The Added Value of Seasonal Climate Forecasts for Integrated Risk Management Decisions (SECLI-FIRM)

EU H2020 Project (ref. n. 776868)

D1.5 Delivery of a Report on cross-sectoral learning from the SECLI-FIRM project

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1 Summary

This Deliverable report 1.5 takes the learning from SECLI-FIRM and considers how the findings with respect to the development and use of seasonal forecast climate services can be further exploited in the energy, water and other sectors.

It first summarises the key scientific messages and lessons learned focusing on the ones most relevant for cross-sectoral learning with respect to:

- Co-design, co-development and co-evaluation
- Decision trees
- Value add of seasonal climate forecasts
- Tailoring seasonal forecasts
- Trial climate services

These key messages were identified by the SECLI-FIRM Work Package (WP) teams in discussions facilitated by WP1 including those held as part of the extended project meeting in April 2021 and Workshop 5 held in May 2021. Material is also included from presentations given at the SECLI-FIRM summer school and final conference which took place in September and October 2021. The key messages are presented as bullet points with links to further information in SECLI-FIRM deliverables and presentations.

The second part of this deliverable focuses on the identification of opportunities internal to and closest to SECLI-FIRM, as well as beyond the SECLI-FIRM consortium. Many of these opportunities build on the SECLI-FIRM expertise in non-standard variables such as significant wave height, offshore windspeed and riverflow.

These opportunities were identified through a desk-top review undertaken as part of Task 1.5 work and through discussions held as part of the extended project meeting (April 2021), the final Advisory Board meeting (April 2021), Workshop 5 (May 2021) and the final conference (October 2021). Section 4 also includes material from the WP4 evaluation survey of the trial climate services. Section 5 benefits from the expertise of various related European climate service projects including CLARA, EU-MACS, MARCO, Med-Gold and WATExR.

Sectors offering potential opportunities to transfer SECLI-FIRM learning and expertise include: the broader water sector, forestry and timber, agriculture, tourism, other energy areas, transportation and logistics (offshore and river), offshore infrastructures, insurance, and food and drink.

This deliverable helps to inform the reader of the SECLI-FIRM exploitation activities identified by Work Package 5.

2 Introduction

This deliverable report 1.5 focuses on cross-sectoral learning from the SECLI-FIRM project. It considers how the findings can be further exploited in the energy and water sectors and in other related sectors.

It is organized in two main parts. Section 3 summarises the key scientific messages and lessons learned focusing on those most relevant for cross-sectoral learning. These are organized into a number of themes. The first set of themes Co-design, co-development and co-evaluation (Section 3.1), Decision trees (Section 3.2) and Value add (Section 3.3) are cross-cutting issues relating to the overall SECLI-FIRM framework developed in Work Package (WP) 1 and implemented in the case studies WP (WP3, Figure 1). Issues relating to the tailoring of seasonal forecasts (WP2) for the case studies are highlighted in Section 3.4. Key messages relating to the trial climate services (WP4) developed for each of the case studies are presented in Section 3.5.

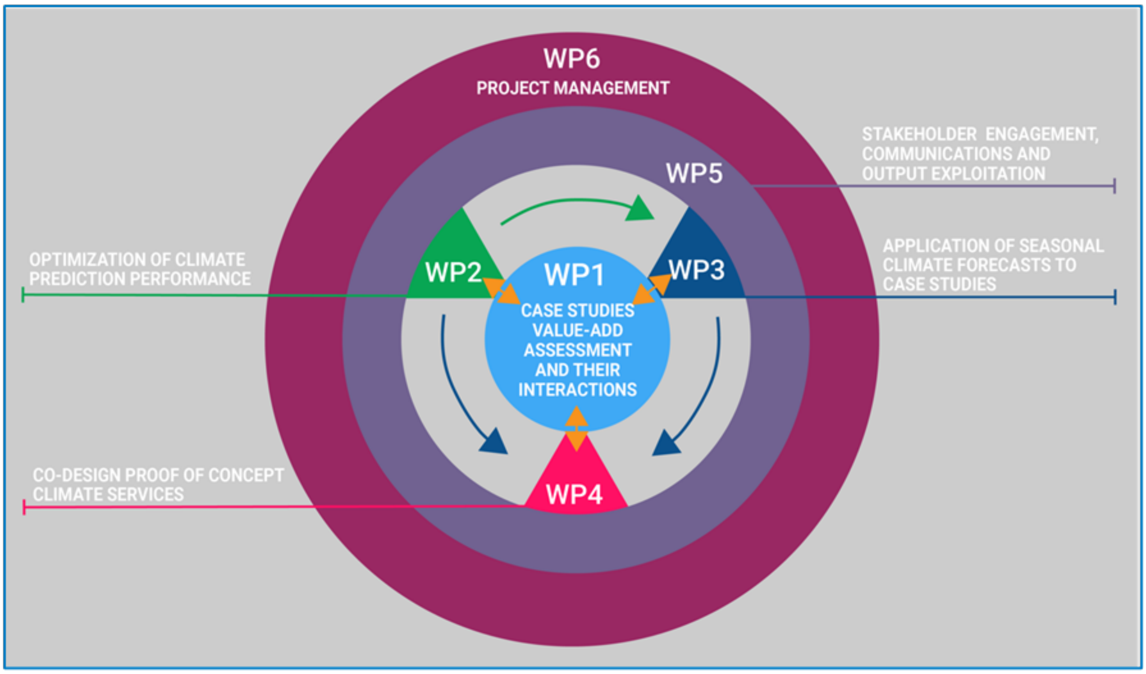

Figure 1: The SECLI-FIRM Work Packages (WPs)

The second part of the deliverable considers the opportunities for transferring the SECLI-FIRM knowledge to other potential users and sectors focusing on opportunities internal to and closest to SECLI-FIRM (Section 4) and those beyond the SECLI-FIRM consortium (Section 5).

The concluding remarks in Section 6 include discussion of how this Task 1.5 work feeds into WP5 work on exploitation. The Section also addresses whether the SECLI-FIRM work may help pave the way to a seamless approach to the use of climate information for decision making extending to climate projection timescales.

3 Lessons learned

3.1 Co-design, co-development and co-evaluation

The SECLI-FIRM framework is built around co-design, co-development and co-evaluation focused on partnerships between the industrial and research partners involved in each of the case studies. The process started with co-design at the project proposal stage – all the case-studies and their underlying partnerships were specified at this first stage. It continued through co-development of the case studies and co-evaluation of both the value add of using seasonal forecasts for decision making (Section 3.3) and the trial climate services (Section 3.4).

The term ‘co-production’ can be used to encompass these different dimensions of co-working. SECLI-FIRM used the following definition of co-production developed by Goodess et al., 2019 based on a review of the relevant literature (Beier et al 2017; Meadow et al 2015; Taylor el al 2017):

> “a sustained collaborative process between scientists and decision makers for the production of useful, actionable and socially robust knowledge”.

In order to fulfil this definition of co-production, SECLI-FIRM aimed to achieve the highest level of engagement between users and providers of climate services identified by Hewitt et al. (2017). At this level, engagement is active, focused, tailored and highly iterative with the aim of reaching in-depth understanding and producing bespoke services and directly usable data (Hewitt et al., 2017).

The benefits and challenges for SECLI-FIRM of adopting this approach to co-production are summarised in Table 1. Challenges associated with language and the use of jargon reflect the different backgrounds of those involved in SECLI-FIRM. The seasonal climate forecast community for example uses the word ‘skill’ to refer to a specific metric of forecast verification, whereas others use it in a much more general way to describe forecast quality. Understanding each others’ language is an often under-estimated requirement of successful collaboration.

Any issues relating to confidentiality and commercial sensitivity were overcome through the building of trust throughout the project and sensitive reporting of results in presentations, deliverable reports and journal papers. Throughout the project a careful distinction between confidential deliverables and public dissemination was maintained. This enabled a two-way learning process and identification of times when confidential information was needed for instance to better understand the decision-making process.

In terms of user expectations, while there was perhaps some disappointment in the relatively low skill inherent to seasonal climate forecasts over Europe (Section 3.4), all industrial partners remained fully committed to SECLI-FIRM and have indicated that they will continue to work with seasonal forecast information going forward (Section 6).

Table 1 – The benefits and challenges of co-production for SECLI-FIRM

Benefits	**Barriers and challenges**
• Better outputs and outcomes - more credible, legitimate, salient • More trust in the providers • Good understanding of users' requirements • An appreciation of the role of climate information in users' decision making • Greater sense of ownership of final product by users / all partners • Building capacity of both providers and users • Higher Technology Readiness Level • Greater uptake and use – market development	• Scale of the necessary time commitment • Language differences including technical language and use of jargon • Unequal expectations and their management • Confidentiality/commercial sensitivity issues • The need to co-opt a wide group of actors from social, economic and decision-making science
Further information Co-design, co-development and co-evaluation	➢ SECLI-FIRM co-design, co-development and co-evaluation: the value of seasonal forecasts – Final Conference, Day 1 on 13th October 2021 http://www.secli-firm.eu/secli-firm-final-conference-2021/ ➢ Collaborative approaches: Co-design, co-development and co-production of climate services – Summer School, Session 2 on 23rd September 2021 http://www.secli-firm.eu/secli-firm-summer-school-2021/

3.2 Decision trees

One major outcome of the co-development approach adopted in SECLI-FIRM was the development of decision trees for each of the case studies. The utility of these decision trees is outlined in Table 2.

Table 2 – The use of decision trees in SECLI-FIRM

Decision trees have value as a tool:	
• By providing systematic and consistent visualisation of key decisions, especially highlighting climate-driven ones; • By identifying the points/nodes in the decision trees where (i) improved climate information and forecasts can be used as input and (ii) where the value of adopting this information can be assessed; • By evaluating how to use probabilistic information from seasonal forecasts in current decision-making processes; • By providing a reproducible and repeatable methodology, built in-house, for a quantitative evaluation of the value-add of the seasonal forecast within the decision-making process; • By provoking useful conversations and sharing of critical information.	
Further information Use of decision trees	➢ SECLI-FIRM Stakeholder Workshop 5, Session 3, 25 May 2021, http://www.secli-firm.eu/events/#1623228980655-54ad6916-5518 Recording: https://www.youtube.com/watch?v=gbkC7dLiOE8 ➢ SECLI-FIRM co-design, co-development and co-evaluation: the value of seasonal forecasts – Final Conference, Day 1 on 13th October 2021 http://www.secli-firm.eu/secli-firm-final-conference-2021/ ➢ SECLI-FIRM Deliverable D3.11 Report on collation and dissemination value-add assessment results, see Section 8 http://www.secli-firm.eu/project-reports/ ➢ SECLI-FIRM case study fact sheets http://www.secli-firm.eu/case-studies/ – include the decision tree developed for each case study

In some cases the decision trees proved quite difficult to construct and initially some case studies had doubts and concerns about their utility. Ultimately however they were recognised as having great value for successful implementation of the case studies, including tailoring of seasonal forecasts (Section 3.4), and for their economic evaluation (Section 3.3) as well as co-development of the trial climate services (Section 3.5). Whilst decision trees can be used in a more formal quantitative way to calculate expected value for example, in the SECLI-FIRM context they were considered invaluable for provoking useful conversations, avoiding misunderstandings and promoting the sharing of critical information.

Thus SECLI-FIRM recommends the use of decision trees at the start of projects across different sectors as a way to 'break the ice' between climate service providers and users, and to accelerate the mutual understanding of what needs to be achieved. They are considered particularly helpful for the iterative and sustained process of identifying user needs. The SECLI-FIRM experience shows that these needs cannot be separated from the user decisions, and that the needs evolve and develop along with the conversation.

3.3 Value add

Value add refers to the potential benefits associated with the use of tailored seasonal forecasts for specific user decision making and outputs. The value add assessment results for the SECLI-FIRM case studies are collated and disseminated in the deliverable D3.11 public report. For a summary of key messages, the reader is referred in particular to Section 9 '*Concluding remarks'* and the '*Executive Summary'* of D3.11. Here, Table 3 provides a high-level summary of lessons learned with respect to the assessment of value add.

Going forward it is recommended that efforts specifically continue on the assessment of both the economic and the more practical value of using seasonal forecasts for decision making. Practical value encompasses factors such as enhanced confidence in decision making and maintaining a leading position in competitive markets. Many examples of such value have been captured for the SECLI-FIRM case studies, albeit in a rather ad hoc way. A more systematic framework for capturing practical value would be beneficial.

Table 3 – Summary of SECLI-FIRM lessons learned with respect to value add

<table>
<tr><td colspan="2">Lessons learned with respect to value add:</td></tr>
<tr><td colspan="2">
• Economic value is harder to assess than was anticipated

• Performance Indicators (econometric modelling) and Relative Economic Value (avoided costs) are promising approaches though they do not capture the whole spectrum of benefits

• Forecast skill and added value are not the same thing – but skill is a limiting factor

• Practical value can be enhanced, e.g. by providing seasonal forecasts:

- in formats which easily integrate with the user’s existing tools, systems and approaches

- as part of a seamless approach to prediction on different timescales, particularly if gradually extending the current user’s setting

- in data forms which are easy to use and user-friendly even for 'unskilled' data users

• There is value in narratives and experiences of champion users and early adopters
</td></tr>
<tr><td>Further information

Value add</td><td>
➢ SECLI-FIRM Stakeholder Workshop 4, 15 June 2020, http://www.secli-firm.eu/presentations, http://www.secli-firm.eu/wp-content/uploads/2020/06/session-2-assessment-of-value-for-decision-making-nicholas-vasilakos.pdf
➢ SECLI-FIRM co-design, co-development and co-evaluation: the value of seasonal forecasts – Final Conference, Day 1 on 13th October 2021 http://www.secli-firm.eu/secli-firm-final-conference-2021/
➢ SECLI-FIRM Deliverable D3.11 Report on collation and dissemination value-add assessment results http://www.secli-firm.eu/project-reports/
➢ SECLI-FIRM Deliverable D1.4 Report on economic assessment methods for value add associated with decision-support tools/systems http://www.secli-firm.eu/project-reports/
</td></tr>
</table>

3.4 Tailoring seasonal forecasts

The ongoing dialogue and interaction between seasonal climate forecast experts involved in WP2 and the industrial and research partners involved in the SECLI-FIRM case studies (WP3) has been critical to the successful implementation of the SECLI-FIRM WPs and to the project as a whole (Figure 1).

A core goal of WP2 was to research and develop a comprehensive set of user-driven techniques aimed at maximizing the prediction performance, the reliability, and the usefulness of the seasonal climate predictions. The WP2 work has aimed to extract the best possible information from the current generation of seasonal forecasting models and systems, recognising that skill is lower in mid-latitudes including the European case-study regions than in tropical regions influenced by El Niño including Colombia (Case Study 5). Nonetheless some windows of opportunity where skill is more promising have been identified. Significant wave height forecasts for the North Sea have more skill in winter than other seasons for example. Windows of opportunity have also been identified for downscaling and bias adjustment in situations where particular weather regimes are better predicted.

Lessons learned from the tailoring of seasonal forecasts for the SECLI-FIRM case studies are summarised in Table 4. As well as endeavouring to maximise forecast skill and boost the forecast signal (e.g., signal inflation based on forecasts of the North Atlantic Oscillation), this tailoring has ensured that the forecasts are relevant to each of the case studies in terms of temporal and spatial resolution, location and variables considered. Thus, the variables provided extend beyond the 'standard' ones of temperature and precipitation to include riverflow, offshore windspeed and significant wave height as well as derived 'impact' variables including water and energy demand, and hydropower production.

Table 4 – Summary of lessons learned with respect to the tailoring of seasonal forecasts for the SECLI-FIRM case studies

Observational data	• Advanced post-processing methods require more data than historical records can provide. • Availability of observations (in some cases those captured by users) is key to optimizing local forecasts. • Reanalysis is often a good reference dataset except for variables such as precipitation in areas with highly variable orography (e.g. Colombia) or wind speed (e.g. there are some sizeable biases in ERA5)

Model selection – addressing the following questions: Is there a model which is better than the others? Which one? Is there a combination of models which is better than any other model alone? Which one? How should I select the best model combination? Are the answers to the above questions universal, or do they depend on the place, variable or other factors?	• The optimal selection of models is different depending on the region/phenomenon. Each model has its own specific performance and may contribute added value for some regions, seasons or variables. • By using model independence information it is possible to reduce the number of models and associated data to produce optimized forecasts. • The added skill associated with using the optimal multi-model combination (typically 2-4 models) compared with the full multi-model combination (around 10 models) was found to be statistically significant in almost 80% of the cases explored. • Linear statistical models are still competitive with dynamical models, due to the relatively short historical record (ca. 25 years) for seasonal forecasts
Post processing	• Raw output of models is meaningless for the users, as is the verification of model values at grid points. • End users want to know the forecast exactly at their location. • Linking raw output to the target application via statistical post processing needs to be tailored. • It is important to assess added value of the post processing with respect to the specific application (i.e., not just temperature and precipitation).
Weather regimes	• Classic/standard weather regimes (e.g. based on *k*-means clustering) can appear promising in some contexts under "perfect forecast" conditions – but this is not universal.

	• Seasonal forecasts of weather regime frequencies are usually not significantly skillful when directly comparing model output with observations (reanalysis) - this limits their use in real forecast conditions. • Tailored regime-based methods may still offer improved forecasts in specific cases.
Further information Tailoring seasonal forecasts	➢ SECLI-FIRM Deliverables D2.2 to D2.6 http://www.secli-firm.eu/project-reports/ ➢ SECLI-FIRM Final Conference, Day 1 on 13th October 2021, session on Tailoring seasonal forecasts for climate services http://www.secli-firm.eu/secli-firm-final-conference-2021/

3.5 Trial climate services

Trial climate services have been co-developed for each of the SECLI-FIRM case studies. The mode of forecast delivery varies between case studies, as do characteristics such as:

- the specific forecast variables (primary variables) used in the forecast
- the calculation of derived variables (secondary variables)
- key visualisation techniques
- forecast lead times provided
- provision of deterministic or probabilistic forecast information
- form in which forecast skill is indicated
- supplementary material accompanying the forecast

Each trial climate service was also co-evaluated in an ongoing dialogue between the service providers and users, as well as using a common evaluation questionnaire. Several of the trial climate services will be further developed and extended as part of exploitation activities beyond the end of SECLI-FIRM (see Section 6).

Table 5 highlights some of the key lessons learned from the SECLI-FIRM trial climate services focusing on the co-development process, rather than the details of the particular solutions implemented for each case study.

Table 5 – Summary of lessons learned with respect to the co-development of trial climate services for the SECLI-FIRM case studies

Co-development of the SECLI-FIRM trial climate services: lessons learned summary	
• A clear and simple presentation of the available data (forecasts and associated skill, climatology) is itself useful to the user, even despite a lack of skill at longer forecast lead times • Developing a trial forecast enabled a targeted discussion with users on their specific wishes and needs. It enhanced the effect of the iterative process to reach an optimised exploitation and value add of seasonal forecast information. • Developing a trial forecast was a very good way of highlighting the limitations of proposed forecast methods – leading to plans for improvements and further iteration • Users with what may at first look like similar needs may in fact have different requirements when those needs are assessed in greater depth (e.g., it is also dependent upon the capacity of each user or the stage that the business is at) • Similar visualisation tools for probabilistic information may be valuable, despite different user needs and vice versa. • Being mindful of these user needs at all stages of development is useful. This comes through ongoing engagement but also through using outputs such as the decision trees (e.g., mapping specific components of the service to key decisions). • The dashboard (such as developed by KNMI for CS7), or a more established climate service visualization tool (such as Teal which allows users to have a simple view as well as the option to download the underlying data), are interesting propositions for interaction with users. • The dashboard is a relatively new concept and could be more developed together with guidelines for standardisation of dashboards created, so that they can be more easily understood by a wider audience.	
Further information Trial climate services	➢ SECLI-FIRM trial climate services – introduction and teasers – Final Conference, Day 3 on 19th October 2021 http://www.secli-firm.eu/secli-firm-final-conference-2021/ ➢ SECLI-FIRM Deliverable 4.3 Report on development, testing and documentation of demonstration of use of trial climate services http://www.secli-firm.eu/project-reports/

4 Opportunities internal to and closest to SECLI-FIRM

4.1 Shared journeys

The SECLI-FIRM case studies were co-designed and co-developed by research and industrial users, focusing on very specific decisions and applications in each case. Nonetheless a number of synergies and opportunities for cross case-study learning emerged and were found to be mutually beneficial. This is illustrated here by the shared journey of case studies 6 and 7 which was presented during the SECLI-FIRM final conference, Day 2 on 14 October 2021 (Figure 2). Both case studies focus on issues relating to offshore logistics and maintenance planning. Case study 6 involved KNMI and TenneT as research and industrial partners respectively, with MO and Shell taking these roles for case study 7. The key messages from this shared experience are summarised in Table 6 and cut across activities relating to WPs 1 (decision trees and assessment of value add), 2 (tailoring of forecasts), 3 (case-study framing and implementation) and 4 (trial climate services).

Table 6 – Key messages from the shared journeys of case studies 6 and 7

<table>
<tr><th colspan="2">Perspectives from KNMI/TenneT and MO/Shell</th></tr>
<tr><td colspan="2">
Stakeholder requirements are similar, but differ in detail
Scientific approaches are different, but results are similar
The paths of the two case studies were different but have substantially benefitted from each others’ respective experience, converging at several key intersections along the journey.
Efficiencies were gained from the close coordination of these case studies.
</td></tr>
<tr><td>Further information

Shared journeys</td><td>➢ Energy logistics: Wind and wave conditions - Science, Key Findings, Results in terms of “Value add” and Case study Trial Climate Service – Final Conference, Day 2 on 14 October 2021 http://www.secli-firm.eu/secli-firm-final-conference-2021/</td></tr>
</table>

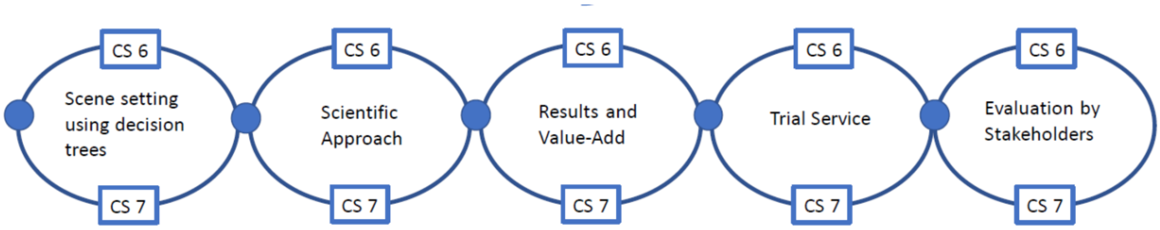

Figure 2: The shared journey of Case Studies 6 and 7.

The learning from case study 7 also proved to be transferable to case study 9, particularly with respect to the use of Relative Economic Value to quantify value add and the approach to visualisation of seasonal forecasts. The MO was the research partner for both case studies. Case study 9 focuses on water demand and maintenance planning, with Thames Water as the industrial user. This is therefore a good example of cross-sectoral learning.

4.2 Cascading to other users

The SECLI-FIRM case studies and trial climate services were co-developed for decision-focused applications and industrial users. The latter tend to be particular individuals with a very specific role within their organisation. These individuals were the people who, for example, provided feedback on the trial climate services via a questionnaire survey. One of the survey questions was:

> "Is there anyone else in your organisation who could benefit from this forecast? If so, what is their job role?"

The responses to this question are summarised in Table 7 and indicate the potential for application of the SECLI-FIRM learning and tools to different decisions and users within the same organisation. It should, however, be noted that these different users may have different expertise and requirements in terms of information and modes of delivery.

For case study 8, seasonal climate forecast information was used to modify the 'Winter Outlook' for energy demand and wind generation produced and disseminated by National Grid to a wide range of users from Energy traders to Utility companies. Thus, National Grid can be considered as a potential purveyor of seasonal forecast information to a wider range of users.

For case study 9, the industrial partner Thames Water has facilitated discussions across the wider UK water industry (especially via the UK Water Demand Group) with the MO on the potential value and utility of seasonal forecasts for the sector. It is anticipated that these discussions will continue on a more organized basis beyond the end of SECLI-FIRM (see Section 6).

These examples illustrate the important role of the SECLI-FIRM industrial partners or champions in cascading the project learning more widely to other potential climate service users within their own organisations and sectors.

Table 7 – Potential users of the SECLI-FIRM trial climate services within the same organisation

Case study	Other potential users within the organization
1-4 (Enel)	Forecasts – energy management. Historical data – Enel Energia.
5 (Enel)	Yes – to be identified.
6 (TenneT)	Yes – to be identified.
7 (Shell)	Marine logistics, exploration, aviation, offshore wind installations and operations and maintenance, survey teams, seismic survey.
9 (Thames Water)	Other departments affected by the weather.

5 Opportunities beyond the SECLI-FIRM consortium

5.1 SECLI-FIRM expertise

The SECLI-FIRM experience highlights the importance and value of tailoring at all stages of climate service development (identification of needs, tailoring of forecasts, development of visualisation tools, evaluation etc) where the service is aimed at supporting very specific user-defined applications and decisions. This case-study approach contrasts with the optimal form of stakeholder engagement which is favoured in the development of a more generic climate service for a broader sector – such as the European Climate Energy Mixes demonstrator (Goodess et al., 2019).

SECLI-FIRM has demonstrated the utility of decision trees (Section 3.2) as a powerful tool to assist the development of bespoke climate services. This tool is considered sufficiently flexible and transferable to facilitate development of such bespoke services for sectors beyond those considered by the project. SECLI-FIRM has also shown how decision trees can be developed with different levels of detail in order to protect confidential and commercially sensitive industrial information while not compromising the co-development process.

The tailoring of seasonal forecasts for the different SECLI-FIRM case studies (Section 3.4) has required consideration of a different suite of primary and derived variables in each case. The SECLI-FIRM consortium has dedicated considerable effort to exploring and improving observations, forecasts and processing tools for a number of 'non-standard' variables, in particular significant wave height, offshore windspeed and riverflow. It has also focused on extreme events including hydrological drought (low riverflow) and heatwaves. This variable and event specific expertise is relevant and potentially transferable to sectors and decisions beyond those considered by SECLI-FIRM. Low riverflow events, for example, may cause issues for river transportation by barge and freighter as well as for nuclear power plant cooling. The wider relevance of this expertise has been considered in the identification of opportunities for cross-sectoral learning beyond SECLI-FIRM (Section 5.2).

5.2 Sectoral analysis

The energy sector is the focus of most of the SECLI-FIRM case studies. This sector was previously identified as an early adopter of seasonal forecasts (Bruno Soares and Dessai, 2015; Bruno Soares et al., 2018). Early analyses of the uptake of climate services tended however to consider each sector as a whole without much focus on the specific decision making within each sector. Many studies made no differentiation between the provision of seasonal forecasts and climate projections – though the use of these two types of information is quite different. Climate projections are more relevant for longer-term strategic decision making, particularly related to climate change adaptation, whereas seasonal forecasts are more relevant for operational and shorter-term decision making. More recent projects and assessments of the potential market for seasonal forecast climate services have placed much more emphasis on identification of the underlying decision making processes and needs, often taking a case-study approach similar to SECLI-FIRM.

A number of these European projects with which SECLI-FIRM has interacted and shared learning are listed in Table 8. A session on cross-sectoral learning held during SECLI-FIRM Workshop 5 in May 2021, for example, included presentations on MED-GOLD and WATExR case studies as well as SECLI-FIRM case studies. The session on value add on the third day of the SECLI-FIRM final conference in October 2021 included perspectives from CLIM2POWER, EU-MACS and S2S4E as well as SECLI-FIRM.

These projects have helped SECLI-FIRM to better understand the types of decisions that can be supported by seasonal forecasts and the types of tailored information that are required. The CLARA project informed early SECLI-FIRM work on value add as well as thinking about value propositions and business models (Larosa and Mysiak, 2019). More recently, outputs from EU-MACS and MARCO have helped SECLI-FIRM to better understand the emerging European climate services market including both 'push' and 'pull' factors (Cortekar et al., 2020; Hoa et al., 2018; Perrels, 2020; Perrels et al., 2020; Tart et al., 2020), particularly in the context of optimising the exploitation of SECLI-FIRM output.

Table 8 – Some of the European climate service projects with which SECLI-FIRM has interacted and shared learning, for completeness SECLI-FIRM is also in the table.

Project	Website
SECLI-FIRM: The added value of seasonal climate forecasting for integrated risk management	https://www.secli-firm.eu
CLARA: Climate forecast enabled knowledge services	https://www.clara-project.eu
CLIM2POWER: Translating climate data into power plant operational guidance	https://clim2power.com/
EU-MACS: EUropean MArket for Climate Services	https://eu-macs.eu/
IMPREX: Climate services for hydrological sectors	https://imprex.eu/
MARCO: MArket Research for a Climate Services Observatory	https://marco-h2020.eu/
MED-GOLD: Developing climate services for European agriculture and food systems	https://www.med-gold.eu/
S2S4E: Climate services for clean energy	https://s2s4e.eu/
WATExR: Extreme climate events and water quality	https://watexr.eu/

Based on this shared learning, internal discussions and a desktop review, we have identified those sectors with greatest potential for transfer of SECLI-FIRM expertise, i.e., cross-sectoral learning (Table 9). The Table uses the classification of sectors developed by the MARCO project (Cortekar et al., 2020). It indicates the focus of the SECLI-FIRM case studies, as well as some relevant Horizon 2020 and ERA4CS projects with a seasonal forecast component (including those listed in Table 8) and areas of activity relating to Copernicus Climate Change Services (C3S) Sectoral Information Systems (SIS).

Table 9 – Overview of sectors and opportunities for SECLI-FIRM

Sector	SECLI-FIRM case studies	Opportunities for SECLI-FIRM (specific variable of interest)	Some relevant H2020 and ERA4CS projects with seasonal forecast component	C3S SIS
Water*	9	Yes	IMPREX, WATExR	✓✓
Forestry and timber		Possibly (Windspeed)	MARCO	✓✓
Agriculture*		Yes	MED-GOLD, VISCA, MARCO	✓✓
Tourism and leisure (incl. hotels)		Water sport tourism (Riverflow)	EU-MACS/MARCO, PROSNOW	✓
Energy* (incl. renewables)	1-8	Yes	CLIM2POWER, S2S4E	✓✓
Building and construction				
Catastrophe management*				
Health* (incl. hospitals and pharmaceuticals)				✓
Biodiversity				✓
Defence				
Exploration and mining				
Ecosystems				
Transportation and logistics	6/7	Offshore (Significant Wave Height and Windspeed). River (Riverflow)		✓✓
(Critical) Infrastructures	[7/8/9]	Offshore (Significant Wave Height and Windspeed)	MARCO	
Industry and trade				
Urban/spatial planning			EU-MACS (adaptation)	
Finance and insurance		Insurance e.g. Agriculture related	EU-MACS	✓
Food* and drink		Links with agriculture	MED-GOLD	

Waste management				
Social structures and governance* (incl. public services and charitable)				
Education	1-5	Yes, e.g. using the Teal tool and its Climate Variables for University and/or High School teaching material		

* GFCS priority areas: Agriculture and food security, Disaster Risk Reduction, Energy, Health, Water

✓ Some C3S SIS activity for this sector. ✓✓ activity includes seasonal forecast component.

6 Concluding remarks

The SECLI-FIRM key messages and discussion on cross-sectoral learning presented in this report are highly relevant to the final project exploitation plans which are described in the confidential deliverable report D5.15. These plans relate to three opportunities which were identified in the early stages of the project:

Opportunity 1 – The discoveries of WP2, concerning optimised multi-model combinations of seasonal climate forecasts, will provide skilled insights and enhanced performance when applied to specific geographical areas to address industry user-defined questions;

Opportunity 2 – The case study examples of the quantified economic benefits to arise from the work in WP3, as planned and elaborated in WP1, add value in enhancing confidence in the use of seasonal forecasts and provide an information base which partners can further develop (e.g. for training purposes) during or after the project;

Opportunity 3 – The trial climate services developed in WP4, in conjunction with the market assessment in WP5, will be showcased within the project, as well as disseminated to other energy stakeholders and climate service providers, for potential post-project adoption on a commercial basis**.**

Of these three exploitation opportunities Opportunity 2 is the most relevant to the material presented here. The final exploitation plans associated with this opportunity are:

- Sharing and adoption of lessons learned in terms of stakeholder engagement approaches, including the value of tools, such as decision trees, to aid understanding of sector-specific decision making processes and how seasonal forecast information can then be embedded within these processes with audiences that can make use of these learnings (e.g. climate services community); this includes the publication of results in scientific papers, in addition to the public dissemination of selected project reports

- Cross sectoral learning, including extensions into other sectors, where there is most scope to transfer learning based on the outputs of other EU climate services projects working on potentially relevant sectors such as agriculture and insurance, and on climate services market projects

Section 3 of this report contributes to the first bullet point above. Many of these key messages will be expanded upon in journal papers currently in preparation for submission to a special issue "Seasonal Forecasting Climate Services for the Energy Industry" of the MDPI *Climate* journal - https://www.mdpi.com/journal/climate/special_issues/climate_services.

For example, in ENEL, the drafting of a decision tree made it possible to discern the added value of the seasonal forecasts and at the same time allowed a deeper comprehension of their decision-making processes. In addition, a full understanding of seasonal forecasts led to the development of tools that no longer use only the climatological value, helping to upgrade the entire decision-making process. The sharing of information therefore, in the case of Enel, brought benefit not only to users outside the Corporation, but also and above all to internal users working in similar sectors.

Section 5 of this report, and in particular Table 9, addresses the second bullet point. Section 4 has also identified further opportunities within the energy and water sectors targeted by SECLI-FIRM. In this respect the plans for the MO and Thames Water to continue discussions on the use of seasonal forecasts with the Water Demand Group, which represents about 70% of the relevant UK community, are highlighted.

The SECLI-FIRM innovation and research activities and the project exploitation plans focus on the use of seasonal forecasts in decision making. The provision of seamless information across different lead forecasting timescales has, however, been identified as important for many users in terms of promoting the uptake of climate information. SECLI-FIRM has helped industrial users to move beyond the starting point of only considering long-term climate averages (climatology) in their decision making to the use of sub-seasonal and seasonal predictions and forecasts, with cognisance of their inherent uncertainties and probabilistic nature. There is scope to consider how this may help to pave the way for these organisations to incorporate longer-term decadal and climate projections in their decision making.

There is also strong potential to exploit opportunity 3 for other sectors, particularly through the extension of the Teal tool (https://tealtool.earth), which allows for flexible new developments, by for instance including new indicators for any other sector. An example of such an extension can be seen in the version of Teal developed in collaboration with the ENEL foundation: https://ef.tealtool.earth.

References

Beier, P., Hansen, L.J., Helbrecht, L. and Behar, D. 2017. A how-to guide for coproduction of actionable science. *Conservation Letters* 10, 288-296. https://doi.org/10.1111/conl.12300

Bruno Soares, M. and Dessai, S. 2015. Exploring the use of seasonal climate forecasts in Europe through expert elicitation. *Climate Risk Management* 10, 8-16. https://doi.org/10.1016/j.crm.2015.07.001

Bruno Soares, M., Alexander, M. and Dessai, S. 2018. Sectoral use of climate information in Europe: A synoptic overview. *Climate Services* 9, 5- 20. https://doi.org/10.1016/j.cliser.2017.06.001

Cortekar J, Themessl M. and Lamich, J. 2020. Systematic analysis of EU-based climate service providers. *Climate Services* https://www.sciencedirect.com/science/article/pii/S2405880719300664

Goodess C., Troccoli, A., Acton, C., Añel, J.A., Bett, P.E., Brayshaw, D., De Felice, M., Dorling, S., Dubus, L., Penny, L., Percy, B., Ranchin, T., Thomas, C., Trolliet, M. and Wald, L. 2019. Advancing climate services for the European renewable energy sector through capacity building and user engagement. *Climate Services* 16, 191–205 https://doi.org/10.1016/j.cliser.2019.100139

Hewitt, C.D., Stone, R.C. and Tait, A.B. 2017. Improving the use of climate information in decision-making. *Nature Climate Change* 7, 614-616. https://doi.org/10.1038/nclimate3378

Hoa, E., Perrels, A. and Le, T-T. 2018. From generating to using climate services – How the EU-MACS and MARCO projects help to unlock the market potential. *Climate Services*, https://doi.org/10.1016/j.cliser.2018.08.001

Larosa, F. and Mysiak, J. 2019. Business models for climate services: An analysis. *Climate Services* https://doi.org/10.1016/j.cliser.2019.100111

Meadow, A.M., Ferguson, D.B., Guido, Z, Horangic, A. and Owen, G. 2015. Moving toward the deliberate coproduction of climate science knowledge. *Weather, Climate, and Society* 7, 179-191. https://doi.org/10.1175/WCAS-D-14-00050.1

Perrels, A. 2020. Quantifying the uptake of climate services at micro and macro level. *Climate Services* https://doi.org/10.1016/j.cliser.2020.100152

Perrels, A., Le, T-T., Cortekar, J., Hoa, E. and Stegmaier, P. 2020. How much unnoticed merit is there in climate services? *Climate Services* https://doi.org/10.1016/j.cliser.2020.100153

Tart, S., Growth, M. and Seipold, P. 2020. Market demand for climate services: An assessment of users' needs. *Climate Services* https://doi.org/10.1016/j.cliser.2019.100109

Taylor, A., Scott, D., Steynor, A. and McClure, A. 2017. Transdisciplinarity, Co-production and Coexploration: Integrating Knowledge Across Science, Policy and Practice in FRACTAL. FRACTAL working paper #3, 19pp. http://www.fractal.org.za/wp-content/uploads/2017/03/Co-co-trans_March-2017.pdf

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