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# Roadmap for the deployment of Solar Heating for Industrial Processes

Deliverable 8.3

WP8. Business model, Replication and Exploitation

SHIP2FAIR - Solar Heat for Industrial Process towards Food and Agro Industries commitment in Renewables

Prepared by: LINKS

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## ABBREVIATIONS

**SME:** Small Medium Enterprises

**CT:** Control Tool

**RT:** Replication Tool

**SHIP:** Solar Heating for Industrial Processes

**MPC:** Model Predictive Control

**LCOE:** Levelized Cost of Energy

**ICS:** Industrial Control Systems

**JSON:** JavaScript Object Notation

**ICT:** Information and Communication Technology

## PARTNERS SHORT NAMES

**CIRCE:** FUNDACIÓN CIRCE CENTRO DE INVESTIGACIÓN DE RECURSOS Y CONSUMOS ENERGÉTICOS

**RINA-C:** RINA Consulting S.p.A.

**CEA:** Commissariat à l'énergie atomique et aux énergies alternatives

**LINKS:** Fondazione links – leading innovation & knowledge for society

**SOLID:** S.O.L.I.D. Gesellschaft für Solarinstallation und Design mbh

**TVP:** TVP Solar

**IS:** Industrial Solar GmbH

**BEST:** Bioenergy and sustainable technologies GmbH

**M&R:** Martini & Rossi S.p.A.

**RODA:** Bodegas Roda S.A.

**RAR:** RAR – Refinarias de Açúcar Reunidas S.A.

**Larnaudie:** SNC JEAN LARNAUDIE

**EDF:** Electricité de France

**EUREC:** EUREC EESV

**SPANISH CO-OPS:** Cooperativas Agro-alimentarias de España, U. de Coop.

**SOLID:** SOLID SOLAR ENERGY SYSTEMS GMBH

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## PUBLISHABLE SUMMARY

Deliverable 8.3 starts with replicability and scalability analysis of Control Tool (CT) and Replication Tool (RT). Then, the analysis extends to the replicability and scalability of the entire project, i.e. the whole integration of Solar Heat for Industrial Processes (SHIP) into industrial processes.

The Control Tool is an online Decision Support System (DSS) to optimize the management of process heating systems through a live monitoring-oriented approach. The Control Tool has a modular structure and it is cloud-based, which means it can be stored, managed, and available through the cloud. These features are attractive to any industrial sector willing to set up a SHIP plant.

The Replication Tool is a software to support the concept design of SHIP projects and the development of techno-economic feasibility studies. It has the opportunity to be coupled with other tools used in the context of energy audits of industrial sites and it is a good illustration of the kind of tool that can be used by different actors.

Replicability analysis held on CT and RT is mainly focused on interoperability and modularity of the components and the whole solution. CT achieves both Technical and Syntactic Interoperability thanks to its architecture design and components development, and to the use of open standards. Semantic Interoperability is not achieved since there is no standardised communication protocol between CT and proprietary systems of the various application plants. CT is based on a modular structure focused on 3 main aspects: data ingestion, data processing, data sharing.

On the other side, RT was developed as a stand-alone solution. All inputs required for its operation are requested to the user and there is no need for interoperability with other platforms or interfaces. RT is designed as modular to allow the possibility of adding solar technologies and processes. These features allow to fully customize the tool for a specific sector and so to sell a specific customization of the tool to companies inside that sector.

The CT architecture is adopting a general “design for scalability” approach. The aspects considered by the design process to scale the solution are reflected on three main aspects:

- the networking, to overcome an excess of requests and to easily spread the security infrastructure and respecting privacy conditions
- the processing, to increase the number of processes to obtain a higher parallelization of the required tasks performed by the overall components
- the storage capabilities of the developed system

Compared to CT, RT does not require the acquisition of data in real time and does not have to manage multiple, parallel requests at large scale. For these reasons, RT has no particular need to be scalable.

Deliverable 8.3 then analyses opportunities and potential barriers to be tackled to replicate the integration of SHIP in other location and/ or sectors. During the last 15 years, in Europe, the power installed associated with SHIP projects for the food and beverage industry shows an ascending trend

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and competitive Levelized Cost of Energy (LCOE) (for South and Central Europe, 0.04-0.11 EUR/kWh based on IRENA report) (solrico). Therefore, solar heat can play a key role in industry decarbonisation.

During the project work, all demo-sites experienced supply chain disruptions, amendments of the Grant Agreement, natural disasters, as well as technical issues. A large number of actors has been involved in the deployment of the solar systems beyond the relevant project partners, including: local engineering and construction companies, thermal energy professionals, installers, suppliers of energy equipment. The collaboration of these actors can evolve in the future to form local value chains or business ‘ecosystems’ on applications of Solar Heat for Industrial Processes (SHIP) and broadly on the decarbonisation of industrial heating and cooling. Such a development can only have positive effects on widening the adoption of solar thermal at industrial scale and facilitate replication and scale-up at a post-project timeframe.

In the final part, this deliverable tries to summarize inputs useful for commercialisation and scale-up to be effective. First it is important to tailor project results on the most promising use cases, i.e. sectors utilizing process temperature between 50°C and 250°C and exploiting SHIP solutions based on vacuum tube solar thermal technology, High Vacuum Flat Panel (HVFP) solar thermal technology for space heating and process steam, HVFP technology for boiler pre-heating and process heat.

In order to successfully scale-up SHIP2FAIR solutions, some additional inputs from *D6.5 - SHIP2FAIR demo-sites commissioning report* and *D7.5 - SHIP2FAIR Best practices guide* are highlighted. Construction permits and other regulatory/ environmental authorisations may be required or not depending on the country and location. Building permit clearance can take a very long time and should be anticipated as soon as possible. For this reason, it is advisable that local engineering consultants are involved in the process.

Local value chain, in coordination with solar energy companies, has to secure a robust logistics during installation and commissioning phase. It is essential that all components required for system installation are available at the required time. Logistics and component procurement activities must be validated and verified prior to system installation and commissioning.

SHIP2FAIR experienced training activities to demo-sites personnel. These activities have been performed paying attention to both theory and practical aspects in the field to ensure the possibility to act quickly in case of failures. In order to effectively replicate the SHIP2FAIR solutions, it is important that staff training is supported by a comprehensive guidebook. This manual should include operation and maintenance standard procedures/ work instructions covering the respective integrated energy systems. The implementation and use of the CT and RT on the SHIP2FAIR demo-sites revealed that in order to interact with the tool, it is necessary to speak English correctly. To improve the scalability of the tools, it might be useful to include a multi-language interface.

A final Roadmap of the replicability of SHIP2FAIR in other industrial sectors is illustrated within a GANTT chart at the end of chapter 5: ROADMAP OF THE REPLICABILITY OF SHIP2FAIR IN OTHER INDUSTRIAL SECTORS.

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# 1 INTRODUCTION

## 1.1 Methodology & structure of the report

Leveraging on the experience gained from the demo-sites this deliverable, result of Task 8.3, will analyze the market steps to be performed out of the project and the sectorial peculiarities of solar heat integration in industrial processes along with the SHIP2FAIR results and assets validated in the food and beverage sector and will present a possible roadmap of the replicability of SHIP2FAIR in other industrial sectors.

Deliverable 8.3 starts with the analysis of replicability and scalability of Control Tool and Replication Tool and then extends to the replicability and scalability of the entire project, which considers not only these 2 tangible results but the entire project work, i.e. the integration of SHIP into industrial processes. Replicability analysis will be carried out using LINKS Methodology, briefly explained in the image below:

## Fostering Replicability: LINKS Methodology and Experiences

**Replicability:** property of an activity, process, or experiment that allows it to be duplicated at another location or time or sector



Figure 1 - LINKS Methodology to foster Replicability

To better foster replication, it is necessary to perform an accurate analysis of the project solutions, identifying its enablers for reproducibility:

- Is the solution modular? Does it allow interoperability?
- Is the solution compliant with regulations and standards?
- Is the solution easily accepted by potential clients/users?
- Does the solution seem attractive to potential clients/users?
- Is the solution effective in addressing the challenge it wants to solve?

Once the solution is truthfully analysed, it is necessary to understand the context where it might be feasible to replicate it and with which actions.

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In the following paragraphs we are going to enlist and analyse the SHIP2FAIR solutions, considering the challenges and opportunities of the context, and the possible commercialization.

The following are the definitions of Replicability and Scalability that will be referred to:

### **Replicability**

Refers to the ability of your product, service or business to be replicated and sold and delivered consistently and reliably, to serve (theoretically) infinite customers (multiple markets) the exact same service or product, to the exact same standard every time. (European Commission)

### **Scalability**

A result, or rather the business exploiting the result, can be considered scalable if it is able to adapt to the changing needs or patterns of its customers/users and to the increased demand, trends, and needs, even in the face of competition, while remaining profitable and keeping high quality standards. Factors such as the flexibility of technology design, resilience of the supply chain and logistics, the organizational structure of the company and the efficiency of its operations affect scalability.

For investors, scaling is about increasing revenue generated by one unit of resources, or simply put, doing more with less. It is about making the business more efficient and improving its unit economics over time.

Growing, instead, is about acquiring and allocating resources. It is about raising funding and using the funds to recruit sales people or expanding to other geographies. It means adding more fuel to the rocket for it to go farther. (European Commission)

Results of Deliverable 8.3 will be uploaded on Horizon Result Platform, to foster replicability and scalability of SHIP2FAIR solutions and to maximize their impact bringing innovation as close as possible to the market.

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## 2 OVERVIEW OF SHIP2FAIR SOLUTIONS

### 2.1 SHIP2FAIR Offerings

SHIP2FAIR aims to foster the integration of solar heat in industrial processes (SHIP) from the agro-food sector, by developing and demonstrating a set of tools and methods for the development of industrial solar heat projects during its whole life-cycle. Thus, the project results will consist in:

1. A Replication tool for easily assessing the techno-economic feasibility of a SHIP project and supporting its design.
2. A Control tool understand as a DSS to support the operation of the complete process.
3. A comprehensive guide for supporting stakeholders in the design, commissioning and operation of their SHIP projects.
4. A complete capacity building program, addressing both professionals and students interested in SHIP applications in the agro-food sector.

These results will be demonstrated and validated at 4 demo-sites:

- RODA, Spain (wine production): Demonstration of vacuum tube solar thermal technology for process heating & cooling.
- Martini & Rossi (M&R), Italy (spirits distillation): Demonstration of High Vacuum Flat Panel (HVFP) solar thermal technology for space heating (winter period) and process steam (summer period) dual mode.
- Larnaudie, France (processing of duck meat): Demonstration of HVFP technology for boiler pre-heating and process heat.
- RAR- Refinarias De Acucar Reunidas, Portugal (sugar refining): Demonstration of linear Fresnel solar thermal technology for process steam generation.

As a result of this demonstration, SHIP2FAIR, aims to achieve up to a 40% of solar fraction with a total of 2.9 kW of installed power for producing 4.04 GWh and allowing 403 m<sup>3</sup> of fossil fuels and 1,145 TeqCO<sub>2</sub> per year. In order to fulfil these challenges a competitive consortium of EU leading entities has been gathered including 4 RTOs (CIRCE, CEA, LINKS and BEST) 2 Engineering companies (RINA-C and SOLID), 2 Solar Technology Providers (TVP and ISG), 4 agro-food companies already mentioned above, 2 sectorial associations (EUREC and SPANISH CO-OPS) and one Utility (EDF), addressing the complete SHIP projects value-chain.

During the course of the project, various criticalities were encountered, which led to the deployment of only one operating loop for the Larnaudie demo-site and the elimination of the RAR demo-site.

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## 2.2 SHIP2FAIR Addressable stakeholders

The main actors of the SHIP value chain are mentioned below.

**Industrial Companies:** Industrial companies whose heat demand fits the range of application of solar thermal (i.e., the agro-food industry). They are the potential clients in the value-chain.

**Energy/Heat Suppliers:** Companies that supply heat to their customers. They can also assume the role of facility operator.

**Government, Policy Makers, European organizations and national institutions:** Policy makers in charge of changing regulation related to renewable heat sources. They shape the environment within the different players involved. They provide guidance for the development of less traditional systems.

**Energy Consulting Companies:** provide a support service to their customers, helping them make informed choices about their energy consumption/provisions. They can also assist them in the building phase.

**Solar Thermal Equipment Manufacturers, Suppliers & Installation Builders:** Companies that manufacture the different types of solar thermal equipment, usually turnkey suppliers are also in charge of physically building the installation.

**Third party investors:** Investment companies that specializes in the third-party financing of renewable heat production projects and energy efficiency projects.

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## 3 CONTROL TOOL

### 3.1 Description

The Control Tool is an online Decision Support System (DSS) to optimize the management of process heating systems through a live monitoring-oriented approach, able to evaluate performance also to better predict maintenance interventions and maximize solar power production also considering weather forecast.

CT is a software to determine the optimal SHIP operating strategy and existing heating producers so that emissions and costs are kept low while the process quality remains high.

The Control Tool aims to optimize the control of the solar plant and the process itself from the low-level aspects (temperature control) to the higher-level aspects (forecast, fault detection, etc.) regarding the level of automation available. CT has been designed to be flexible. The tool is composed by five modules:

1. **Control of thermal solar plant** - This module aims to provide a stable outlet temperature from the solar plant.
2. **Control of integration of solar energy into the process** - This module aims to provide heat in a stable hydraulic condition to the process.
3. **Optimal interaction on plant level** (by rule or Model Predictive Controller) - This module provides an optimized overall control on the whole system (solar plant & industrial process).
4. **Forecasting methods** - This module aims to forecast the heat that the solar plant will produce.
5. **Distribution learning features** - This module provides an efficient and smart monitoring.

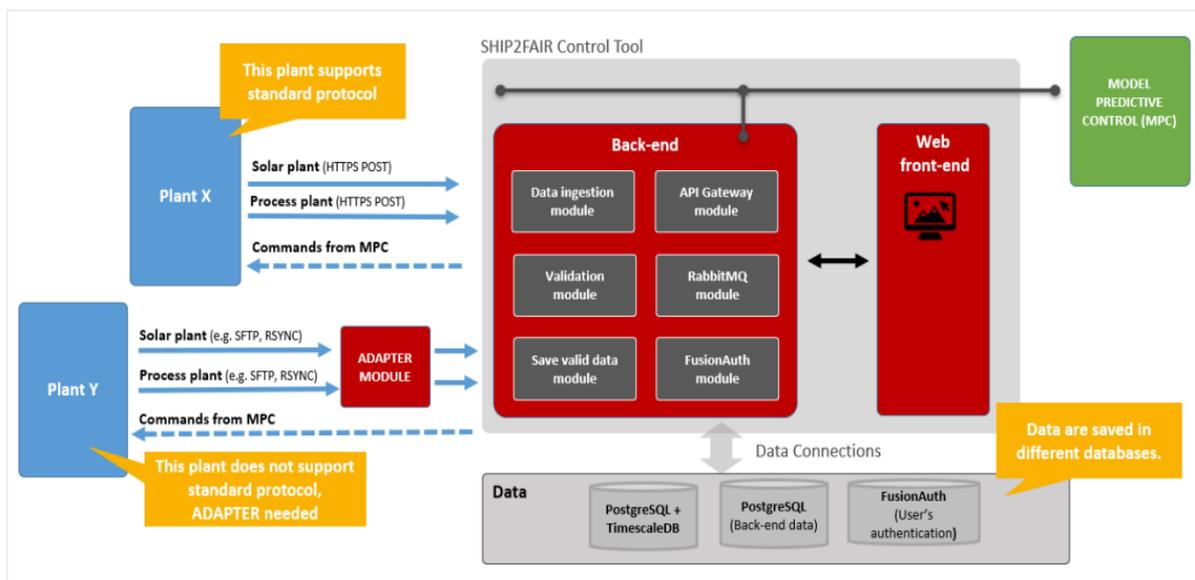


Figure 2 - ICT infrastructure for data management and monitoring

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### 3.2 Opportunities to be tackled to replicate the Control Tool in other location and/or sectors

The Control Tool has a modular structure and it is cloud-based, which means it can be stored, managed, and available through the cloud. These features are attractive to any industrial sector willing to set up a SHIP plant.

The CT is equipped with a Model Predictive Control (MPC) system that allows data analysis using machine learning and forecasting algorithms to evaluate the best plant operation mode to optimize the production process. Through comparison with a set of appropriately defined KPIs MPC can assess whether the industrial plant is efficiently utilizing the energy produced by the Solar Plant.

### 3.3 Potential Barriers

The tool as it is used in the project relies on a server infrastructure of the partners BEST and LINKS which are research institutes which cannot offer 24 hours support.

#### Sensor Dependency

Control Tool uses a live-monitoring oriented approach to optimize the management of process heating systems. In order to achieve this effectively, several sensors must be installed both in solar system and process system to record parameters useful to the Control Tool. Currently, few SMEs use sensors in their industrial automation processes; this could be a barrier in the adoption of Control Tool in location and/or industrial sectors interested in SHIP.

#### Communication Protocols – Proprietary Systems

Experience on demo-sites revealed a communication problem on data exchange between the internal network of the demo-site and the CT infrastructure. This communication problem is connected with the proprietary software used by the plant. It is therefore necessary to adopt a different strategy for each individual case, with no possibility of a standardised communication method.

In the case of RODA and M&R, it was possible to develop a middleware (a tool that acts as a communication bridge between the internal network and the CT infrastructure) to overcome the barrier of proprietary software. In the case of Larnaudie, it was not possible to build the middleware, since the company relies on a subcontractor to manage the software. A special system had to be created to manage the transmission of data to the Control Tool.

#### Communication Protocols – Industrial Devices

Another issue faced with the communication protocols concerns the impossibility of direct interaction between the https protocol used by the CT and the various industrial devices that use Modbus protocol, i.e. TVP's HVFP-based solar thermal systems and ISG's LF-11 solar thermal system. To solve this issue, the CT should be installed on premise, abandoning the cloud-based setup.

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## MPC

The CT has a Model Predictive Control (MPC) system that allows data analysis using machine learning and forecasting algorithms to evaluate the most correct plant operation mode to optimize the production process. The algorithms send instructions to the plants to maintain a certain level of energy efficiency, savings, etc. Experience on demo-sites has shown that these instructions may not be implemented for reasons of policy, safety, or economics (there is no will to stop/slow down production at that particular time perhaps). Actually, MPC does not have the possibility of directly executing the actions it considers necessary, but simply alerts a human operator. The actions that the MPC proposes remain a suggestion, thus not ensuring that the pre-set KPIs are actually met. This creates a barrier in the application of a part of what was developed during the project.

At the same time, however, it must be said that limiting the MPC's range of action provides important security in terms of Cyber Crime. If a hacker were able to breach the CT's security system, he could use the MPC to penetrate the plant's security system, stealing data or even damaging the plant's operation. Both of the above barriers related to the MPC could be solved by installing the CT on premise.

## 3.4 Replicability of the Control Tool (or tool components)

### 3.4.1 Regulation – Standard Compliance

Control Tool was developed respecting front end and back end standards, as well as https communication protocol standards. The Modbus data communication protocol is used for both, TVP's HVFP-based solar thermal systems and ISG's LF-11 solar thermal system (Modbus is widely deployed in Industrial Control Systems (ICS)) (Modbus)

#### Legal and Regulatory aspects

One important legal aspect is the European Data Protection rules, implemented in 2021. The use of CT requires a lot of valuable and sensitive data entering from the company. It has to be very clear where the data is stored and what kind of protection is guaranteed.

Installing CT on premise without having dependencies with other third-party products can be a solution to comply with the Data Protection rules for every plant using the tool.

#### Security

FusionAuth module provides authentication, authorization, and user management for the SHIP2FAIR Control Tool. The core of FusionAuth is a set of APIs that allow integrating login, registration, and advanced User management features into SHIP2FAIR Control Tool. All services are https with symmetric encryption.

#### Data format

HTTP requests (Hypertext Transfer Protocol) are made to Representational state transfer (REST) endpoints. Routing refers to selecting how an application responds to a specific client request towards a particular endpoint. A single endpoint is formed by a Uniform Resource Identifier (URI) and a specific HTTP or HTTPS (Http Secure) request method (GET, POST, PUT, DELETE). Each route can have one or more handler functions, which are executed if the route is matched. Data are exchanged in JavaScript Object Notation (JSON) format, a lightweight data-interchange format, easy for humans to read and

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write and easy for machines to parse and generate. It is based on a subset of the JavaScript Programming Language.

### Other local/national regulations

There are no specific national regulations related to the Control Tool architecture itself.

### Ethics

There are no specific ethical considerations related to the Control Tool architecture itself.

### 3.4.2 Interoperability

Interoperability refers to the ability of different information and communication technology (ICT) systems and components to communicate and work together effectively. There are several levels of interoperability in ICT systems, ranging from basic to advanced, including:

- *Technical interoperability*: This is the most basic level of interoperability and refers to the ability of two systems to exchange data or information in a common format or protocol. Technical interoperability is necessary for systems to be able to communicate with each other, but it does not ensure that the information exchanged is meaningful or useful.
- *Syntactic interoperability*: This level of interoperability is concerned with the structure and format of data or information exchanged between systems. Syntactic interoperability ensures that systems can exchange data in a consistent and standardized way, which makes it easier to understand and use the information exchanged.
- *Semantic interoperability*: This is the highest level of interoperability and refers to the ability of systems to exchange data or information with common meaning. Semantic interoperability ensures that systems can understand the context and meaning of the information exchanged, even if they use different terminologies or vocabularies. This level of interoperability requires the use of standard ontologies, taxonomies, and other semantic structures that define the meaning of data elements and how they relate to each other.

Technical and Syntactic Interoperability are both achieved thanks to the CT architecture design and components development, and to the use of open standards. Semantic Interoperability is not achieved by the CT since there is no standardised communication protocol between CT and proprietary systems of the various application plants.

An opportunity for scale-up improvement would be to map the CT upon a reference ontology commonly adopted by various industries interested in SHIP applications.

### 3.4.3 Modularity

The Control Tool has been designed to be flexible. It is based on a modular structure focused on 3 main aspects: Data ingestion, data processing, data sharing. Currently, the CT has 5 different modules, each focusing on its own application area:

1. *Control of thermal solar plant*. This module aims to provide a stable outlet temperature from the solar plant.

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2. *Control of integration of solar energy into the process.* This module aims to provide heat in a stable hydraulic condition to the process.
3. *Optimal interaction on plant level (by rule or Model Predictive Controller).* This module provides an optimized overall control on the whole system (solar plant & industrial process).
4. *Forecasting methods.* This module aims to forecast the heat that the solar plant will produce.
5. *Distribution learning features.* This module provides an efficient and smart monitoring.

#### 3.4.4 Effort

The main effort in the replicability of the CT consists in the steps to be performed to replicate the communication between internal network of a new demo-site and the CT infrastructure. An opportunity for scale-up improvement would be to map the CT upon a reference ontology commonly adopted by various industries interested in SHIP applications.

Another effort that can occur in replicating the CT concerns sensors. Sensors as well as actuators of the solar system and their location are defined in a P&ID which is result of the system engineering. The sensor definition includes the information if the sensor is part of the safety chain or for control and monitoring purpose. As described in *D7.5 – SHIP2FAIR Best Practice Guide*, attention must be paid to the integration of new sensors with existing ones (protocol compatibility).

### 3.5 Scalability of the Control Tool (or tool components)

Scalability and performance are important factors in ICT systems, no matter if they are used in monolithic applications or in applications for fully distributed systems. It is one of the elements that impacts on the replicability potential of a solution, as mentioned in the introduction of the document. The CT architecture is adopting a general “design for scalability” approach.

The technical definitions of scalability adopted is the following “Scalability is the ability of the cloud layer to increase the capacity of the software service delivery by expanding the quantity of the software service that is provided”. To provide a clearer view on the scalability aspects foreseen by the CT, it is important to further classify the involved topics and the overall resulting considerations. The aspects considered by the design process are reflected on three main aspects:

- the networking, to overcome an excess of requests and to easily spread the security infrastructure and respecting privacy conditions
- the processing, to increase the number of processes to obtain a higher parallelization of the required tasks performed by the overall components
- the storage capabilities of the developed system

In detail, the main scalability aspects related to the network load are foreseen in two different ways. Thanks to the selection of a cloud-based machine and to the monitoring of the necessary resources, the steps to overcome an excess of requests can be simply managed by increasing the bandwidth provided to the machine itself, basically, to add resources over that node, usually referred to as vertical scalability. This process requires changes on the previously signed contract by selecting a greater set of network resources to be assigned on it, with major fees but granting a constant service.

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Then, the scalability factor can be further increased by adjusting the nginx load balancer settings and consequently leading to a parallelized and improved forwarding process of the requests, exploiting different machines behind it, usually referred to as horizontal scalability. As already mentioned, the security design and the development strategy allow to safely spread the security infrastructure, the dependable LBS (location-based services) and the Privacy-Aware DBMS (data base management systems) on different dedicated machines. By following the same approaches exposed above, can be improved also the disk size and the consequent amount of data that the platform can persistently store.

On the processing perspective, those necessities can be obtained, as already mentioned for the network load, by signing a different contract and by requesting more hardware resources, without the necessity of any software reconfiguration. Other than that, thanks to the adoption of proper development strategies, without any change on the source code except for single configuration files, the processing capability can be enhanced by increasing the number of processes to obtain a higher parallelization of the required tasks performed by the overall components.

In addition, all the aspects faced in the current paragraph can be applied also to each Docker container built to properly isolate and manage every single software instance.

### 3.5.1 Acceptance

CT must be used by specialised personnel. In order to interact with the CT interface and read the results of machine learning, specific technical expertise in the energy sector is required.

Each demo-sites according to its corporate structure defines who interacts on the platform. This may be internal company personnel or third-party subcontractors. A user manual and staff training are therefore necessary.

In order to improve the acceptance component of the CT, it is necessary to develop a support tool with which personnel dedicated to managing the tool can interact.

In this section, we also analyse acceptance from the end user's perspective.

The nature of the control tool does not give an estimation of how its presence might improve the operational control performance of a production plant that is interested in acquiring it.

In fact, the control tool does not run simulations, but works on the basis of inputs from the sensors installed in the plant. It can therefore only provide data and information downstream of its installation on a real plant. This has several reasons:

- Fluctuating energy systems are hard to evaluate in practice since the weather strongly affects the performance and it is changing from time to time.
- There is no data to evaluate the control performance in simulations.

Within SHIP2FAIR project it was possible to evaluated just parts of it:

- e.g. For the forecasting module D - *method can be used to forecast the solar yield for a large variety of collector settings under real conditions with an average deviation of only 4.54 %*,

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*which can be seen as very promising to be used for energy management systems (EMS) (Science Direct).*

- For the fault detective module E (Science Direct)
- For the MPC it is always hard to say and it strongly depends on the complexity of the system, but can be considered to be in the range 2 – 7%.

The site to reach and use the control tool may be open to those who request it, but it only provides forecasting and suggestions on active plants.

### 3.5.2 Effort

CT Scalability efforts are described in chapter 3.5 Scalability of the Control Tool (or tool components) above.

## 3.6 Demonstration and results

The experience from the SHIP2FAIR project highlighted the difficulty of entering into the production process of a company to develop and test new technologies that impact on production. Solutions that can theoretically improve the energy efficiency of the plant may in fact not meet the economic and production objectives.

Positive features of the Control Tool compared to systems currently used by demo-sites can be summarized as follows:

- The Control Tool enables the demo-sites to inform themselves regarding the status of the plant (e.g. temperatures, pressure, status of storages) or the course of specific measurements from everywhere through the browser
- The MPC provides suggestions for the operation of the system which can be carried out by the plant operators
- Forecasting methods show the most important weather quantities like solar radiation and ambient temperature for the next days and calculate the expected amount of solar heat allowing the operator to reschedule the production to some extent
- Fault detection algorithms alert operators to potential problems
- The calculated KPIs give the operators a quick overview of the performance of the plant and the energy saved up to now

The implementation and use of the CT on the SHIP2FAIR demo-sites revealed that in order to interact with the tool, it is necessary to speak English correctly. To improve the scalability of the tool, it might be useful to include a multi-language interface.

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## 4 REPLICATION TOOL

### 4.1 Description

The Replication Tool is a software to support the concept design of SHIP projects and the development of techno-economic feasibility studies. This tool combines both data from solar generation and process features to provide a first outlook on SHIP integration and optimize the system according to user's needs.

This tool is constituted by five modules:

1. **General information** - in this module, the user fills basic information (company information, contact name, email address, production information).
2. **Solar Mapping** - In this module, the user fills the information needed for an estimation of the solar resource (the location of industrial site, the panel azimuth and slope, the area available for the collectors, the kind of collectors, the type of installation, the shading). The output of this module is the solar resource, meteorological data (wind, temperature, etc.), usable area and optimized angle (slope and azimuth).
3. **Thermal demand characterization** - The Thermal demand characterization module aims to define the energy needs from the industrial process. For that, the user must provide some basic information:
  - The energy sources (type, consumption, costs)
  - The equipment inventory (type, power, load factor, etc.)
  - The process definition (thermal use (heat/cold), working fluid, operating temperature, etc.)
4. **Simulation module** - This module provides the yearly solar heat delivered by the solar plant to the process and several KPIs (technical, environmental and economic) selected by the user. For that, the user is asked to choose one solar technology and other basic features of the desired solar plant. The output will be the solar energy production, the collector surface, thermal efficiency, size of the thermal storage, ROI, payback, CO2 saved.
5. **Integration module** - The module for solar integration identifies and ranks which is the best solar integration point within the different process in the industry. The integration gathers the output of the simulation module in one pdf file that can be downloaded.

Figure 3 shows the SHIP2FAIR database, which stores inputs and outputs of the 4 modules composing the Replication Tool as well as the additional data required to execute the Replication Tool.

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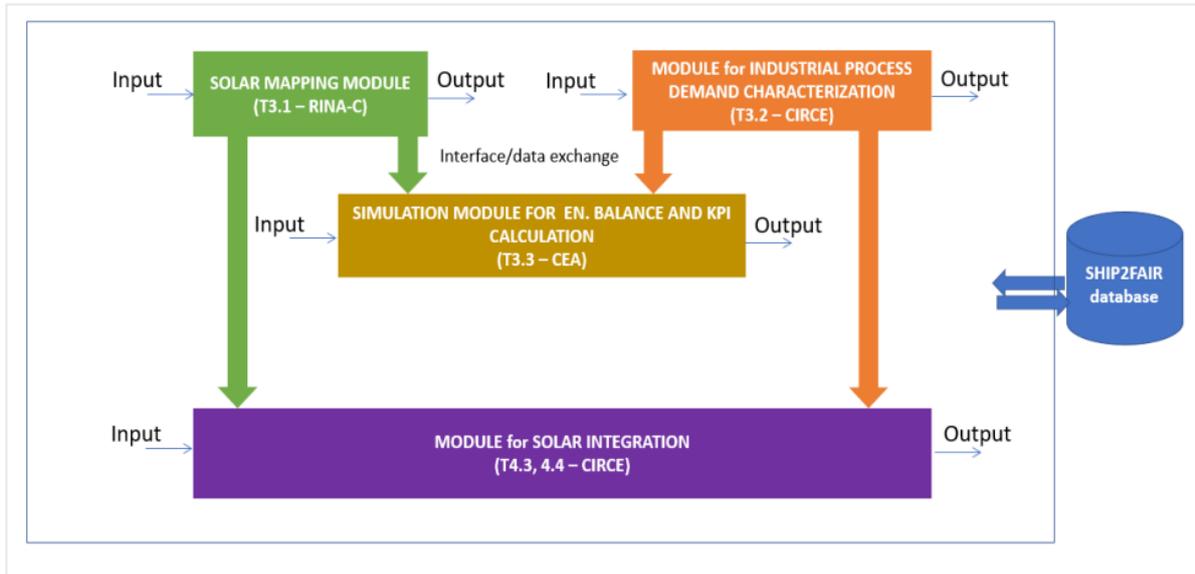


Figure 3 - Replication Tool general scheme

## 4.2 Opportunities to be tackled to replicate the Replication Tool in other location and/or sectors

### RT Unique Value Proposition

As described in *Business Plan Development Report*, Replication Tool will be able to combine the data from the solar generation (location and radiation of the site, technical data from the solar collectors to be evaluated, CAPEX and OPEX costs and surface available) and the industrial process features (type of process, heat demand requirements, daily and monthly profiles, and the technical data of the existing heating system to be replaced) in order to provide a first outlook on the SHIP integration within the process and to optimize the system according to the user's needs (optimisation against one defined KPI). These features will give RT a unique value proposition.

Moreover, RT has the opportunity to be coupled with other tools used in the context of energy audits of industrial sites (e.g. PVGIS has become a standard tool to evaluate at a high-level the potential for installing a PV plant on a specific site. SHIP2FAIR RT could potentially become the standard tool for evaluating the potential for solar heat integration in industrial processes).

There are other tools that can make comparisons between different technologies (e.g. Solaris) that may be similar, but do not have the online service. Another existing simulation tool capable of calculating the efficiency of a solar thermal system is T\*SOL, from the software Valentine, but it is necessary to design a new system and choose all settings each time before obtaining the results of that system. This tool has no generic terms, so it is necessary to choose each specific technology and specify all parameters.

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### RT Spin-Off Generation

More and more actors enter the field of energetic transition. Towards that goal, the Replication Tool is suitable to be a potential Spin-Off solution of SHIP2FAIR. It is a good illustration of the kind of tool that can be used by different actors: engineering companies and industrial companies for designing and planning, banks, and financing actors for assessing projects submitted for funding.

As described within *Horizon Results Booster Report*, it is possible to use the tool as a kind of hook for potential clients. Interested partners will use the tool and when they will need some more added value analysis or initial prefeasibility, then the partner could sell the respective services to the users. This model is better than selling the tool. Using the Replication Tool could lead a Company to buy a system from a technology provider.

The product provides project developers in the SHIP field with a tool able to provide pre-feasibility studies and first indications on the suitable configuration of the solar field.

- The tool should increase the penetration of solar thermal technologies in the industry by providing easier access to interested parties and shorter time for developing pre-feasibility studies.
- The tool should provide technology providers with a third-party tool to benchmark their internal analysis.

### 4.3 Potential Barriers

The SHIP2FAIR experience highlighted the difficulty of integrating the different RT modules and making them communicate with each other. The 4 main modules were in fact developed by different project partners. The outputs of the modules were not directly usable as inputs by the next module. Coordination between the partners was necessary to make the modules communicate within the RT.

SHIP2FAIR RT experienced the use of a wide range of standard parameters that could not be fully representative of the site conditions. This affected the availability of data required for the definition of the thermal energy balances (a detailed energy audit is needed; otherwise large margins of error are introduced; generally, data availability regarding electrical aspects is better than thermal aspects).

The tool as it is used in the project relies on a server Infrastructure of the partners BEST and LINKS which are research institutes which cannot offer 24 hours support.

#### Solar Mapping Module

The solar mapping module provides an estimate of the plant's production potential and is based on climatological data. Considering the actual climate change, the solar mapping module may provide inaccurate estimates compared to more recent tools for climatological data analysis that experienced important developments, for instance on solar irradiation.

The solar mapping module is developed on PVGIS and is therefore bound to its existence. If PVGIS would no longer be an open resource, the solar mapping module could not function.

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### Industrial Process Demand Characterization Module

The module for industrial process demand characterization (DCM) assesses the thermal demand of the industrial processes selected by the user according to simplified models. The reference database for the DCM is only based on data from the last year. This means that the output of the DCM is not statistically representative of consumption.

### Simulation Module

The simulation module was developed mapping two main processes (heating & cooling, water & steam). The module's functionality is therefore limited to the application area of hot water and steam production. It can be replicated wherever a solar thermal installation exists and where the industrial process requires cooling/heating with water. The application in other industries with different needs is not guaranteed unless an adaptation effort is made.

Simulation Module operates on the basis of assumptions made on the technology used, for any future technologies used within solar installations, the RT will have to be adapted.

### Integration Module

The solar integration module identifies and ranks which is the best solar integration point within the different processes in the industry. It gives an idea of how efficient the energy produced is in relation to utilization. The integration tool assumes 2 standard layouts, one based on hot water and the other on steam as described in figure below:

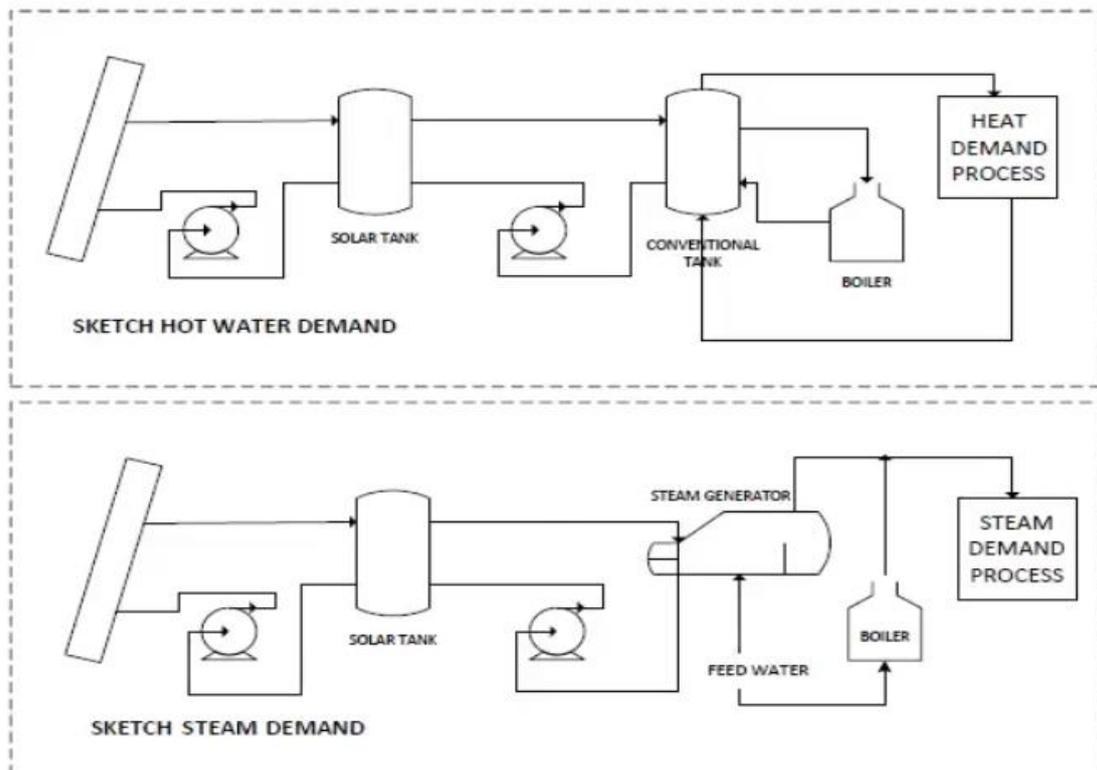


Figure 4 - Integration Module's standard layouts

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If there are more complex layouts than the ones on the tool, the integration module may not work accurately.

## 4.4 Replicability of the Replication Tool (or tool components)

### 4.4.1 Regulation – Standard Compliance

#### Legal and Regulatory aspects

One important legal aspect is the European Data Protection rules, implemented in 2021. The use of this tool requires a lot of valuable and sensitive data entering from the company. It has to be very clear where the data is stored and what kind of protection is guaranteed.

Installing RT on premise without having dependencies with other third-party products can be a solution to comply with the Data Protection rules for every plant using the tool.

#### Security

FusionAuth module provides authentication, authorization, and user management for the SHIP2FAIR Replication Tool. The core of FusionAuth is a set of APIs that allow integrating login, registration, and advanced User management features into SHIP2FAIR Replication Tool.

All services are https with symmetric encryption.

#### Data format

HTTP requests (Hypertext Transfer Protocol) are made to Representational state transfer (REST) endpoints. Routing refers to selecting how an application responds to a specific client request towards a particular endpoint. A single endpoint is formed by a Uniform Resource Identifier (URI) and a specific HTTP or HTTPS (Http Secure) request method (GET, POST, PUT, DELETE). Each route can have one or more handler functions, which are executed if the route is matched. Data are exchanged in JavaScript Object Notation (JSON) format, a lightweight data-interchange format, easy for humans to read and write and easy for machines to parse and generate. It is based on a subset of the JavaScript Programming Language

#### Other local/national regulations

There are no specific national regulations related to the Replication Tool architecture itself.

#### Ethics

There are no specific ethical considerations related to the Replication Tool architecture itself.

### 4.4.2 Interoperability

The Replication Tool was developed as a stand-alone solution. All inputs required for its operation are requested to the user and there is no need for interoperability with other platforms or interfaces.

The modules that make up the replication tool allow output data to be saved and downloaded in pdf and JSON (simulation module) format. These data can then be used on other platforms by loading them manually, thus making the RT interoperable.

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#### 4.4.3 Modularity

RT is conceived as modular to allow the possibility to add solar technologies and processes. In the thermal demand characterization, the tool can be customized in order to have sectorial default data about different processes and this can help users to perform the analysis easier and quickly. These features allow to fully customize the tool for a specific sector and so to sell a specific customization of the tool to companies inside that sector.

The replication tool was developed providing a decoupling with bus communication between the stand-alone modules. This guarantees independence in updating the individual modules while preserving the input and output interfaces.

Given the strong restriction that each module requires specific inputs (from the user and other modules), one single module could be potentially replaced by another piece of software / module written in different programming language in order to allow flexibility and additional exploitation options.

#### 4.4.4 Effort

From a replicability perspective, the effort required may be to modify one of the 4 main modules of the RT to align with the input data of a new plant.

### 4.5 Scalability of the Replication Tool (or tool components)

Compared to CT, RT does not require the acquisition of data in real time and does not have to manage multiple, parallel requests at large scale. For these reasons, RT has no particular need to be scalable. When allocated on a powerful infrastructure (server) and equipped with a time series database, RT allows a large number of users to perform the necessary simulations.

#### 4.5.1 Acceptance

RT must be used by specialised personnel. In order to interact with the RT interface and read the results, specific technical expertise in the energy sector is required.

Each demo-sites according to its corporate structure defines who interacts on the platform. This may be internal company personnel or third-party subcontractors. A user manual and staff training are therefore necessary.

In order to improve the acceptance component of the RT, it is necessary to develop a support tool with which personnel dedicated to managing the tool can interact.

In this section, we also analyse acceptance from the end user's perspective.

Differently from CT, RT by its very nature supports simulation. In fact, the instrument can be used independently of data provided by sensors installed on a SHIP system already in function. An industrial plant interested in adopting the RT with a view to developing a SHIP solution can therefore make use of the RT by accessing the website (SHIP2FAIR Replication Tool) and entering the data required to carry out a simulation.

The RT therefore meets acceptance requirements even for end users.

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## 4.6 Demonstration and results

SHIP2FAIR Replication Tool was used to realize 10 Pre-Feasibility studies in order to show the potential replicability and the techno-economic viability, maturity and affordability of solar heat technology for industrial process. As described in *D8.4 - Pre-Feasibility Studies in 10 additional sites all around Europe*, the use of RT enabled the comparison of different technologies with the same tool, starting from the same data collection (tools developed by technology providers usually only consider a single technology).

RT also demonstrated the possibility of evaluating technologies that consider heat in different forms (steam, water, etc.) and at different temperature levels with the same tool.

The implementation of the RT revealed that in order to interact with the tool, it is necessary to speak English correctly. To improve the scalability of the tool, it might be useful to include a multi-language interface.

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## 5 ROADMAP OF THE REPLICABILITY OF SHIP2FAIR IN OTHER INDUSTRIAL SECTORS

After a detailed focus on Control Tool and Replication Tool, this chapter extends to the replicability and scalability of the entire project, which considers the entire project work as a whole, i.e. the integration of SHIP into industrial processes.

Chapter 5 begins by describing the opportunities and potential barriers to be tackled to replicate the integration of SHIP in other location and/ or sectors.

Some useful aspects for commercialisation and scale-up of SHIP integration solutions are then analysed.

Finally, a Roadmap for the replicability of SHIP2FAIR is proposed, consisting of a series of Milestones, outlined in a GANTT diagram. The Roadmap refers to all the key aspects highlighted in Chapters 3, 4 and 5.

### 5.1 Opportunities to be tackled to replicate the SHIP2FAIR experience in other location and/or sectors

#### Ascending Trend and LCOE

As described in *D8.1 - Business models for deployment of solar heating for industrial processes*, during the last 15 years, in Europe, the power installed associated with SHIP projects for the food and beverage industry shows an ascending trend. The reduction of costs enabled through economies of scale gave a push in the right direction. Solar thermal has today competitive Levelized Cost of Energy (LCOE) (for South and Central Europe, 0.04-0.11 EUR/kWh based on IRENA report) in comparison to fossil fuels. The capital takes between 50-70% of the total costs. The thermal needs are very important (50% of the energy), and industry represents a third of the energy consumption. Only 25% of the industry energy consumption is addressed by electricity. Therefore, solar heat can play a key role in industry decarbonisation.

#### SHIP2FAIR generated knowledge

As described in *D6.5 - SHIP2FAIR demo-sites commissioning report*, while the same main steps of the commissioning process have been applied in all demo-sites, each site has had unique characteristics in relation to: the implementation scheme (e.g. RODA has used a commercially available solar thermal technology and a technology provider and contractor outside the SHIP2FAIR consortium), type of solar thermal technology (non-concentrated or concentrated), regulatory requirements (different in the four countries and types of applications), installation surfaces (on rooftop or on the ground), layout of the solar system (e.g. two subsystems in Larnaudie), operational mode (dual – hot water during winter, steam during summertime – in M&R). All demo-sites experienced supply chain disruptions, amendments of the Grant Agreement, natural disasters, as well as technical issues. The above difficulties have challenged the capacity to deliver of the SHIP2FAIR consortium. However, at the same time, they have forced both technology and user partners to improve the solar thermal solutions and generate new knowledge that can fundamentally facilitate replication and scale-up at a post-project

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timeframe. For instance, TVP Solar has completely reengineered its panel-to-panel connectors so that it can eliminate leaks caused during steam mode operation (due to a combination of relatively high pressure and temperature variations throughout the day).

## 5.2 Potential Barriers

### Regulation Compliance

As previously described, Regulatory Requirements revealed to be a challenging issue during SHIP2FAIR project work. Each country had unique characteristic in terms of regulation compliance and this issue caused delays during commissioning phase. An example is reported in *D6.5 - SHIP2FAIR demo-sites commissioning report*, regarding Larnaudie demo-site. The problems at the beginning of the project are related to the building permit and the "porter à connaissance" procedure because the installation is unknown to the French authorities, which slows down the project. French laws are more restrictive than in other countries for a solar power plant and require a very specific process to be followed. To facilitate replication and scale-up of SHIP2FAIR solution it will be important to start dealing with regulation compliance in parallel with the design phase, in order to avoid delays in commissioning phase.

### Language Barrier

The implementation of CT and RT revealed that in order to interact with the tools, it is necessary to speak English correctly. Both *D6.5 - SHIP2FAIR demo-sites commissioning report* and *D7.5 - SHIP2FAIR Best practices guide* highlighted that language barrier has been an obstacle with the different interlocutors. Replication and Control Tools' scalability analysis highlighted the importance of having specific technical expertise in the energy sector to interact with the tools. This makes even more important to include multi-language interface on the tools to facilitate replication and scale-up of SHIP2FAIR solution.

### Lack of specialized personnel

*D6.5 - SHIP2FAIR demo-sites commissioning report* highlighted the importance of the smooth integration of solar thermal into the legacy and/or new thermal energy systems. The type of integration i.e. direct process integration (Larnaudie – low temperature hot water), centralised integration (M&R – low pressure process steam) or simply aesthetics can significantly affect the solar-to-heat energy conversion efficiency. The type of integration may also affect the complexity of the final energy system, its management, and the required learning curve. This leads to a barrier in the replication and scale-up of the SHIP2FAIR solution, as it is difficult to find specialised personnel in the energy and solar sector within SMEs. Another challenge is the lack of an IT department in many SMEs, which can be challenging in order to make data available for the control tool in a respective quality. An acceptable level of digitization and automation must be ensured before CT and RT can be applied.

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### 5.3 Inputs useful for commercialisation and scale-up of SHIP2FAIR solutions

#### Target Market – Tailor the most promising use cases

For commercialisation and scale-up to be effective, it is important to focus on the target market and then to restrict the attention on the most promising use cases based on the experience gained within the project work.

As described in *D8.1 - Business models for the deployment of Solar Heating for Industrial Processes*, the target market is identified in industrial sectors with process temperatures in the range between 50°C and 250°C. Considering the total heat demand for low and medium temperature applications the identified sectors are the following:

- Food & beverage
- Transport equipment
- Textile
- Machinery
- Pulp and paper industries
- Chemical industries

As highlighted in figure 4 below, an extremely high percentage of heat demand in the low temperature range is found in food, beverages, paper and textiles with medium temperature ranges in the plastics and chemical industries. The paper and food industries have the highest heat demand. Other sectors potentially interested are fast moving goods, automotive, mining and pharmaceutical and all the industrial process that need heat in medium and low temperatures.

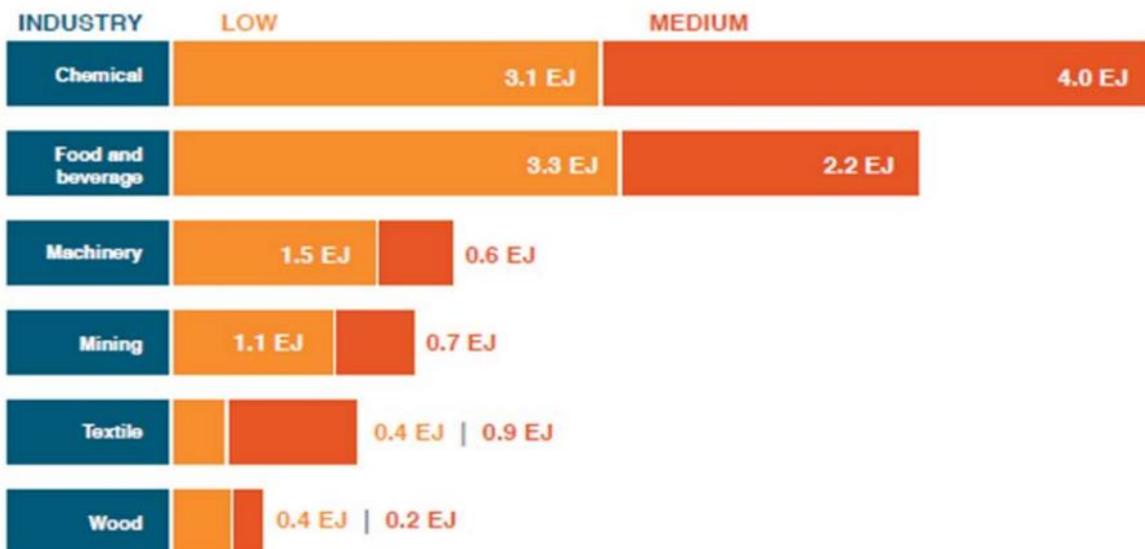


Figure 5 - Total heat demand for low and medium temperature applications

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As discussed in Chapter 4, the features of the RT enable the commercialisation and scale-up of the tool independently. If we consider this possibility, the target market extends. As described in the *Business Plan Development Report*, due to the high level of customization and the possibility to pre-fill the tool with sectorial default data, other potential customer/use cases could be the following:

- sectorial associations. In fact, they can be interested in supporting its associates to go forward with SHIP installation to decrease energy costs;
- energy service company who can offer to their customers additional potential sources of energy savings;
- big companies with a huge dependence on thermal energy sources (as the demo-sites), they have engineering department that has the knowledge to run the tool properly and analyze several options;
- industrial facility/energy managers willing to gain first insight on their facility potential;
- consultants to support the development of SHIP projects;
- SHIP developer to benchmark their solutions and have 3rd party validation;
- companies in general interest in sustainability aspects and which want to consider the solar thermal technology as a potential pathway.

Based on the experience gained in the activities related to CT and RT implementation and development, engineering and system integration, demo-sites commissioning, it emerged that SHIP2FAIR solutions are more suited wherever the industrial process requires cooling/heating with water. In fact, RT simulation module was developed mapping two main processes (heating & cooling, water & steam). The module's functionality is therefore limited to the application area of hot water and steam production. It can be replicated wherever a solar thermal installation exists and where the industrial process requires cooling/heating with water. The application in other industries with different needs is not guaranteed unless an adaptation effort is made. Moreover, Simulation Module operates on the basis of assumptions made on the technology used, for any future technologies used within solar installations, the RT will have to be adapted.

The most promising use cases can be found in industrial sectors utilizing process temperature between 50°C and 250°C and exploiting SHIP solution based on the technology used in SHIP2FAIR (vacuum tube solar thermal technology for process heating & cooling, High Vacuum Flat Panel (HVFP) solar thermal technology for space heating (winter period) and process steam (summer period), HVFP technology for boiler pre-heating and process heat).

### **Creation of a Local Value Chain**

As described in *D6.5 - SHIP2FAIR demo-sites commissioning report*, a large number of actors has been involved in the deployment of the solar systems beyond the relevant project partners, including: Local engineering and construction companies, thermal energy professionals, installers, suppliers of energy equipment. A practical example is related to Components Procurement. Additional materials and equipment are usually needed to connect the solar system to the point of integration. Such materials include piping, insulation, connectors, etc. are typically sourced locally (at the location of the client/user) and usually by the subcontractor in charge for installation of the allocated material.

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With so many actors involved and numerous factors that may affect the scheduling and cost of the procurement, deviations in site preparation and installation seem inevitable. In this respect, change and risk management are key parameters in the successfully and (nearly) on-time completion of the relevant activities. Moreover, local engineering companies are familiar with local/ regional regulatory requirements and thus they can bear this responsibility more easily and efficiently, while the involvement of local contractors can keep costs at acceptable levels.

The collaboration of these actors can evolve in the future to form local value chains or business ‘ecosystems’ on applications of Solar Heat for Industrial Processes (SHIP) and broadly on the decarbonisation of industrial heating and cooling. Such a development can only have positive effects on the widening the adoption of solar thermal at industrial scale.

### Design Phase - engineering and system integration

As described in *D7.5 - SHIP2FAIR Best practices guide*, during engineering and system integration phase of the SHIP solution, it is important that the following points are carefully considered. This serves to reduce the risk of changes during the commissioning phase leading to delays and higher costs.

- Connection point - The connection point defines the integration scheme; that is, how the solar thermal system will be integrated into the thermal energy system and the production processes of the user. Such a decision is actually reflecting a compromise between convenience, cost and efficiency (given the particularities and needs of its specific case). The following generic integration strategies are considered:
  - Integration into the central steam network implies minimum disruption and modifications in the energy infrastructure and operational mode. It also means that the solar system should operate at higher temperatures and thus at lower efficiency.
  - Integration at process level allows operation of the solar system at hot water mode and temperature set points that are typically much lower than the central steam network. This increases the efficiency of the solar thermal system and thus reduces the levelized cost of heat (LCoH). However, it also requires additional piping to connect to the application point and control at process level.
  - Integration into the return piping – for feedwater pre-heating – allows operation of the solar field at lower temperatures and hot water generation at the expense of a low share of solar heat (around a maximum of 10% on the demand). It is of crucial importance to consider the impact of feedwater temperature increase on the steam boiler efficiency.

Based on the above it becomes clear that the identification of the right connection points is critical for the feasibility of the solar system and the user acceptance. In this respect, the following steps & rules can be applied:

- Analysis of the current thermal energy system and application points (based on P&ID, process diagrams, heat demand profile, and other relevant information that are made available).
- Identification of potential integration schemes in relation to the three above mentioned integration strategies.

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- Impact on boiler efficiency in case of feedwater pre-heating.
  - Assessment of the techno-economic feasibility of these integration schemes (taking into consideration the installation point of the solar field).
  - Discussion of the 2-3 more attractive options with the client/ user and agree on the most suitable one.
- Engineering dual operation modes - Dual mode of operation is possible as a strategy to maximise usable heat production and minimise excess heat (that may be wasted). Such strategy means that the solar system operates at a lower temperature set point during the winter period (or at times where solar irradiance is relatively low), and at a higher temperature during the summer period (sunny conditions). This implies that there are needs for low(er) temperature at the application point.
  - Environment – It is important to have the maximum space availability in order to increase the solar share. In case of ground installation, do not install the solar field on a bare land because the weeds will grow between the panels and the panel maintenance and the weeding control will be more difficult. In case of a rooftop installation, accessibility should be a priority for the maintenance. In the case of concentration technologies, even if the mirrors structure itself is relatively light, a heavy substructure may be required in order to consider the extra load induced by the local meteorological conditions (wind and snow). Depending on the roof shape and the steel structure, the required substructure can increase the total roof weight significantly and can even demand an enforcement of the existing structure. The cost for the substructure material and installation may have a decisive impact on the economic feasibility of the project. Therefore, it is recommendable to evaluate the roof load requirements in a very early project phase. Concrete roofs tend to have a very high load carrying capacity and are therefore suitable for the installation of solar thermal collectors in most cases.

### **Installation and Commissioning Phase - Logistics**

In order to successfully scale-up SHIP2FAIR solutions, pre- assembling of different components can simplify logistics operations on assembly and commissioning. As described in *D7.5 - SHIP2FAIR Best practices guide*, Solar Thermal Systems’ pre-manufacturing increases the shipping volume not significantly but shortens the installation time and complexity onsite. No pre-assembly is currently being performed at the factory. However, TVP is working towards this direction so that in the future a number of panels (e.g. 6) are pre-assembled in a macro-structure at the manufacturing site and thus reduce installation costs. Most collector parts can be shipped directly from the manufacturer to the installation site. This reduces both, shipping volume and transport duration.

### **Local Regulations**

Construction permits and other regulatory/ environmental authorisations may be required or not depending on the country and location, type (rooftop, on the ground) and size of the installation, operational mode (hot water or steam). National/ European regulatory requirements and authorisations for pressure equipment should be met. This building permit clearance can take a very

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long time and should be anticipated as soon as possible. For this reason, it is advisable that local engineering consultants are involved in the process.

### Training Activities

Once the commissioning phase was completed, training activities were provided to demo-site personnel. These activities have been performed paying attention to both theory and practical aspects in the field to ensure the possibility to act quickly in case of failures, as well as to be able to perform standard procedures like the loading and emptying of the solar circuit, as well as operation in the case of alarms. Also, Training of local operators has been performed related to standard operating procedures and minor trouble shooting. Training will continue during the demonstration phase, while in parallel all parties involved in the operational support and maintenance will gain further experience and know-how particularly regarding the operational integration of the solar systems with other energy systems or machinery.

In order to effectively replicate the SHIP2FAIR solutions, it is important that staff training is supported by the engineering, operation and maintenance type of manual with standard procedures/ work instructions covering the respective integrated energy systems.

## 5.4 Dedicated GANTT and Milestones

The Roadmap for the replicability of SHIP2FAIR refers to all the key aspects highlighted in Chapters 3, 4 and 5. It consists in a series of activities and milestones to be achieved to replicate a SHIP project effectively. Down below there is a short description of the different tasks presented in the GANTT diagram (milestones are highlighted in bold):

### Regulations Compliance – 7 months

Regulation Compliance is one of the main challenges highlighted in SHIP2FAIR experience. It is important to deal with regulatory/ environmental authorisations and construction permits right from the start. In fact, legal aspects might become design constraints within design phase thus causing delays. Obtaining the necessary authorisations can take lots of time so the activity duration extends over design phase start.

### Design Phase – 4 months

The Design phase consists of solar plant engineering activities and operations to integrate the solar plant into the site's production facility. This phase can be influenced by Regulations Compliance, which is why they are partially carried out in parallel.

### Replication Tool – 6 months

Multi-language implementation: The multi-language implementation of the RT involves a Development Phase and a subsequent Testing Phase. This activity can start in parallel with Regulation Compliance and Design Phase because it is independent from both of them.

Module Features Upgrade: Upgrading different RT modules may require input data derived from the type of integration conducted between the solar plant and the production facility. It therefore takes place after the design phase.

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Module Upgrade - if a new site requires RT functionality not currently supported by one of its modules, a module upgrade is required.

### **Local Business Ecosystem Development – 5 months**

The creation of a local value chain can be started by the solar energy suppliers involved in the SHIP project. These companies can guide the selection of engineering and construction companies based on their references in the region where the new SHIP site is developing. These companies, by their side, have local references on installers and suppliers of energy equipment. This chain of connections generates an organised and efficient local ecosystem that guarantees a faster installation and commissioning phase.

### **Installation and Commissioning Phase – 7 months**

The system installation and commissioning phase is based on the output of the design phase, which determines the material required. The local value chain, in coordination with solar energy companies, has to secure a robust logistics. It is essential that all components required for system installation are available at the required time. Logistics and component procurement activities must be validated and verified prior to system installation and commissioning.

### **Control Tool – 8 months**

Multi-language implementation - the multi-language implementation of the CT involves a Development Phase and a subsequent Testing Phase.

Communication Protocols – Based on the proprietary software used by the plant, it is necessary to develop and test data exchange between the internal network of the demo-site and the CT infrastructure.

MPC – Model Predictive Control System (MPC) must be developed and tested according to the facility policy and requirements. This ensure to target the MPC to achieve the desired KPI.

### **Training – 7 months**

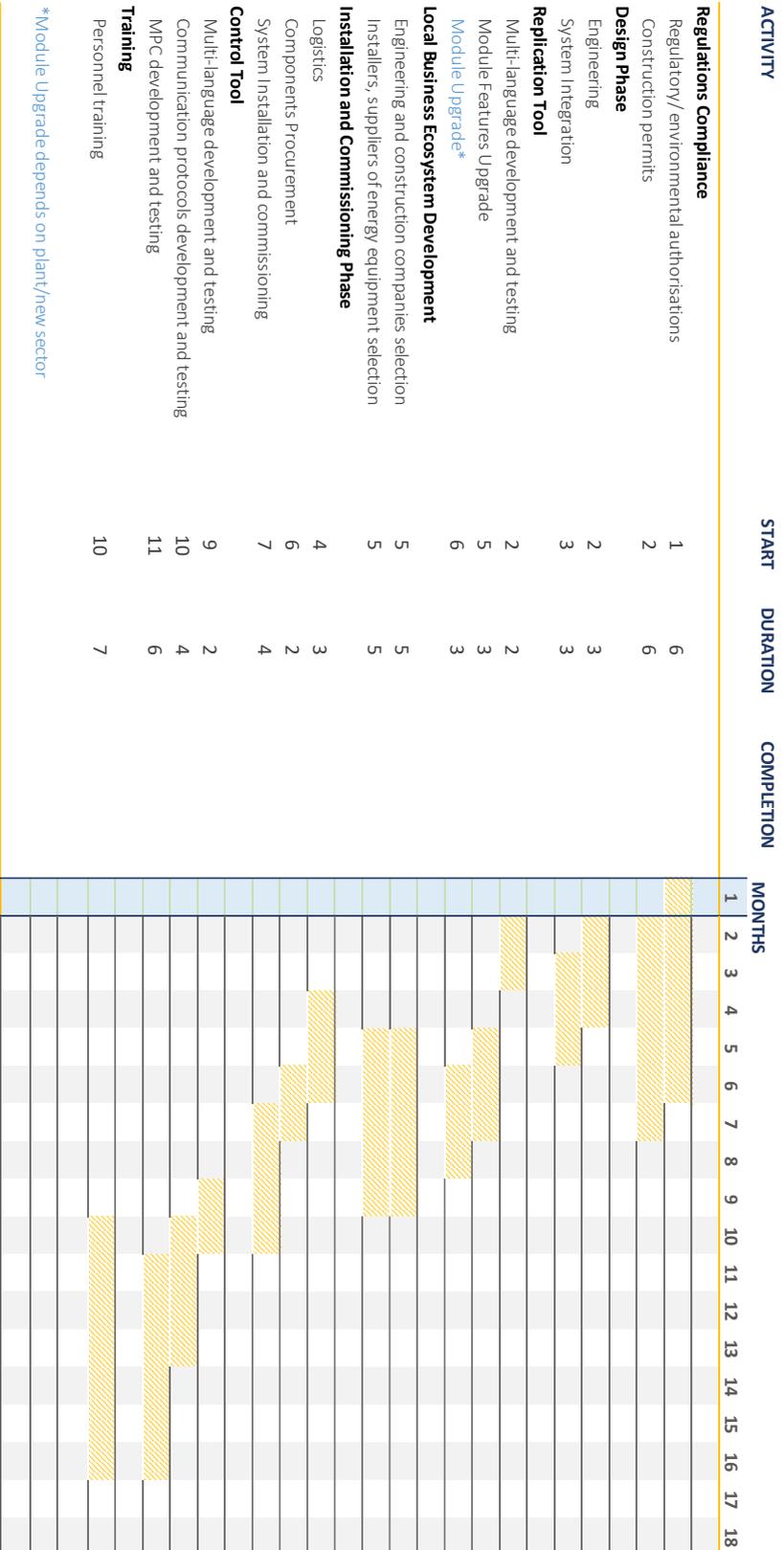
Facility Personnel must be trained to interact with the SHIP plant. These activities have to be performed paying attention to both theory and practical aspects in the field to ensure the possibility to act quickly in case of failures, as well as to be able to perform standard procedures like the loading and emptying of the solar circuit, as well as operation in the case of alarms.

# SHIP Deployment Roadmap

Select a period to highlight on the right. Legend describing the graph follows.

Highlight Month 1

Duration



\*Module Upgrade depends on plant/new sector

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Figure 6 - SHIP Deployment Roadmap

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## 5.5 Replicability Cost Assessment

Replicability Cost Assessment refers to the possibility of estimating what the costs of replicating the SHIP2FAIR solution might be at a new production site. To date, it is not possible to estimate these costs in detail, especially regarding pre-construction/civil works or other site-dependent costs. The size of the solar field, the distance between the solar field and the actual application, as well as other parameters can significantly affect the unit cost of a turnkey solution. These are aspects related to the particular situation of the new demo-site and therefore have to be estimated on a case-by-case basis.

However, it must be considered that, thanks to Replication Tool, a production site interested in adopting SHIP solutions can run simulations to define *LCOH - Levelized Cost of Heat and PBT - Pay Back Time* values. In fact, *Deliverable 8.4 - SHIP2FAIR Pre-Feasibility Replication studies* exploited RT for this purpose involving 10 case studies. The table with the results obtained is shown below:

	Thermal Demand Temperature	Best Technology Selected	Collectors Area	LCOH	PBT	Solar Share	GHG Emissions Avoided
	°C	-	m <sup>2</sup>	EUR/MWh	y	%	tCO <sub>2e</sub> /y
Case Study 1 – Textile, Italy	50-70	FPC	827	76.4	18.5	2.3	68
Case Study 2 – Chemical, Slovenia	130-180	LFR	25,981	44.9	11.0	6.0	2,315
Case Study 3 – Office/Laboratory, Italy	90-160	LFR	180	49.8	12.1	2.0	434
Case Study 4 – Waste Treatment, France	57-90	HVFPC	190	54.9	n.a.	n.a.	n.a.
Case Study 5 – Dairy, Spain	85	HVFPC	1,665	17.5	3.4	78.7	301
Case Study 6 – Meat Processing, France	55-96	HVFPC	2,200	44.0	12.0	18	520
Case Study 7 – Brewery, Spain	35-100	HVFPC	6,577	34.7	5.6	7.2	1,240
Case Study 8 – Food, Jordan	175	LFR	2,216	51.0	4.4	80.9	581
Case Study 9 – Chemical, Spain	195	LFR	19,684	109.0	20.2	51.9	1,224
Case Study 10 – Textile, India	170	LFR	17,100	16.8	8.0	4.3	7,633

Figure 7 - Replication Studies' Results

If the 10 case studies analysed in deliverable 8.4 would decide to integrate SHIP2FAIR solutions, there would be the possibility to collect all information necessary to estimate design, integration, installation and commissioning costs useful to define a complete Replicability Cost Assessment. In this way, it would be possible to recalculate LCOH and PBT values and compare them with the theoretical values obtained with RT.

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## 6 CONCLUSIONS

SHIP2FAIR developed and demonstrated a set of tools and methods for the development of industrial solar heat projects. To effectively replicate and scale-up SHIP projects, it is important to focus on key aspects related to both the tools developed and the integration method applied during the project work.

Potential barriers in CT replicability and scale-up can be summarised as follows:

- Very low-level of automation:
  - no sensor installed recording important physical quantities necessary for the control tool
  - only manual readings available instead of digitally recorded data
  - no reasonable ICT (Information, Communication and Technology) infrastructure for handling the data management (storing data, sending/receiving data)
  - a reasonable fast internet connection must be available to send and receive data over the internet
- Restrictive data policies
  - data from the plant cannot be made available for the control tool over the internet for security reasons, thus trying to avoid cyber crimes
  - plant is not capable of receiving data over the internet
- No technical staff available on-site to fix issues (e.g. change settings for technical devices like pumps, or ensure robust sending and receiving data on-site)

Opportunities to solve them would be to map the CT upon a reference ontology commonly adopted by various industries interested in SHIP applications and to install the tool on premise.

On the other side, Replication Tool was developed as a stand-alone solution and there are no potential barriers in terms of replicability and scalability wherever a solar thermal installation exists and where the industrial process requires cooling/heating with water and/or steam production. Both CT and RT share a common check list in order to be replicated in other location and/or sectors:

- Evaluate status of the replication tool and interactions between modules
- Address the data protection issues
- Identify most useful output to the users to be improved
- Optimise the replication tool functioning by reducing computation time
- Prepare a benchmark analysis on tool functionalities
- Collect partners /companies interested in the product (potential costumers)
- Identify improvement areas and necessary fine tuning
- Validation of the results compared with real installation performance
- Allow technology providers to add to the database data easily

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- Provide the necessary infrastructure (servers), timeseries databases, webspace to provide the tool

SHIP2FAIR proved that each site has had unique characteristics in relation to: the implementation scheme (e.g. RODA has used a commercially available solar thermal technology and a technology provider and contractor outside the SHIP2FAIR consortium), type of solar thermal technology (non-concentrated or concentrated), regulatory requirements (different in the four countries and types of applications), installation surfaces (on rooftop or on the ground), layout of the solar system (e.g. two subsystems in Larnaudie), operational mode. The collaboration of the actors involved in SHIP2FAIR experience generated new knowledge that can evolve in the future to form local value chains or business ‘ecosystems’ on applications of Solar Heat for Industrial Processes (SHIP) and broadly on the decarbonisation of industrial heating and cooling. Such a development can only have positive effects on the widening the adoption of solar thermal at industrial scale and can facilitate replication and scale-up at a post-project timeframe.

Solar Heat for Industrial Processes (SHIP) is still a nascent market: few innovators and early adopters have installed SHIP applications. For this reason, know-how on the installation, integration and commissioning of such systems is hardly found at local level. To fill this gap, training activities on each new SHIP plant will be key. In order to effectively replicate the SHIP2FAIR solutions, it is important that staff training is supported by a comprehensive guidebook. This manual should include operation and maintenance standard procedures/ work instructions covering the respective integrated energy systems.

In terms of acceptance, the implementation and use of the CT and RT on the SHIP2FAIR demo-sites revealed that in order to interact with the tool, it is necessary to speak English correctly. To improve the scalability of the tools, it might be useful to include a multi-language interface.

In conclusion, after the end of the project, it would be interesting to continue monitoring the demo-sites in order to collect data to verify whether the initially estimated PBT is confirmed or not. It would also be interesting to analyse all the costs incurred in the design, integration, commissioning and installation phases in order to understand which can be taken as fixed and which as variable (perhaps due to delays, unforeseen events or uncertainties). This would provide a more comprehensive replication cost estimate.

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