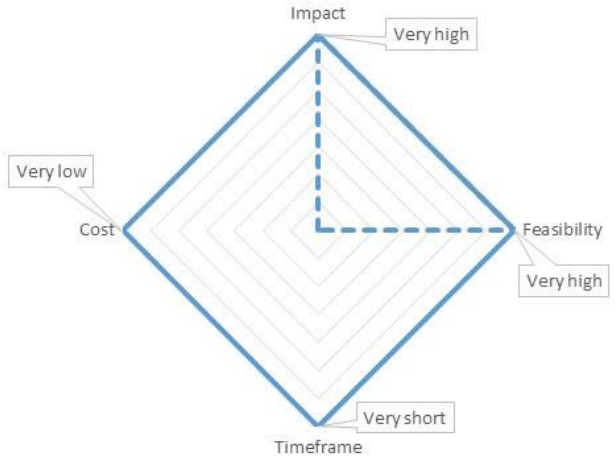
To monitor soil condition and pollution.

To monitor vegetation phenology changes through the analysis of time series.

Main RENEWABLE ENERGY TECHNOLOGY sector associated	**BIOENERGY**
Other RET sector(s) potentially addressed	-

Project phase(s) associated	Exploration, siting	Design	Operation
Actors involved	Engineering company, research institute/university, IT and data analysis company		

Impact	Very high
Feasibility	Very high
Timeframe	Very short (EU) Very long (global)
Cost	Very low (EU) Very high (global)



Cost range

Lower than 0.5M€ (EU level)
Higher than 20M€ (global level)

Need of public financing and related average percentage expected

YES (50%)

Impact on technology installations

Already in-place and New installations

Potential applicability, OoM (%)

10%

Expected improvement, OoM (%)

Production of energy	10%)[21]
Energy cost reduction	10%

Overall priority after the Validation Workshop

30 out of 34

[20] This action can be intended to cover European territory only (EU level) or worldwide (global level)

[21] Percentages are low because biomass moisture content –if that is what the vegetation water content is – is more or less known for each crop type and more accurate data will not significantly affect the energy production or the applicability.

R&D NEED #4

Short description

To obtain inventories of unused, abandoned and marginal land, suitable for energy crops.

Actions needed to cover the R&D need[22]

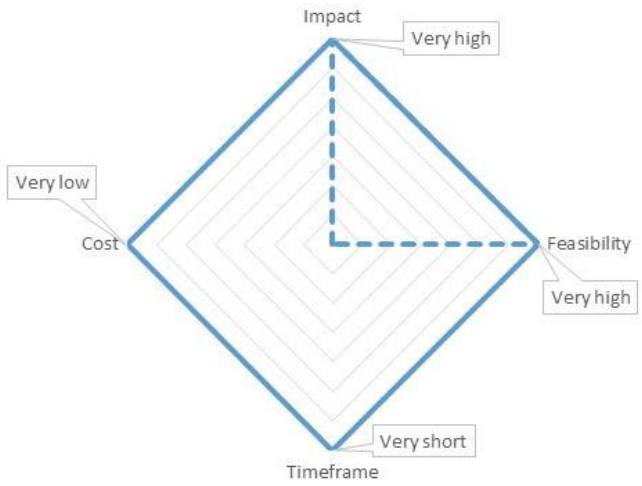
To develop inventories of data records for several years to identify if the lands are permanently abandoned and thus available for energy/non-food crops cultivation.

To define semantics of abandoned land for automatic recognition from satellite data.

Main RENEWABLE ENERGY TECHNOLOGY sector associated	**BIOENERGY**
Other RET sector(s) potentially addressed	-

Project phase(s) associated	Exploration, siting
Actors involved	Engineering company, research institute/university, IT and data analysis company

Impact	Very high
Feasibility	Very high
Timeframe	Very short (EU) Very long (global)
Cost	Very low (EU) Very high (global)



Cost range

Lower than 0.5M€ (EU level)
Higher than 20M€ (global level)

Need of public financing and related average percentage expected

YES (100%)[23]

Impact on technology installations

New installations

Potential applicability, OoM (%)

10%[24]

Expected improvement, OoM (%)

Production of energy	15%[25]
Energy cost reduction	-

[22] This action can be intended to cover European territory only (EU level) or worldwide (global level)

[23] Hypothesis: this kind of data are kept in public services databases, thus public their collection may require high public funds.

[24] Percentage is low on the assumption that not many plants will be interested in having contracts with farmers owing marginal lands due to the high risk in assuring a consistent biomass supply, both in terms of quantities throughout the year and quality of the harvested material.

[25] Although this information is very valuable, it is expected that the total bioenergy production will not be more significantly improved, because these lands could be either poor resulting in low biomass/bioenergy production, not available or the

biofuels quality (i.e. ash and heavy metal content) may be low. As for the cost reduction of energy, it will not be improved, on the contrary it may turn to be higher than if biomass is produced in better lands

R&D NEED #5

Short description

To use existing biomass terrestrial data (agricultural, forest, grasslands) from various sources.
To use available algorithms to estimate standing forest biomass from remote sensing and terrestrial data. For agricultural biomass crop area estimation and yield are often supported by modelling including meteorological, pedological data and phenological information as well.

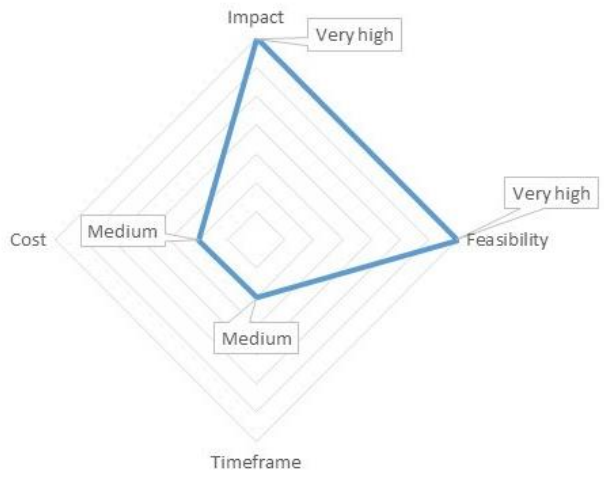
Actions needed to cover the R&D need

To retrieve terrestrial data for ground truthing.
To calibrate of the regressions between biomass and EO data for biomass potential assessment.
E.g. to be integrated with k-nearest neighbours (k-NN) and multiple regressions.

Main RENEWABLE ENERGY TECHNOLOGY sector associated	**BIOENERGY**
Other RET sector(s) potentially addressed	-

Project phase(s) associated	Exploration, siting	Design
Actors involved	Engineering company, research institute/university, IT and data analysis company	

Impact	Very high
Feasibility	Very high
Timeframe	Medium
Cost	Medium



Cost range

Between 2M€ and 5M€

Need of public financing and related average percentage expected

YES (50-75%)

Impact on technology installations

New installations

Potential applicability, OoM (%)

10%

Expected improvement, OoM (%)

Production of energy	10%
Energy cost reduction	15%

Overall priority after the Validation Workshop

7 out of 34

R&D NEED #1

Short description

To increase the accuracy of the in situ measurements in coastal areas for marine renewable energies: bathymetry, seabed geotechnics, tides, waves/swell, currents.

Actions needed to cover the R&D need

To set up more in-situ observations: bathymetry and seabed geotechnics. To provide longer term wave data so that planning marine operations can be made in advance more accurately.
To exploit SAR images or images in visible- NIR range together with computer models for mapping geophysical parameters including sea-states.

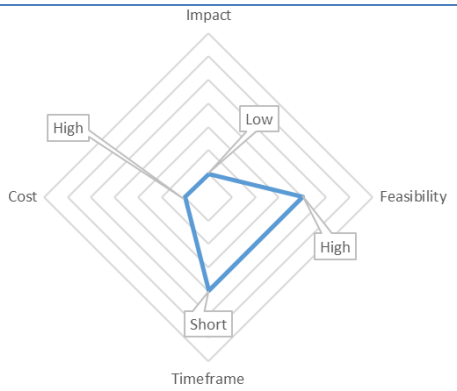
Main RENEWABLE ENERGY TECHNOLOGY sector associated

OCEAN

Other RET sector(s) potentially addressed

Project phase(s) associated	Exploration, resource assessment, siting	Design	Operation
Actors involved	Research organization or university, engineering company		

Impact	Low
Feasibility	High
Timeframe	Short
Cost	High



Cost range

HIGH
Between 5M€ and 20M€

Need of public financing and related average percentage expected

YES, 100%[26]

Impact on technology installations

Already in-place and New installations

Potential applicability, OoM (%)

100%

Expected improvement, OoM (%)

Production of energy	10% - 20%
Energy cost reduction	10% - 20%

Overall priority after the Validation Workshop

2 out of 34

[26] 100% as this specific sector still requires support until going fully commercial.

R&D NEED #1

Short description

To develop downscaling procedure and validation techniques at local (watershed) scale.

Actions needed to cover the R&D need

To develop new low-cost sensor networks.
To improve existing dynamical and statistical downscaling algorithms.
To use Sentinel at watershed scale.

Main RENEWABLE ENERGY TECHNOLOGY sector associated

HYDROPOWER

Other RET sector(s) potentially addressed

-

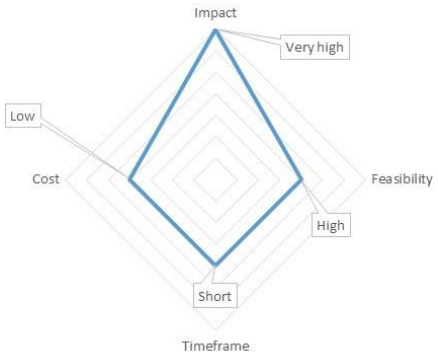
Project phase(s) associated

Exploration, resource assessment, siting | Design | Operation

Actors involved

Engineering company, research organization, university

Impact	Very high
Feasibility	High
Timeframe	Short
Cost	Low



Cost range

Between 0.5M€ and 2M€

Need of public financing and related average percentage expected

YES (30%)

Impact on technology installations

Already in-place and New installations

Potential applicability, OoM (%)

100%

Expected improvement, OoM (%)

Production of energy	5%
Energy cost reduction	10%

Overall priority after the Validation Workshop

19 out of 34

R&D NEED #2

Short description

To estimate hydropower potential from snow and ice (snow-water equivalent (SWE), especially in mountain areas).

Actions needed to cover the R&D need

To use very-high resolution EO data about snow and ice run-off to create models for estimation of energy potential stored in snow and ice and forecast about duration and timing of the melting phase.

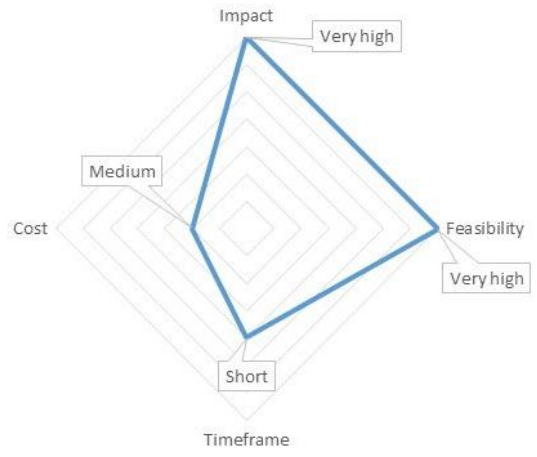
Main RENEWABLE ENERGY TECHNOLOGY sector associated

HYDROPOWER

Other RET sector(s) potentially addressed

Project phase(s) associated	Exploration, resource assessment, siting — Design — Operation
Actors involved	Engineering company, research organization, university, data processing company

Impact	Very high
Feasibility	Very high
Timeframe	Short
Cost	Medium



Cost range

Between 2M€ and 5M€

Need of public financing and related average percentage expected

YES (30-50%)

Impact on technology installations

Already in-place and New installations

Potential applicability, OoM (%)

50%

Expected improvement, OoM (%)

Production of energy	10%
Energy cost reduction	-

Overall priority after the Validation Workshop

30 out of 34

R&D NEED #3

Short description

To improve spatial resolution for land topography assessment. Detection and quantitative evaluation of high-potential areas (in terms of head availability).

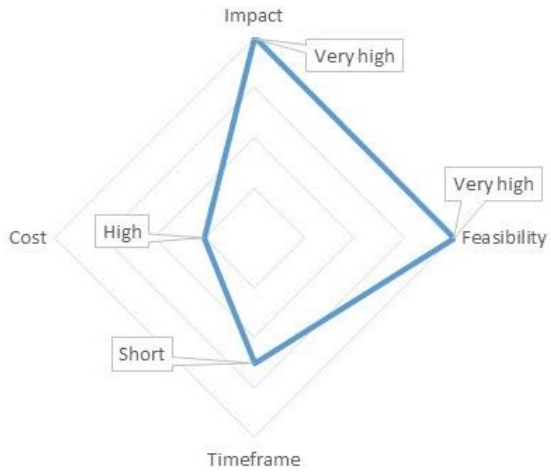
Actions needed to cover the R&D need

To develop EO data processing in order to highlight high-drop areas, which could be developed into high-head penstock installations.
To improve accuracy of high-resolution spaceborne global digital elevation models (DEMs).
To improve existing post-processing algorithms for the generation of digital terrain models (DTMs) from DEMs.

Main RENEWABLE ENERGY TECHNOLOGY sector associated		**HYDROPOWER**
Other RET sector(s) potentially addressed	**WIND**	**SOLAR**

Project phase(s) associated	Exploration, resource assessment, siting
Actors involved	Engineering company, research organization, university, data processing company

Impact	Very high
Feasibility	High
Timeframe	Short
Cost	High



Cost range

Between 5M€ and 20M€

Need of public financing and related average percentage expected

YES (30-50%)

Impact on technology installations

New installations

Potential applicability, OoM (%)

10%

Expected improvement, OoM (%)

Production of energy	5%
Energy cost reduction	-

Overall priority after the Validation Workshop

10 out of 34

R&D NEED #4

Short description

To enable 3D monitoring of landslide faces for statistical processing of sudden collapse probability and for scheduling maintenance / corrective actions.
To improve detection of areas affected by landslide phenomena.

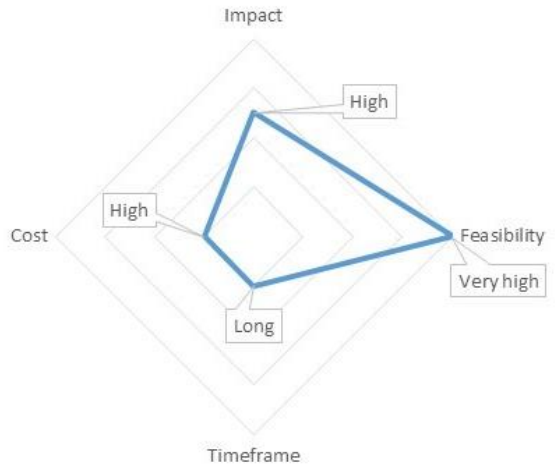
Actions needed to cover the R&D need

To increase spatial and time data resolution to allow near real-time monitoring, also by means of more economic in-situ sensors.
To develop easy-to-install artificial reflector for INSAR analysis in case of lack of natural reflectors.
To perform image processing for landslide area recognition.
To create an images database capable of tracking the landslide evolution in space and time.

Main RENEWABLE ENERGY TECHNOLOGY sector associated	**HYDROPOWER**
Other RET sector(s) potentially addressed	-

Project phase(s) associated	Exploration, resource assessment, siting — Operation
Actors involved	Engineering company, research organization, university, data processing company

Impact	High
Feasibility	Very high
Timeframe	Long
Cost	High



Cost range

Between 5M€ and 20M€

Need of public financing and related average percentage expected

YES (50%)

Impact on technology installations

Already in-place and New installations

Potential applicability, OoM (%)

15%

Expected improvement, OoM (%)

Production of energy	<5%
Energy cost reduction	15%

Overall priority after the Validation Workshop

19 out of 34

R&D NEED #5

Short description

To allow the (at least) qualitative assessment of water flows of small/medium size rivers (basin area minor than 50k km^2).

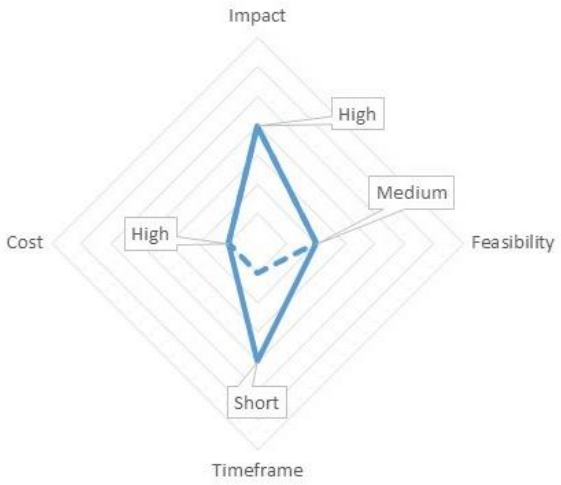
Actions needed to cover the R&D need[27]

To develop algorithms for the calculation of water depth, river mean width and water velocity from EO data.

Main RENEWABLE ENERGY TECHNOLOGY sector associated	**HYDROPOWER**
Other RET sector(s) potentially addressed	-

Project phase(s) associated	Exploration, resource assessment, siting
Actors involved	Engineering company, research organization, university, data processing company

Impact	High
Feasibility	Medium
Timeframe	Short (hydraulic) Long (hydrological)
Cost	High



Cost range

Between 5M€ and 20M€

Need of public financing and related average percentage expected

YES (50%)

Impact on technology installations

Parameters affected

Expected improvement, OoM (%)

Potential applicability, OoM (%)

Production of energy (5%)

10%

Impact on technology installations

New installations

Potential applicability, OoM (%)

10%

Expected improvement, OoM (%)

Production of energy	5%
Energy cost reduction	-

[27] This action can be differentiated to address only depth (hydrological aspects) or speed (hydraulic aspects).

R&D NEED #6

Short description

To improve the environmental mapping and characterization of rivers and river disturbances and/or modifications.

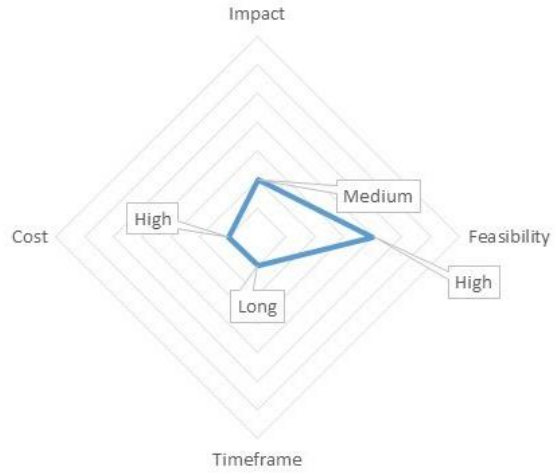
Actions needed to cover the R&D need

To develop algorithms for the qualitative characterisation of the health status of rivers from EO data and on-site sensors.

Main RENEWABLE ENERGY TECHNOLOGY sector associated	**HYDROPOWER**
Other RET sector(s) potentially addressed	-

Project phase(s) associated	Exploration, resource assessment, siting / Operation
Actors involved	Engineering company, research organization, university, data processing company

Impact	Medium
Feasibility	High
Timeframe	Long
Cost	High



Cost range

Between 5M€ and 20M€

Need of public financing and related average percentage expected

YES (50%)

Impact on technology installations

Already in-place and New installations

Potential applicability, OoM (%)

10%

Expected improvement, OoM (%)

Production of energy	5%
Energy cost reduction	-

Overall priority after the Validation Workshop

30 out of 34

R&D NEED #1

Short description

Data that combine high spatial and temporal resolution and combination of multisource EO data.

Actions needed to cover the R&D need

Implementation of schemes for operationally fusing multi source data.[28]

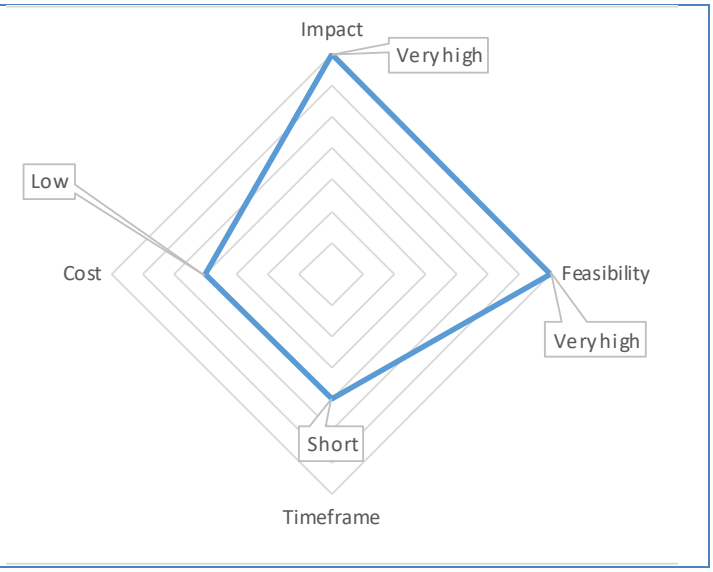
Main RENEWABLE ENERGY TECHNOLOGY sector associated

CROSS CUTTING

Other RET sector(s) potentially addressed

Project phase(s) associated	Exploration, resource assessment, siting	Design	Operation
Actors involved	Engineering company, research organization, university, data processing company		

Impact	Very high
Feasibility	Very high
Timeframe	Short
Cost	Low



Cost range

LOW
Between 0.5M€ and 2M€

Need of public financing and related average percentage expected

NO[29], -

Impact on technology installations

Already in-place and New installations

Potential applicability, OoM (%)

100%

Expected improvement, OoM (%)

Production of energy	5%
Energy cost reduction	1% - 10%

Overall priority after the Validation Workshop

8 out of 34

[28] ESA launched a tender on this topic

[29] Obviously integration of different dataset at different level is always a plus

R&D NEED #2

Short description

To harmonize the existing databases (in-situ and satellite derived) related to earthquake and seismic hazards.[30]

Actions needed to cover the R&D need

Creation of a common database.

Main RENEWABLE ENERGY TECHNOLOGY sector associated

CROSS CUTTING

Other RET sector(s) potentially addressed

WIND

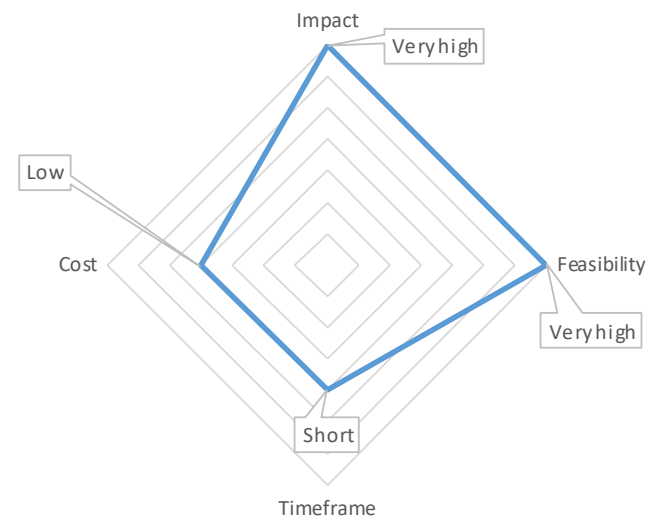
Project phase(s) associated

Exploration, resource assessment, siting | Design | Operation

Actors involved

Engineering company, research institute/university, IT and data analysis company

Impact	Very high
Feasibility	Very high
Timeframe	Short
Cost	Low



Cost range

LOW
Between 0.5M€ and 2M€

Need of public financing and related average percentage expected

YES[31], 70%

Impact on technology installations

Already in-place and New installations

Potential applicability, OoM (%)

100%

Expected improvement, OoM (%)

Production of energy	-[32]
Energy cost reduction	-

Overall priority after the Validation Workshop

30 out of 34

[30] This will be important for offshore wind projects in countries such as Taiwan

[31] Can be a classical H2020 CSA to facilitate the harmonisation of EU datasets

[32] It's more related to avoiding losses

R&D NEED #3

Short description

To provide easy and affordable access to SMEs and local authorities to meteorological measurements and EO data.

Actions needed to cover the R&D need

Set up a networking activity to demonstrate to governments supporting meteorological offices that providing easy access at very limited costs to companies foster the development of renewable energy projects. To support international commitments in climate and environment.
To provide easy access to data and to processing software at very limited costs to companies and/or local authorities to foster the development of renewable energy projects. The data much be presented in a format that is not too onerous for operators working in the field and is easy to evaluate and implement. To support local authorities commitment to promote the projects with higher added value.

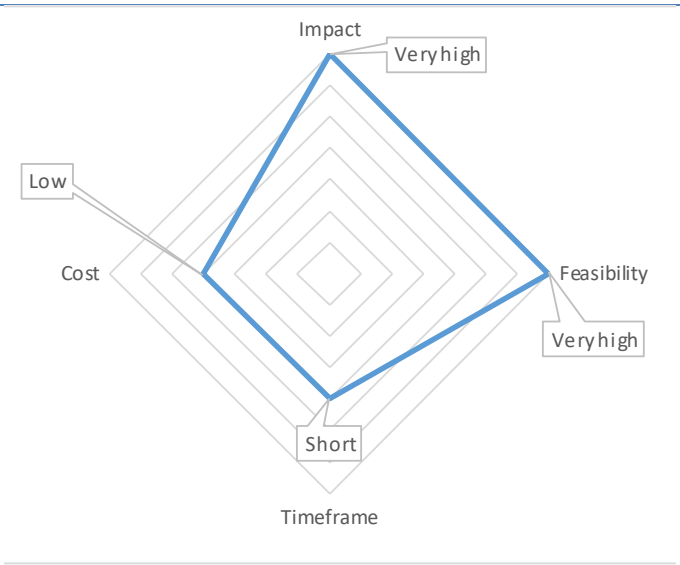
Main RENEWABLE ENERGY TECHNOLOGY sector associated

CROSS CUTTING

Other RET sector(s) potentially addressed

Project phase(s) associated	Exploration, resource assessment, siting	Design	Operation
Actors involved	Public Institution, data processing company		

Impact	Very high
Feasibility	Very high
Timeframe	Short
Cost	Low



Cost range

LOW
Between 0.5M€ and 2M€

Need of public financing and related average percentage expected

YES[33], 70%

Impact on technology installations

Already in-place and New installations

Potential applicability, OoM (%)

100%

Expected improvement, OoM (%)

Production of energy	-
Energy cost reduction	-

Overall priority after the Validation Workshop

5 out of 34

[33] It can be a classical H2020 CSA to promote and facilitate the access to EU EO datasets

R&D NEED #4

Short description

To increase the awareness and the level of education on the use of EO data for site potential assessment, to support the preliminary design and preliminary operational cost assessment and decision making for end-users.

Actions needed to cover the R&D need

To set up a central repository for training.
To raise awareness with systematic activities (workshop, conferences, training sessions, etc) on the scope and quality of satellite data database and how to use them.
Set up professional trainings and education of stakeholders, also specific for the energy sector.

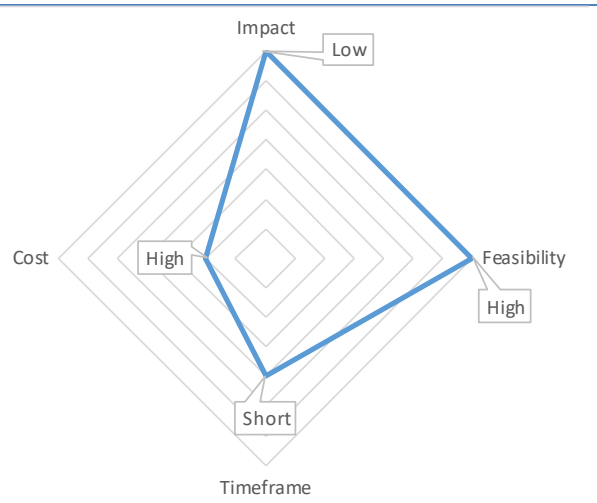
Main RENEWABLE ENERGY TECHNOLOGY sector associated

CROSS CUTTING

Other RET sector(s) potentially addressed

Project phase(s) associated	Exploration, resource assessment, siting	Design	Operation
Actors involved	University, professional training company, public institution		

Impact	Very high
Feasibility	Very high
Timeframe	Short
Cost	Medium



Cost range

MEDIUM
Between 2M€ and 5M€

Need of public financing and related average percentage expected

YES[34], 70%

Impact on technology installations

Already in-place and New installations

Potential applicability, OoM (%)

100%

Expected improvement, OoM (%)

Production of energy	-
Energy cost reduction	-

Overall priority after the Validation Workshop

8 out of 34

[34] It can be a classical H2020 CSA to promote and facilitate the access to EU EO datasets also via specific training programmes (i.e. Marie Curie Programs, Erasmus+ programs, centre Jean Bonnet).

R&D NEED #5

Short description

To improve handling of large amounts of data from MTG, EPS SG and Sentinels, especially in nowcasting scenarios.

Actions needed to cover the R&D need

To release new or improved SW able to process this large amount of data.

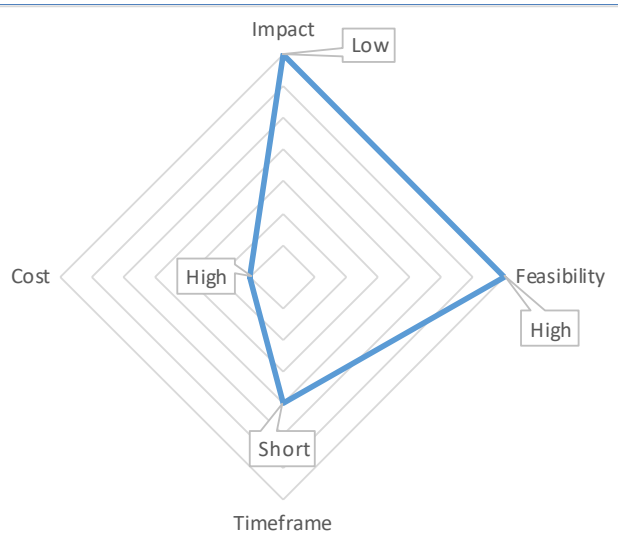
Main RENEWABLE ENERGY TECHNOLOGY sector associated

CROSS CUTTING

Other RET sector(s) potentially addressed

Project phase(s) associated	Exploration, resource assessment, siting	Design	Operation
Actors involved	Engineering company, research organization, university, data processing company		

Impact	Very high
Feasibility	Very high
Timeframe	Short
Cost	High



Cost range

HIGH
Between 5M€ and 20M€

Need of public financing and related average percentage expected

YES[35], 70%

Impact on technology installations

Already in-place and New installations

Potential applicability, OoM (%)

100%

Expected improvement, OoM (%)

Production of energy	-
Energy cost reduction	2%

Overall priority after the Validation Workshop

30 out of 34

[35] Big data management, handling and instructions are useful in different type of sectors – algorithms here developed could be useful for other kind of applications as well – BIG DATA for EO could be or a dedicate H2020 initiative or a sub-activity of a larger one

R&D NEED #6

Short description

Need of standardization (format, practices, …) and interoperability for EO data processing.

Actions needed to cover the R&D need

To agree on standards for the EO data processing in order to make possible the validation of the results coming from the processing of raw data.

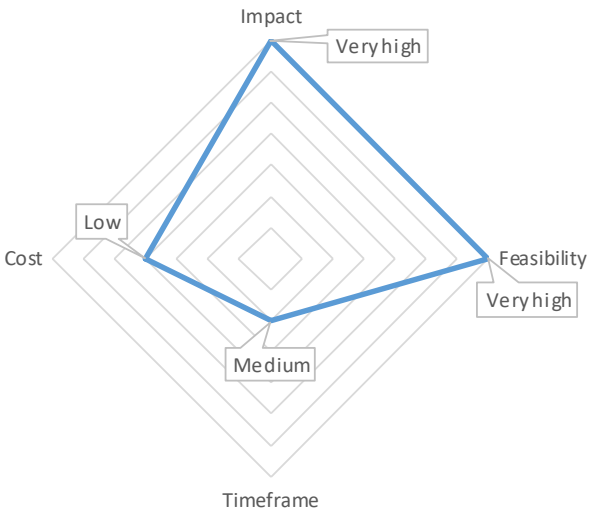
Main RENEWABLE ENERGY TECHNOLOGY sector associated

CROSS CUTTING

Other RET sector(s) potentially addressed

Project phase(s) associated	Exploration, resource assessment, siting	Design	Operation
Actors involved	Engineering company, research organization, university, data processing company, association, standardization bodies		

Impact	Very high
Feasibility	Very high
Timeframe	Medium
Cost	Low



Cost range

LOW
Between 0.5M€ and 2M€

Need of public financing and related average percentage expected

YES[36], 80%

Impact on technology installations

Already in-place and New installations

Potential applicability, OoM (%)

100%

Expected improvement, OoM (%)

Production of energy	-
Energy cost reduction	-

Overall priority after the Validation Workshop

3 out of 34

[36] Need of a EU standard – Public funding has to push this kind of action

R&D NEED #7

Short description

To improve spatial and temporal resolution for the assessment of the resources and preliminary design.

Actions needed to cover the R&D need

To investigate how the spatial (new cameras, …) and temporal resolution of the satellite measurements can be refined. To integrate low temporal/very high spatial resolution with low spatial/very high temporal. To create sets of simulated data to study the gain of having more spatial and temporal resolution. Better integration with local (in-situ) measurement systems.

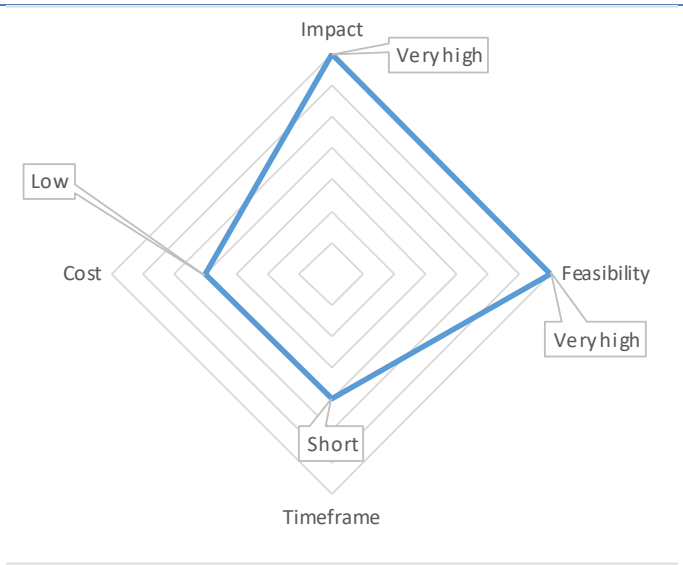
Main RENEWABLE ENERGY TECHNOLOGY sector associated

CROSS CUTTING

Other RET sector(s) potentially addressed

Project phase(s) associated	Exploration, resource assessment, siting	Design	Operation
Actors involved	Engineering company, research organization, university, data processing company		

Impact	Very high
Feasibility	Very high
Timeframe	Short
Cost	Low



Cost range

LOW
Between 0.5M€ and 2M€

Need of public financing and related average percentage expected

NO[37], -

Impact on technology installations

Already in-place and New installations

Potential applicability, OoM (%)

70%[38]

Expected improvement, OoM (%)

Production of energy	1% - 5%
Energy cost reduction	-

Overall priority after the Validation Workshop

19 out of 34

[37] Too generic objective to be public funded – probably a private company/national agency can fund an intervention on this kind of activities, driven by their own R&D/data exploitation interests

[38] Not always possible to integrate with in-situ measurements systems

Getting in touch with the EU

IN PERSON
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EU LAW AND RELATED DOCUMENTS
For access to legal information from the EU, including all EU law since 1952 in all the official language versions, go to EUR-Lex at: http://eur-lex.europa.eu

OPEN DATA FROM THE EU
The EU Open Data Portal (http://data.europa.eu/euodp/en) provides access to datasets from the EU. Data can be downloaded and reused for free, both for commercial and non-commercial purposes.

As the EU's Earth Observation programme, Copernicus, is entering its operational phase, the European Commission with the European Space Agency has launched a number of initiatives to promote and to increase the use of Copernicus data and information.
This study was meant to perform an in-depth analysis of how EO data are being used in the six RE sectors identified (Solar energy, Geothermal energy, Wind energy, Bioenergy, Ocean energy, Hydropower), to identify possible research and development paths that would significantly improve EO and to finally provide a cost-benefit analysis of introducing such R&D outcomes associated to EO in the RE sector.
Crucial to the achievement of the project's purposes was the multidisciplinary approach, combining expertise both in the RE sector and in the field of EO and the involvement of key stakeholders in each of the two workshops, to provide support and feedback to the project team and ensure that the final outcome of the study is commonly agreed and not biased by personal interpretations.
The implementation of the study is articulated around the following main activities: evaluation of the State of Play, assessment of the R&D needs and finally provision of a cost / benefits analysis.

Studies and reports

Publications Office
of the European Union