# Modified Installation, Operations, Maintenance and Logistics model for Irish and Welsh wave and tidal technologies and locations

Work Package 8: Installation, Operations & Maintenance and Logistic models

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## Document information

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## Abbreviations

| | |
|---|---|
| CM | Corrective maintenance |
| EBA | Energy-base availability |
| GUI | Graphical User Interface |
| GUI | Graphical User Interface |
| LCOE | Levelized Cost of Energy |
| MC | Monte Carlo Simulation |
| MTTF | Mean Time to Failure |
| O&M | Operation and Maintenance |
| OE | Ocean Energy |
| ORE | Offshore Renewable Energy |
| PM | Preventative maintenance |
| STD | Standard Deviation |
| TBA | Time-base availability |
| TEC | Tidal Energy Converter |
| TRL | Technology Readiness Level |
| WEC | Wave Energy Converter |
| WES | Wave Energy Scotland |
| WP | Work Package |
| WW | Weather Window |

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# 1 Introduction

The SEKLIE project is developing a decision-support tool that will compliment and/or fill the gaps in the existing models for wave and tidal energy. The tool will be open-access, user-friendly and flexible, able to assess a wide range of different technologies with varying levels of information available. This will be a key challenge considering the large range of technologies and concepts for wave and tidal energy.

The SELKIE model will consider synergies and learning from existing tools including the DTOcean installation and O&M modules; the WES O&M model; and existing tools for the offshore wind sector, particularly the LEANWIND Financial model. Feedback is also currently being gathered from key industry players including Sabella and OceanEnergy to ensure the model can simulate the strategies and scenarios of most interest to industry. The questionnaire used to gather feedback is included in Appendix 1. This was presented at a SELKIE Webinar 8th October 2020 and distributed via the project social media links and website.

The objective of the tool is to allow users to:

- model operations across the lifecycle considering uncertain factors e.g. weather and failures and their impact on the costs and duration of a project
- optimise the logistics required for the installation and O&M phase e.g. port, offshore vessel fleet, activity schedule etc.

The tool will be applied to

- Pilot case-studies (based on existing projects by OceanEnergy (wave) and Sabella (tidal));
- A series of generic case-studies relevant to Ireland and Wales, analyzing areas for optimisation.

The latter will be presented in D8.3-8.5. This document provides an overview of the SELKIE model (section 2 and 3) including the inputs and outputs, as well as processing logic (the main assumptions and how the tool operates) in sections 4 and 5. It also provides an overview of the development timeline (section 6) and how this tool may interact/be used with the WP4 GIS Techno-economic tool (section 7).

# 2 System requirements

The tool is compatible with windows, coded using C#. Model and code (open-source) has been made available on GitHub (https://github.com/fdevoymcauliffe/Selkie) and can be viewed using Visual Studio community edition (free).
This section details the software requirements needed to set up and run the model on a standard PC.

Download the latest version of the Visual Studio Community edition. System requirements to install Visual Studio Community 2022 are as follows:

Supported Operating Systems

- Windows 11 version 21H2 or higher: Home, Pro, Pro Education, Pro for Workstations, Enterprise, and Education
- Windows 10 version 1909 or higher: Home, Professional, Education, and Enterprise.
- Windows Server 2022: Standard and Datacenter.
- Windows Server 2019: Standard and Datacenter.
- Windows Server 2016: Standard and Datacenter.

Hardware

- 1.8 GHz or faster 64-bit processor; Quad-core or better recommended
- Minimum of 4 GB of RAM.
- Hard disk space: Minimum of 850 MB
- Video card resolution of 1920 by 1080 or higher.

Additional Requirements and Guidance

- Administrator rights are required to install or update Visual Studio.
- Read/write Excel functionality requires Microsoft Office latest version.

# 3 Set-up

## 3.1 Save model in folder

To set up the model, save the model files to a folder on your PC e.g. “Documents”.

## 3.2 Open tool and GUI

To open the tool select the visual studio solution file “SELKIE.sln” and select “Program.cs” and the start button to load the GUI. Create a project and run a scenario following the steps outlined in section 4.

The user can also **create a shortcut** to the GUI by selecting the “bin” folder; “Debug” folder; right click the SELKIE application and select “send to” desktop. The user can then open the GUI directly from their desktop.

The user is advised to prepare their Metocean and Power Matrix or Power Curve input data in advance of creating their first project, following the instructions in section 3.3 and 6.

## 3.3 Format data

Using the SELKIE format tools described in section 7 (if needed), format a Metocean data time series and a Power Matrix (if relevant).6. A Power Curve template (for tidal devices) has also been provided as an excel file for users. Model overview

The Selkie model has been designed to consider the key logistics activities for the installation and O&M phase of an ocean energy array (wave and tidal). This includes:

1. Installation of the device and substructure. Installation costs of the electrical infrastructure (including substation) can be considered by entering an estimated total cost that is added to the final installation cost figure.
2. O&M for components specified by the user.

Figure 1 present an overview of the SELKIE O&M and logistics model and how they interact.

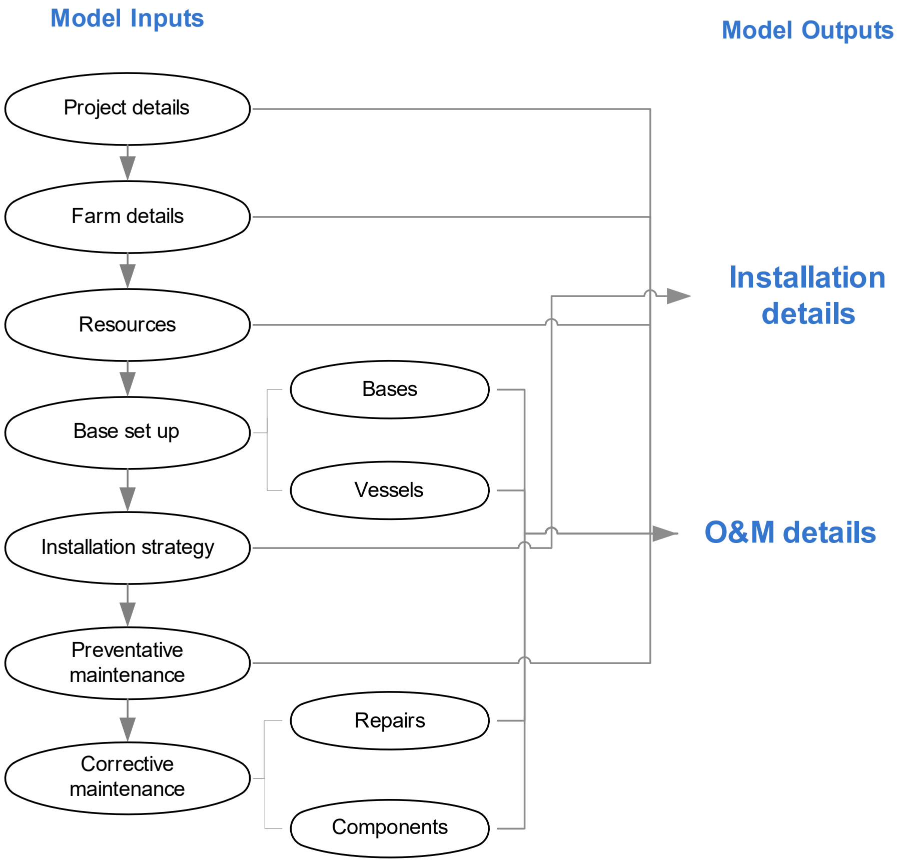



*Figure 1 SELKIE O&M and logistics model - overview*

Section 4 describes the inputs in detail including model screenshots, as well as results the model will track and record. Section 5 details the processing logic for the installation and O&M stages. This involves how the model will simulate and process the installation and maintenance logistics strategy specified by the user.

# 4 SELKIE model

## 4.1 Inputs

The following details the inputs required by the model to run an installation and/or O&M scenario and the outputs that can be expected. When loaded (either using the shortcut installed on your desktop or by running the visual studio solution file), Figure 4.1 is the main screen.

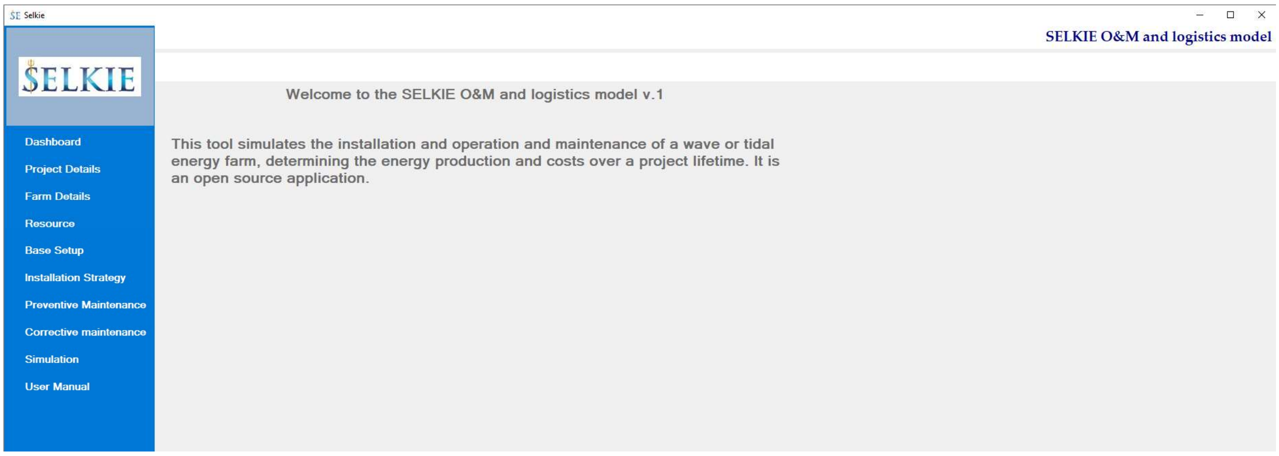



*Figure 4.1 Main screen*

### 4.1.1 Dashboard

The dashboard (Figure 4.2) allows the user to:

- Create their own project by selecting the "create own" button;
- Save inputs as a project ("Save Project") that will appear in the window list and can be loaded again at any time or deleted by selecting "Load" or "Delete" for the relevant project in the list.[1]
- Saved projects will be stored in the SELKIE roaming folder "C:\Users\username\AppData\Roaming\Selkie\Projects" (automatically created when you first run the model). The projects can then be edited directly using the excel file or the GUI. User should be sure to save changes.

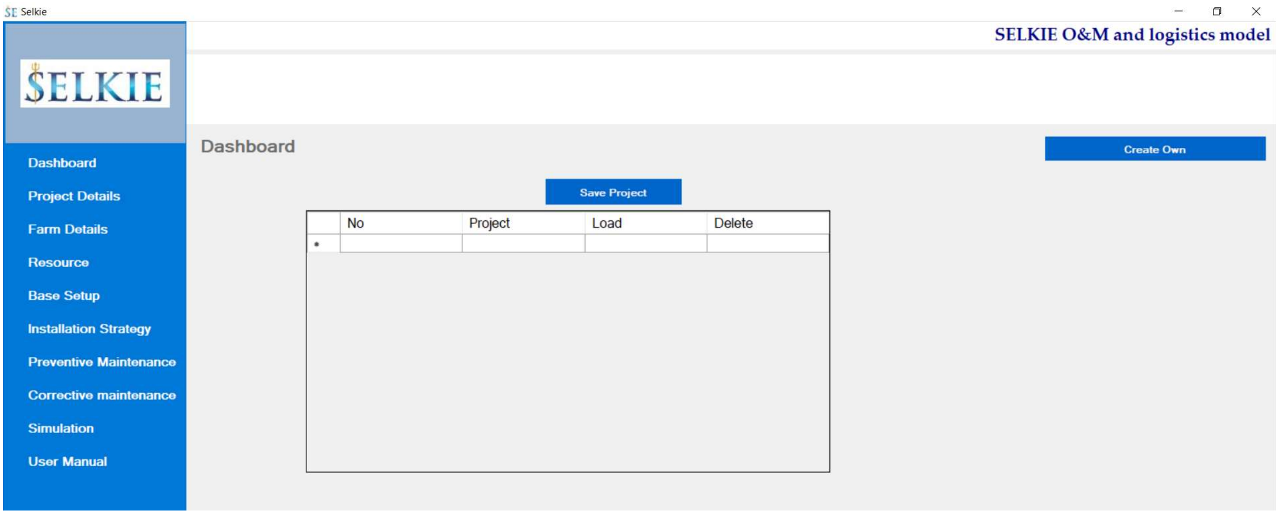



*Figure 4.2 Dashboard*

[1] If the user creates their own project but does not save it, then their inputs will be lost if they close the tool and re-open.

### 4.1.2 Project details

To begin a new project the user should select the tabs on the left in sequence starting with "Project Details." This will display the screen shown in Figure 4.3. Figure 4.4 provides details of each input category including the unit, description and the data limits.

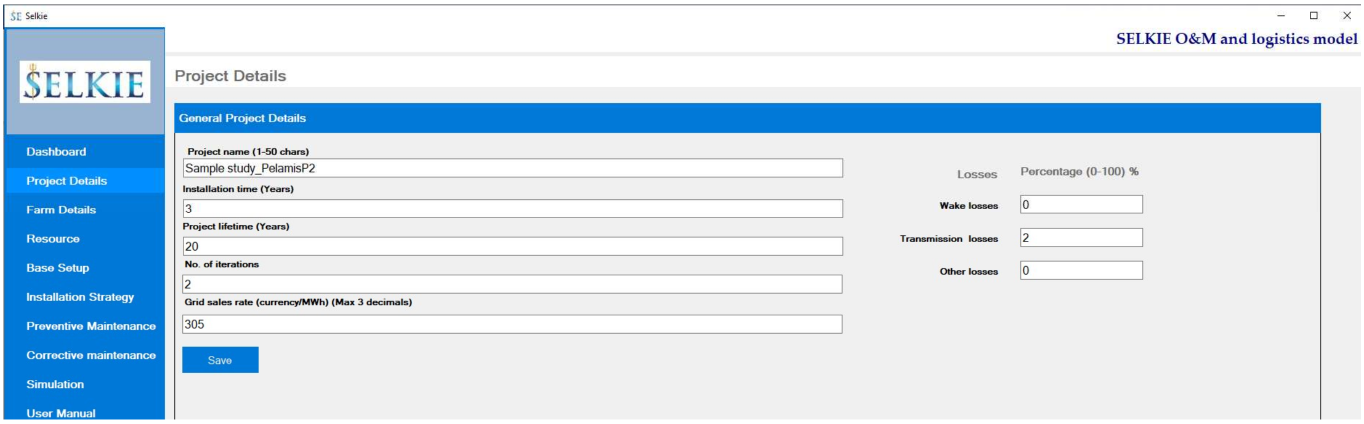



*Figure 4.3 Project details – model screen*

| Field | Unit | Description | Data limits |
|---|---|---|---|
| Project details | | | |
| Project name | text | Unique description of scenario e.g. Monitor validation case-study | Min 1 - max 200 characters |
| Installation time | years | Expected number of years to install array | Min 0 - max 10 years |
| Project lifetime | years | Lifetime of the project | Min 0 - max 60 years |
| No. of iterations | integer | Specify number of iterations of the scenario to process | Min 1 - max 5000 iterations |
| Grid sales rate | €/MWh | What the operator is paid for electricity generated | Min 0.00 - max 1000.00 |
| Wake losses | % | Losses due to presence of devices in the wind/wave/current flow | Min 0.00 - max 100% |
| Transmission losses | % | Energy losses due to the transmission of electricity over long distances (e.g. via cabling) | Min 0.00 - max 100% |
| Lost production due to downtime of elements not simulated | % | Represents the availability of elements not considered in O&M simulation e.g. electrical infrastructure | Min 0.00 - max 100% |

*Figure 4.4 Project details - inputs*

Notes:

- Installation time refers to the expected number of years it will take to install an array. Selecting a realistic timeframe will help speed up scenario processing but, if the model finds a scenario takes longer, it will extend this estimate automatically.
- It is important to always click the "save" button before you leave a tab in the model or any changes will be lost.
- The number of iterations refers to the number of Monte Carlo simulations the model will complete. For each iteration, the model will vary the failure occurrence and weather data, allowing the user to see the impact of uncertainty in these key areas on results which will be displayed per iteration and an average across all simulations.

### 4.1.3 Farm Details

Selecting "Farm Details" will display the screen shown in Figure 4.5. Figure 4.6 provides details of each input category including the unit, description and the data limits.

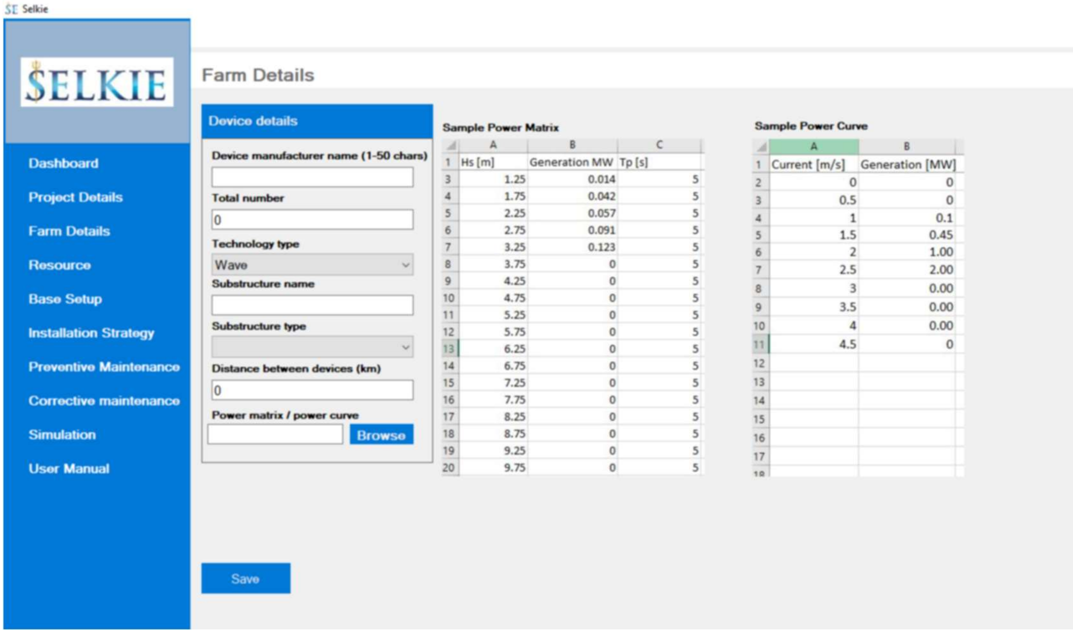


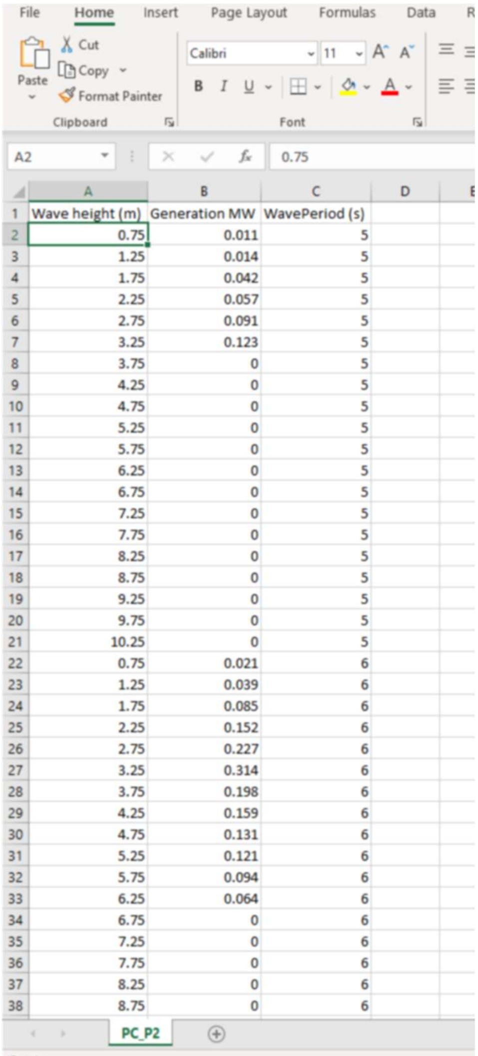

*Figure 4.5 Farm Details - model screen*

| Field | Unit | Description | Data limits |
|---|---|---|---|
| Farm details | | | |
| Device manufacturer name | text | Name of manufacturer (reference only) | Min 0 - max 200 characters |
| Total number | integer | No. of devices in the farm | Min 1 - max 500 |
| Technology type | select | Specify if this is wave or t | Dropdown list |
| Specify power matrix/power curve | integer | Insert in Power calculation tab | Insert in pow |
| Substructure name | text | Name of substructure (reference only) | Min 0 - max 200 characters |
| Substructure type | select | Type of substructure fixed/floating | Dropdown list |
| Distance between devices | km | Specify distance to travel between devices in farm | Min 0.00 - max 1000.00 |

*Figure 4.6 Farm details – inputs*

The power matrix or power curve for wave or tidal respectively should be input by creating in excel file in the format shown in Figure 4.5. The user is advised (but not required) to save these in the SELKIE roaming folder "C:\Users\username\AppData\Roaming\Selkie\PC" (created when you first run the model). The file should then be selected in the model using the "Browse" button.

While the power curve is simply formatted as a list in excel of the current speed (m/s) and the corresponding power output (kW or MW); the power matrix is currently required in an unconventional input format with 3 columns listing the significant wave height (m); Power output (kW or MW); and wave period (s). An example matrix is shown in Figure 4.7 and is included with the sample case study. A small tool has been created (compiled in Matlab), to help convert data from a standard power matrix into the SEKLIE model excel format required. Further details are provided in Section 6.



| | A | B | C |
|---|---|---|---|
| 1 | Wave height (m) | Generation MW | WavePeriod (s) |
| 2 | 0.75 | 0.011 | 5 |
| 3 | 1.25 | 0.014 | 5 |
| 4 | 1.75 | 0.042 | 5 |
| 5 | 2.25 | 0.057 | 5 |
| 6 | 2.75 | 0.091 | 5 |
| 7 | 3.25 | 0.123 | 5 |
| 8 | 3.75 | 0 | 5 |
| 9 | 4.25 | 0 | 5 |
| 10 | 4.75 | 0 | 5 |
| 11 | 5.25 | 0 | 5 |
| 12 | 5.75 | 0 | 5 |
| 13 | 6.25 | 0 | 5 |
| 14 | 6.75 | 0 | 5 |
| 15 | 7.25 | 0 | 5 |
| 16 | 7.75 | 0 | 5 |
| 17 | 8.25 | 0 | 5 |
| 18 | 8.75 | 0 | 5 |
| 19 | 9.25 | 0 | 5 |
| 20 | 9.75 | 0 | 5 |
| 21 | 10.25 | 0 | 5 |
| 22 | 0.75 | 0.021 | 6 |
| 23 | 1.25 | 0.039 | 6 |
| 24 | 1.75 | 0.085 | 6 |
| 25 | 2.25 | 0.152 | 6 |
| 26 | 2.75 | 0.227 | 6 |
| 27 | 3.25 | 0.314 | 6 |
| 28 | 3.75 | 0.198 | 6 |
| 29 | 4.25 | 0.159 | 6 |
| 30 | 4.75 | 0.131 | 6 |
| 31 | 5.25 | 0.121 | 6 |
| 32 | 5.75 | 0.094 | 6 |
| 33 | 6.25 | 0.064 | 6 |
| 34 | 6.75 | 0 | 6 |
| 35 | 7.25 | 0 | 6 |
| 36 | 7.75 | 0 | 6 |
| 37 | 8.25 | 0 | 6 |
| 38 | 8.75 | 0 | 6 |

*Figure 4.7 Power matrix excel format - example based on Pelamis P2*

### 4.1.4 Resource

Figure 4.8 is a screenshot of the “Resource” tab. Figure 4.9 provides further details of each input. A yearly timeseries of Metocean data must be included for the model to operate. Ideally the user will provide at least 10 years of data in an excel file formatted as shown in Figure 4.8 including the hour; wind speed (m/s); significant wave height Hs (m); wave period (Tp/Te as relevant) (s); and current speed (m/s). If the user does not have an element e.g. current speed as they are looking at wave energy, they should input a column of zeros. Data should be split into tabs by year, always starting with the year 2000 irrespective of the actual data year. An example file of a 20 year timeseries is included with the sample case study using data for Farrpoint generated by the Wave Energy Scotland model [1]. A small tool has been created (compiled in Matlab), to help convert data from a standard power matrix into the SEKLIE model excel format required. Further details are provided in Section 6.

Once formatted and saved in a folder, the user selects “browse” to identify the excel file of Metocean data. The user is advised (but not required) to save their Metocean data files in the SELKIE roaming folder “C:\Users\username\AppData\Roaming\Selkie\WW” (created when you first run the model).

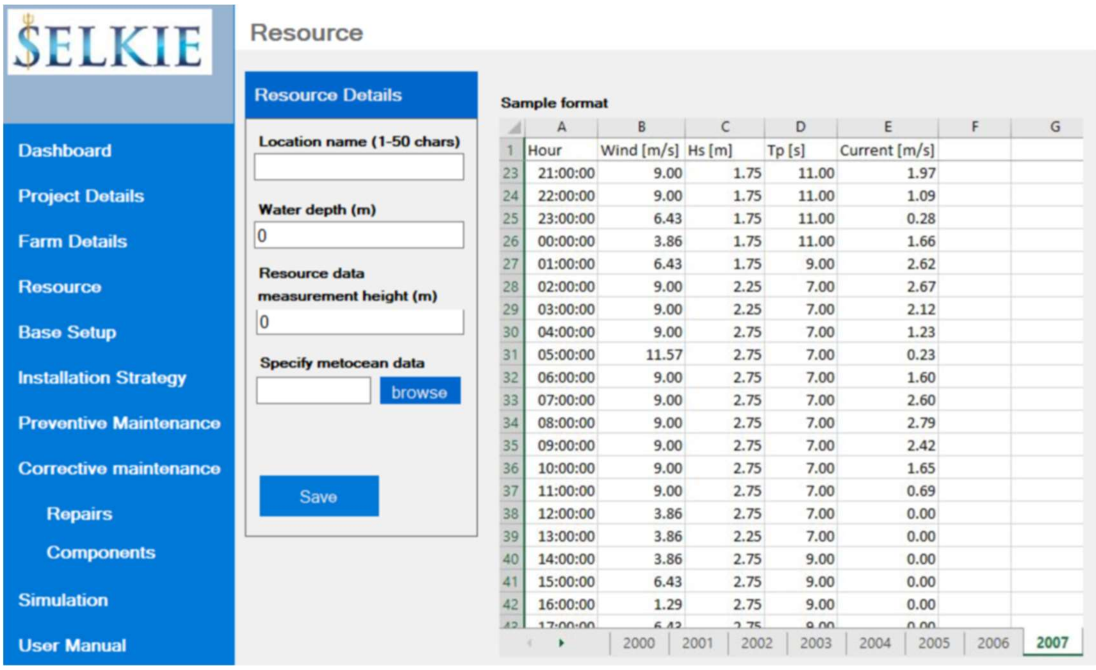



*Figure 4.8 Resource - model screen*

| Field | Unit | Description | Data limits |
|---|---|---|---|
| | | Resource details | |
| Location name | text | Location for resource data (reference only) | Min 0 - max 200 characters |
| Water depth | m | Water depth at site (reference only) | Min 0.00 - max 1000.00 |
| Resource data measurement height | m | Height at which resource data measured (tidal - height) (reference only) | Min 0.00 - max 1000.00 |
| Specify metocean data | integer | Insert in Metocean data tab | Insert in r |

*Figure 4.9 Resource – inputs*

### 4.1.5 Bases

The user can specify up to 3 different bases for activities by selecting the “Base Setup” and then “Bases” tab, and “Add Bases” as per Figure 4.10 and inputting the data requested in Figure 4.11. Input requirements are further detailed in Figure 4.12.

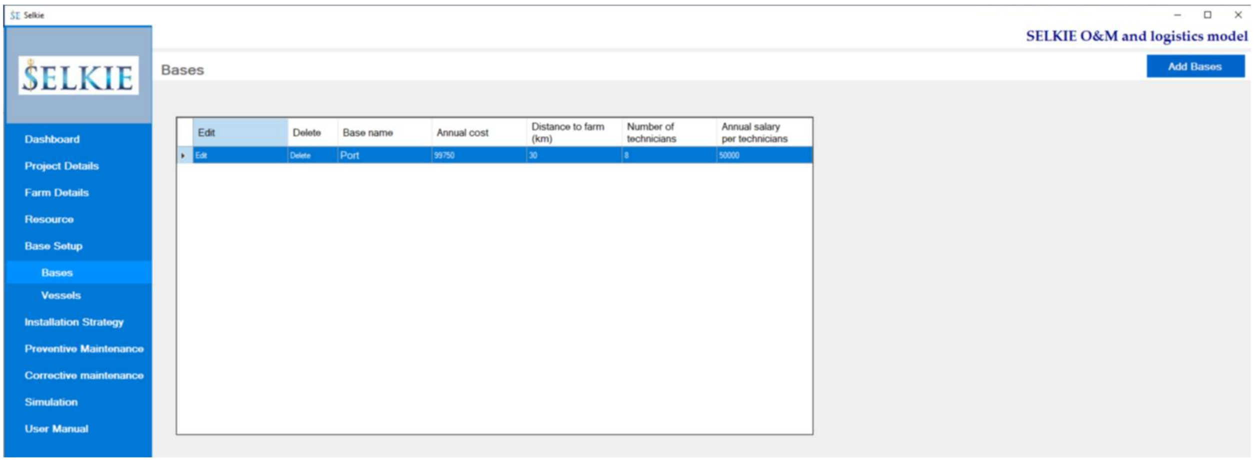



*Figure 4.10 - Base Setup - Bases - model screen*

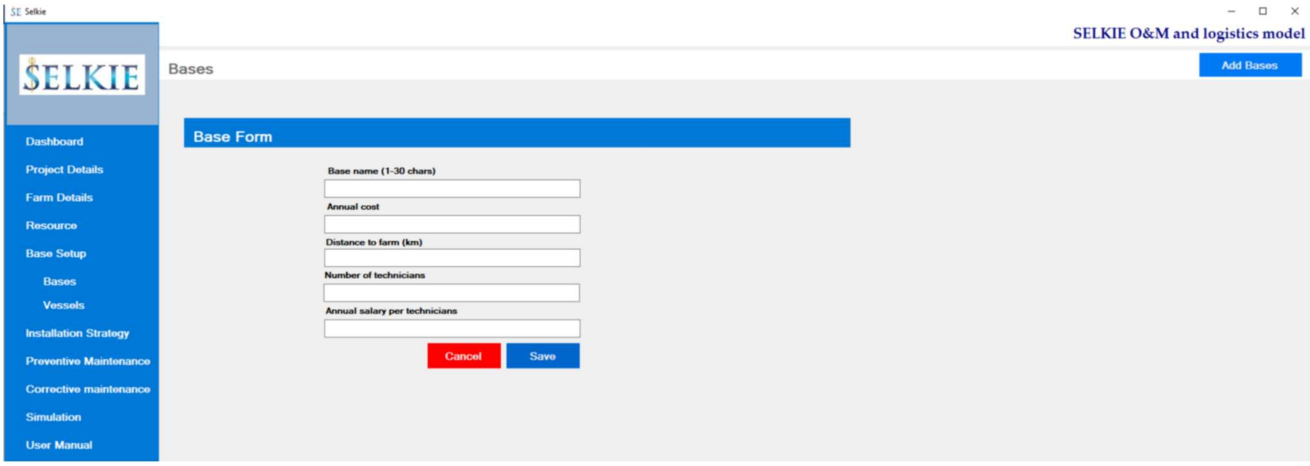



*Figure 4.11 Add Bases - model screen*

| Field | Base name | Annual cost | Distance to farm | Number of technicians | Annual salary per technician |
|---|---|---|---|---|---|
| Unit | Text | € | km | integer | € |
| Description | Name of base | Annual cost associated with maintaining/leasing an onshore base | Distance of the base to the farm. Used to calculate vessel transit times. | Number of full-time technicians employed at the base available to carry out repairs. | Used to calculate the cost of technicians. |
| Data limits | Min 1 - max 200 characters | Min 0 - max 10000000000 | Min 0.00 - max 1000.00 | Min 0 - max 10000 | Min 0 - max 1000000 |
| Input data | | | | | |
| Input data | | | | | |
| Input data | | | | | |
| Input data | | | | | |
| Input data | | | | | |
| Input data | | | | | |

*Figure 4.12 Bases – inputs*

Notes:

- It is important that the number of technicians specified here is enough to carry out the tasks undertaken from that base. For example, if the user says it will take 6 technicians from Base A to install a device but they have only specified that 2 technicians are available at Base A, then the task cannot be completed.

### 4.1.6 Vessels

The user can specify up to 6 types of vessels that can be used for activities (installation and/or O&M). Figure 4.13-Figure 4.16 show the model screen inputs for adding a purchased and a rented vessel type. Figure 4.17 provides further details of the inputs.

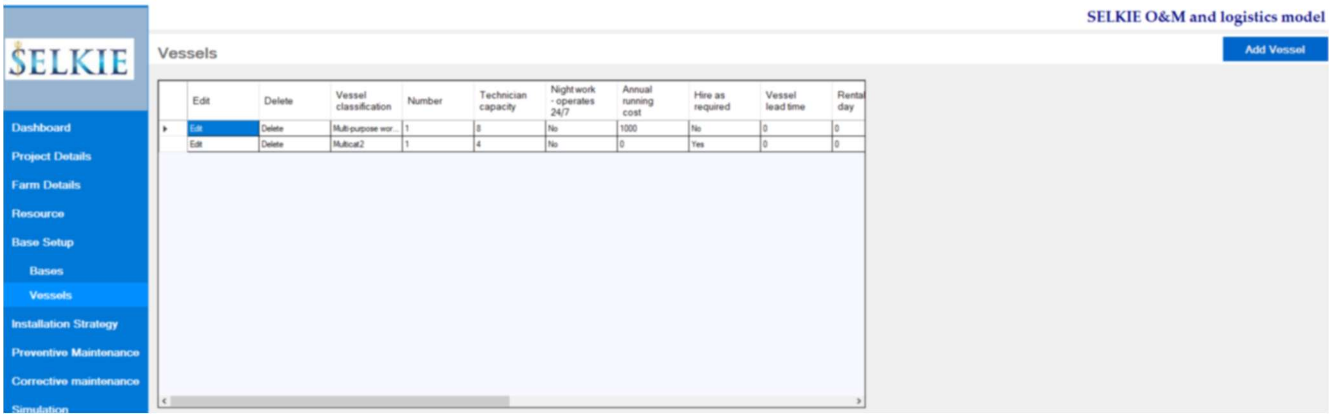



*Figure 4.13 Base Setup - Vessels - model screen*

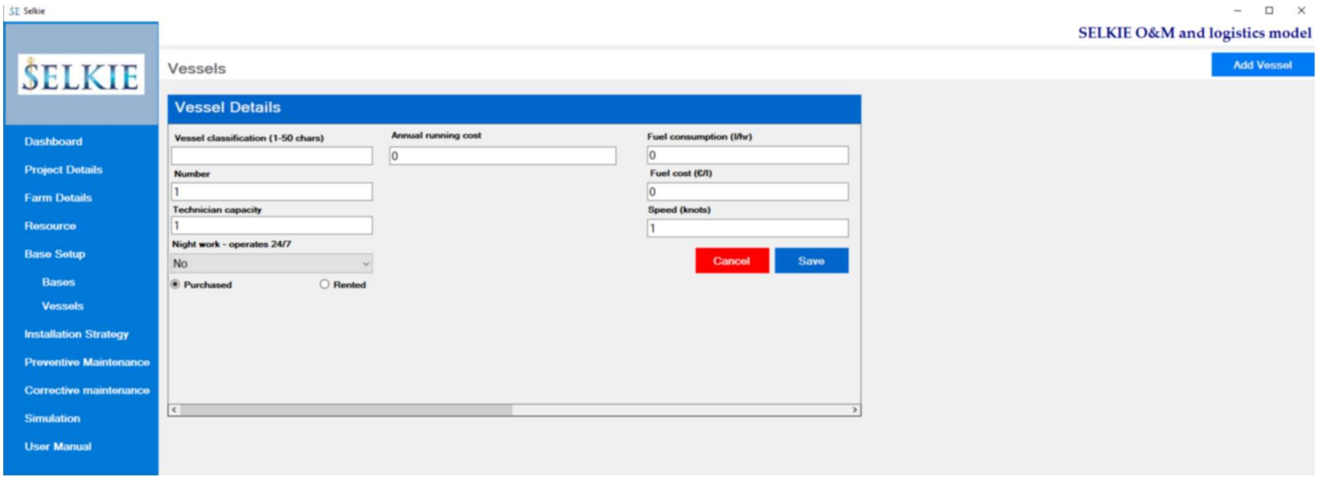



*Figure 4.14 Add purchased Vessel - model screen*

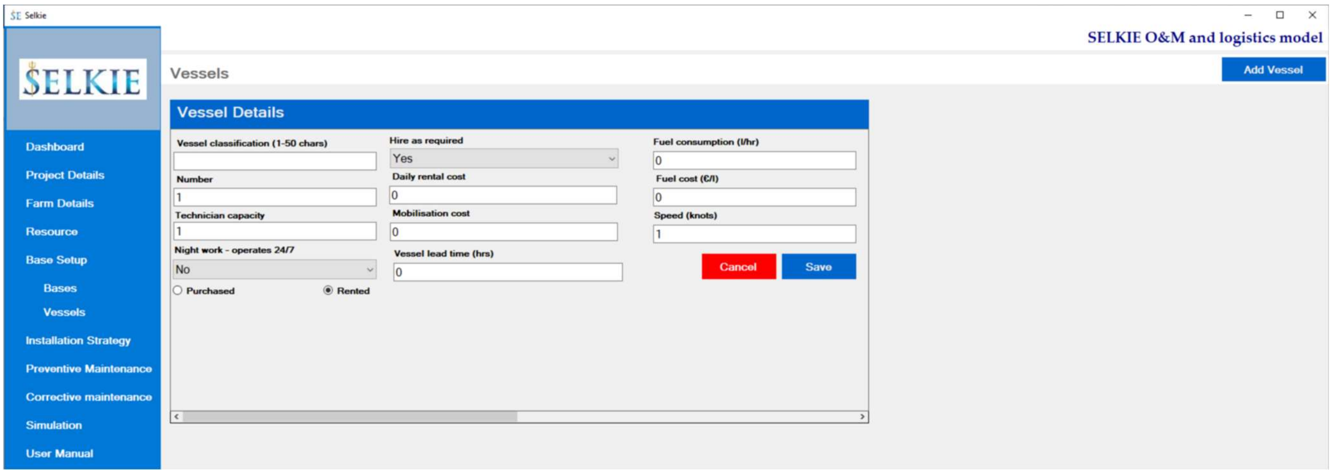



*Figure 4.15 Add vessel hire as required – model screen*

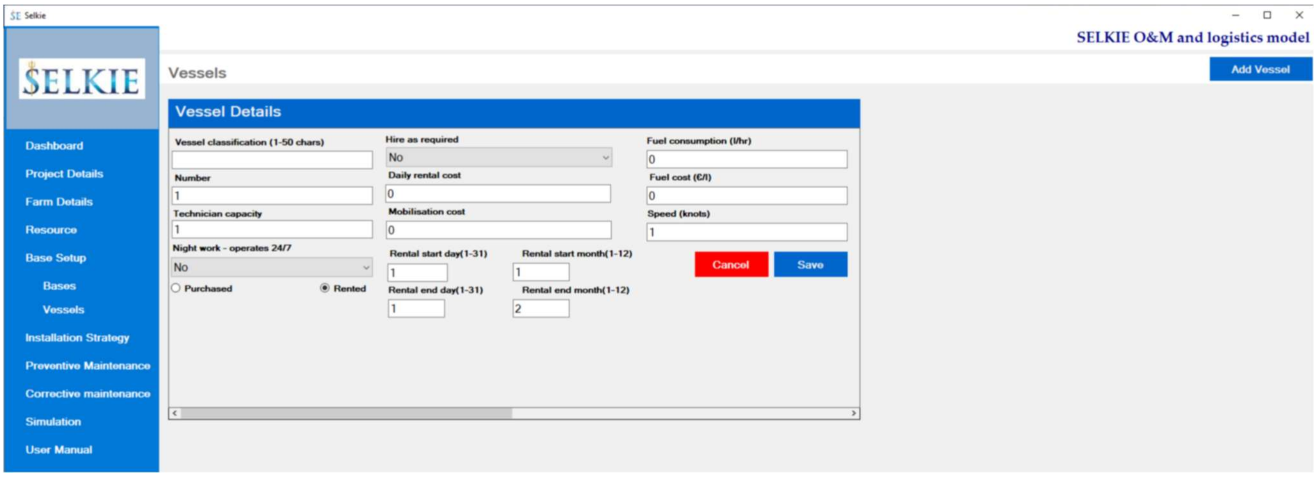



*Figure 4.16 Add rented vessel - model screen*

| Field | Vessel classification | Number | Technician capacity | Night work | Purchased/rented | Annual running cost | Hire as required | Vessel lead time | Annual rental start month | Annual rental end month | Daily rental cost | Mobilisation cost | Fuel consumption | Fuel cost | Speed |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Unit | text | integer | integer | select | select | € | select | hrs | select | select | € | € | l/hr | €/l | knots |
| Description | Vessel type | Number of vessels of this type available either purchased or available to rent | Number of technicians vessel can carry | Can vessel undertake work at night *(only O&M model)* | Specify whether vessel is purchased or chartered | If purchased, annual cost of maintaining vessel | *NB option only available for O&M activites.* If rented, specify if rented for a season or hire as required. Each time vessel hired, it is hired for the duration of an activity. | If hire as required, time needed for vessel to arrive at port. | If rented for a season, month that rental starts each year | If rented for a season, month that rental ends each year | Daily cost of renting vessel either for a season or hire as required | Cost of mobilising vessel if rented | Vessel fuel consumption | Cost per litre | Vessel transit speed |
| Data limits | Min 1 - max 200 characters | Min 1 - max 10 | Min 1 - max 1000 | Dropdown list | Dropdown list | Min 0 - max 1000000000 | Dropdown list | Min 0-max 10000 | Dropdown list | Dropdown list | Min 0 - max 1000000000 | Min 0 - max 1000000000 | Min 0.00 - max 100000.00 | Min 0.00 - max 1000000.00 | Min 0.01 - max 1000.00 |
| Input | Multi-purpose workboat | 1 | 12 | No | Rented | | No | | May | Sep | 4000 | 5000 | 0 | 0 | 5 |
| Input | | | | | | | | | | | | | | | |
| Input | | | | | | | | | | | | | | | |
| Input | | | | | | | | | | | | | | | |
| Input | | | | | | | | | | | | | | | |
| Input | | | | | | | | | | | | | | | |

*Figure 4.17 Vessels – inputs*

Notes:

- While only 6 vessel classifications can be added, an unlimited number of each vessel type can be specified e.g. you can have 1 tug or 3 workboats available to the project.
- Nightwork refers to whether a vessel can undertake work any time of day or only during daylight hours (currently assumed to be from 7am-7pm).
- The user should be careful if day time work is selected when the travel time takes a large portion of the 12 hours daytime. In this case, several days will be used to complete tasks adding considerably to vessel hire and fuel costs.
- Vessels can be purchased with an annual running cost; hire as required with a lead time to consider any wait time before a vessel can start work; or rented for a season.
- If rented a mobilisation cost will be added annually.
- It is important that the user ensures the technician capacity is large enough for any tasks assigned to it. For example, if it requires 6 technicians to install a device but the selected vessel can only carry 2, the task cannot be completed.

### 4.1.7 Installation strategy

The user can consider the installation of the substructure and device. Figure 4.18 shows the main model screen for Installation Strategy inputs while Figure 4.19 shows the form to input the device or substructure installation task details. Figure 4.20 provides further information on input requirements. For any activity the user can specify the base where the vessel, technicians and equipment will come from and the vessel type required to complete that activity. They can also specify the weather restrictions for that operation. For example, an offshore operation that takes 5 hours can only be completed where the significant wave height (Hs, m) is under the wave height limit specified.

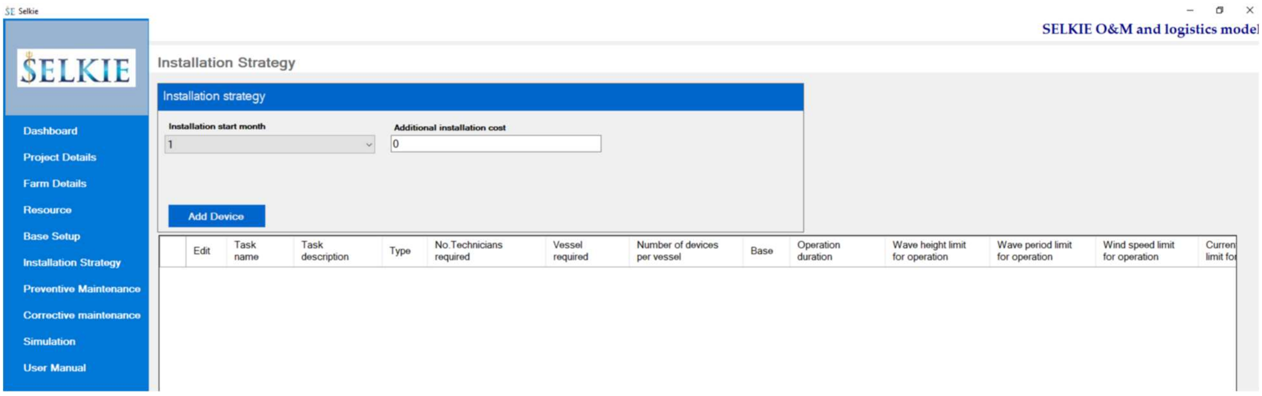



*Figure 4.18 Installation Strategy - model screen*

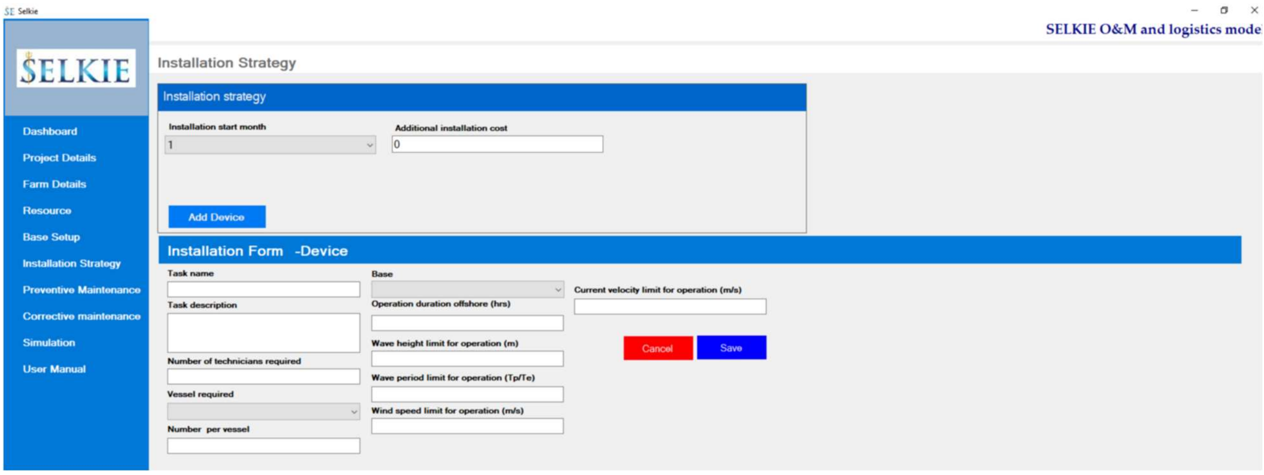



*Figure 4.19 Installation form - device/substructure - model screen*

| Field | Unit | Description | Data limits | Input data |
|---|---|---|---|---|
| Installation start month | integer | Specify month of year installation activities to commence | Min 1 - max 12 | |
| Additional installation costs | € | Cost to install elements not included in simulation e.g. electrical infrastructure. Added to final total | Min 0 - max 10000000000 | |

| Field | Task name | Task description | No. of technicians required | Vessel required | Number of devices per vessel | Base | Operation duration | Wave height limit for operation | Wave period limit for operation | Wind speed limit for operation | Current velocity limit for operation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Unit | select | text | integer | select | integer | select | hrs | m | s | m/s | m/s |
| Description | Specify task name (for reference only) | Additional details of operation (for reference only) | No. of technicians required to carry out the operation. | Select from vessels specified | No. of devices a vessel can carry and will be installed per trip | Select base the vessel comes from | Time taken to complete installation per device | This is a general wave height limit for completing the operation | This is a general wave period limit for completing the operation | General wind speed limit for completing the operation | General current velocity limit for completing the operation |
| Data limits | Min 0 - max 200 characters | Min 0 - max 1000 characters | Min 0 - max 100 | Dropdown list | Min 1 - max 100 | Dropdown list | Min 0.01 - max 1000.00 | Min 0.00 - max 100.00 | Min 0.00 - max 100.00 | Min 0.00 - max 100.00 | Min 0.00 - max 100.00 |
| Input | | | | | | | | | | | |

*Figure 4.20 Installation Strategy – inputs*

Notes:

- The model currently simulates the installation of a substructure and device. If the user wishes to consider balance of plant in the outputs, they can include an estimated cost under “Additional installation costs”.
- It is important to note that the weather restrictions specified for any task will be applied by the model for the operation offshore but also the vessel transit to and from site. For example, if the wave height restriction to install the device is set to 1m Hs, wave period is 8s Tp and wind speed is 14m/s; installation

takes 2 hours; and transit is 30 mins, the model must find a window length of 3 hours where the weather is within the specified limits.

- The number per vessel is the number of devices or substructures that can be carried on the vessel per trip. If the user specifies 2, then the model will increase the operation duration by 2 to consider the time required. The Weather Window (WW) needed will also extend accordingly assuming all devices need installation in 1 trip.

### 4.1.8 Preventive maintenance

The user can simulate 2 preventive maintenance tasks using the input screens shown in Figure 4.21 and Figure 4.22. Inputs are further detailed in Figure 4.23.

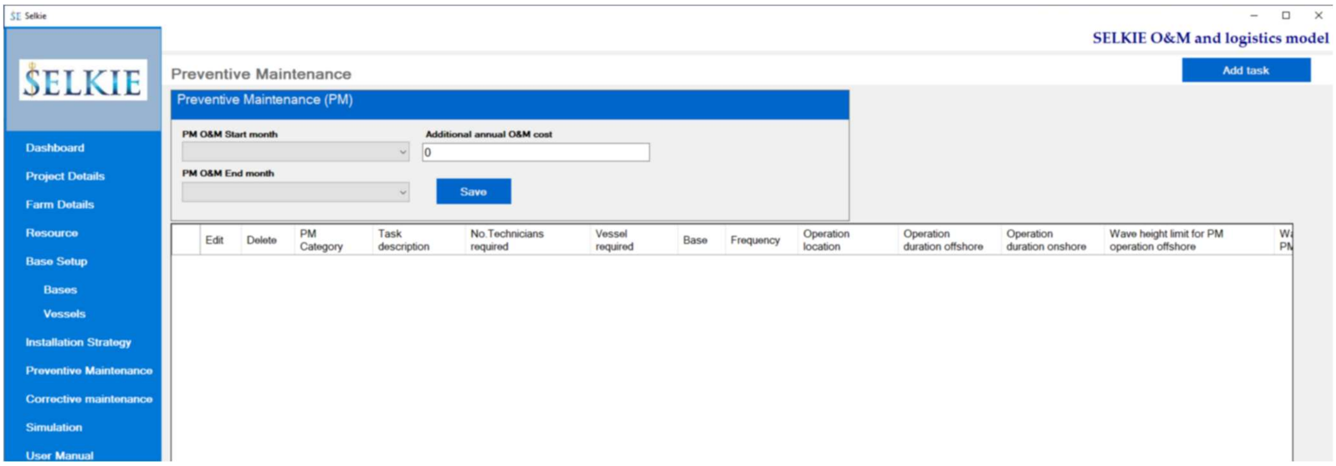



*Figure 4.21 Preventive Maintenance - model screen*

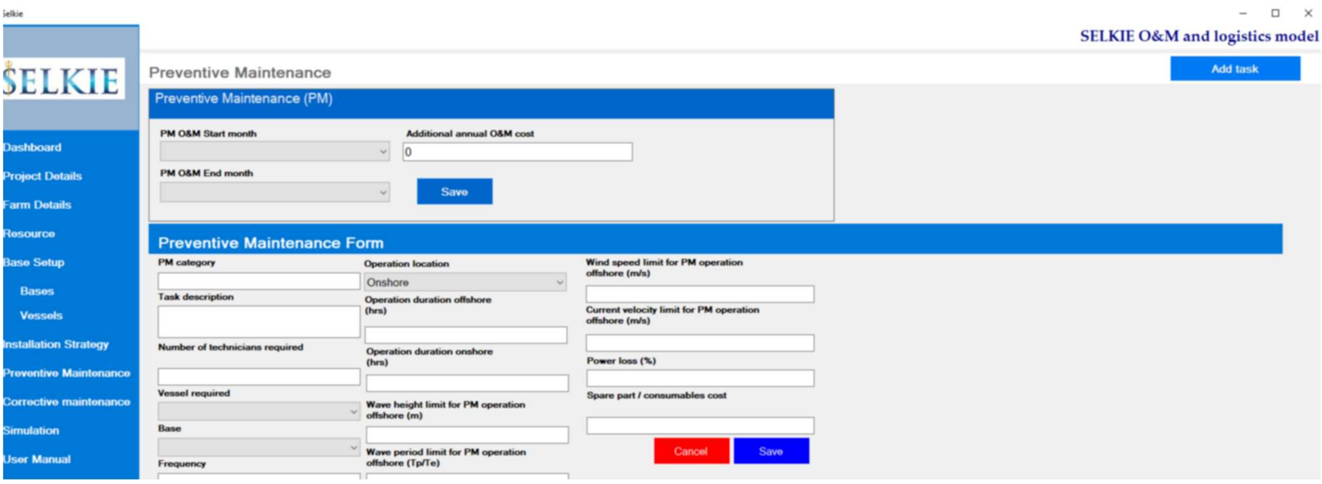



*Figure 4.22 Preventive Maintenance - Add Task - model screen*

| Field | Unit | Description | Data limits |
|---|---|---|---|
| PM O&M start month | select | Specify season start month for PM to commence | select |
| PM O&M End month | select | Specify season start month for PM to end | select |
| Additional annual O&M costs | € | Cost to maintain elements not included in simlulation e.g. electrical infrastructure. Added to annual total | Min 0 - max 10000000000 |

| Field | PM category | Task description | No. of technicians required | Vessel required | Base | Frequency | Operation location | Operation duration offshore | Operation duration onshore | Wave height limit for PM operation offshore | Wave period limit for operation offshore | Wind speed limit for PM operation offshore | Current velocity limit for PM operation offshore | Power loss | Spare part/consumables cost |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Unit | text | text | integer | select | select | integer | select | hrs | hrs | m | s | m/s | m/s | % | € |
| Description | Name of Preventive Maintenance Activity | Additional details of repair (for reference only) | No. of technicians required to carry out the operation. | To specfiy details under vessels/equipment | Select base the vessel comes from and/or repair occurs | Specify frequency of PM task per year. | Does the operation take place offshore or must the device be towed to shore for maintenance | Operation duration offshore e.g. if operation onshore this could represent the time required to detach the device to tow to shore | Operation duration onshore if applicable | This is a general wave height limit for completing PM | This is a general wave period limit for completing PM | General wind speed limit for completing PM | General current velocity limit for completing PM | Power loss when PM is being undertaken i.e. if the turbine is fully stopped until the repair is complete, the power loss is 100 % | Cost of any spare parts/consumables necessary for operation |
| Data limits | Min 1 - max 200 | Min 0 - max 200 | Min 0 - max 100 | Dropdown list | Dropdown list | Min 0.01 - max 100.00 | Dropdown list | Min 0.00 - max 1000.00 | Min 0.00 - max 1000.00 | Min 0.00 - max 100.00 | Min 0.00 - max 100.00 | Min 0.00 - max 100.00 | Min 0.00 - max 100.00 | Min 0 - max 100% | Min 0 - max 1000000000 |
| Input | | | | | | | | | | | | | | | |
| Input | | | | | | | | | | | | | | | |
| Input | | | | | | | | | | | | | | | |
| Input | | | | | | | | | | | | | | | |
| Input | | | | | | | | | | | | | | | |
| Input | | | | | | | | | | | | | | | |

*Figure 4.23 Preventive Maintenance - inputs*

Notes:

- Preventive maintenance can be undertaken all year round, but the user can also specify a season to ensure it is only taken, for example, when the weather is likely to be good and/or production is likely to be low.
- Similarly to installation, the user can add additional costs annually for preventive maintenance to consider items not currently included in the scope of this model such as additional operational costs.
- The user specifies the task similarly to an installation operation with a few additional items including the frequency of occurrence, operation location, power loss and spare part/consumables cost.
- Frequency determines how often a PM task is undertaken e.g. 1 means annually; 0.1 means every 10 years for a 20 year project.
- Operation location refers to whether maintenance occurs on or offshore. If it is onshore, the user must also specify the onshore operation duration. The task will be broken down into 3 separate consecutive operations: retrieve device; onshore maintenance; and redeploy device. No weather restrictions apply during the onshore maintenance operation.
- Power loss refers to whether the device is turned off for maintenance or whether it can continue producing energy. If the operation is onshore, the model will automatically make this 100%.
- The user can add a cost of maintenance for consumables (e.g. oil) or spare parts required.

### 4.1.9 Corrective Maintenance

Corrective maintenance tasks can be specified by completing the “Repairs” and “Components” tabs. The Repairs are added first, detailing a list of repair activities including their operation location, the vessel required, the base etc.

Then a list of components is added, the number per device, specifying their annual failure rate, and linking each failure to a repair. It is hoped that this will reduce the number of inputs the user has to make since it is likely a number of failures will require the same response in terms of repair operation.

#### *4.1.9.1 Repair Categories*

Figure 4.24 and Figure 4.25 display the screens shown when you select the “Repairs” tab while Figure 4.26 provides further detail for each input required.

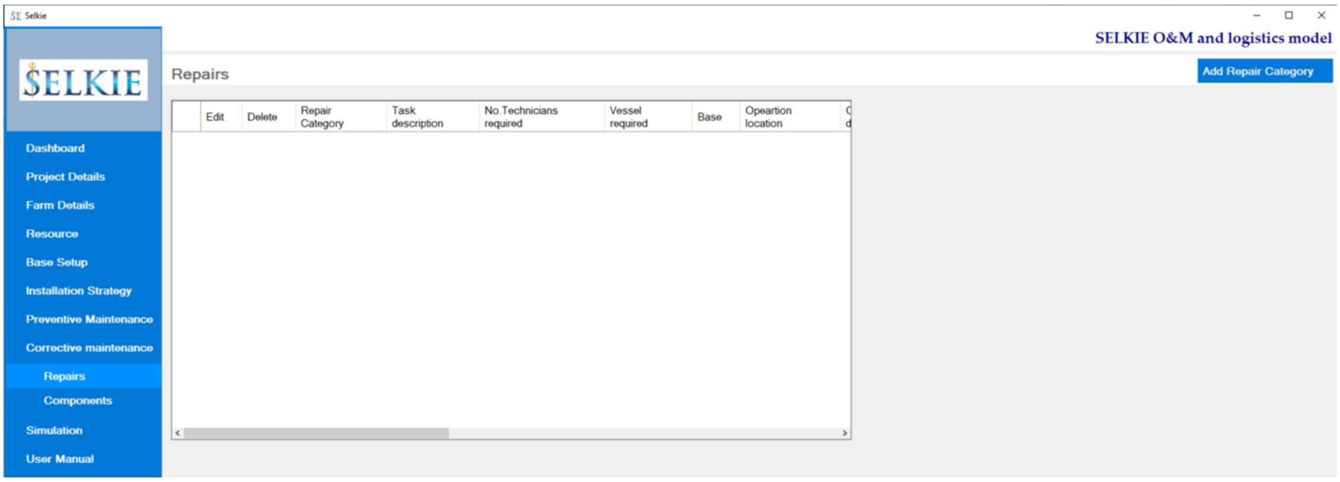



*Figure 4.24 Repairs - model screen*

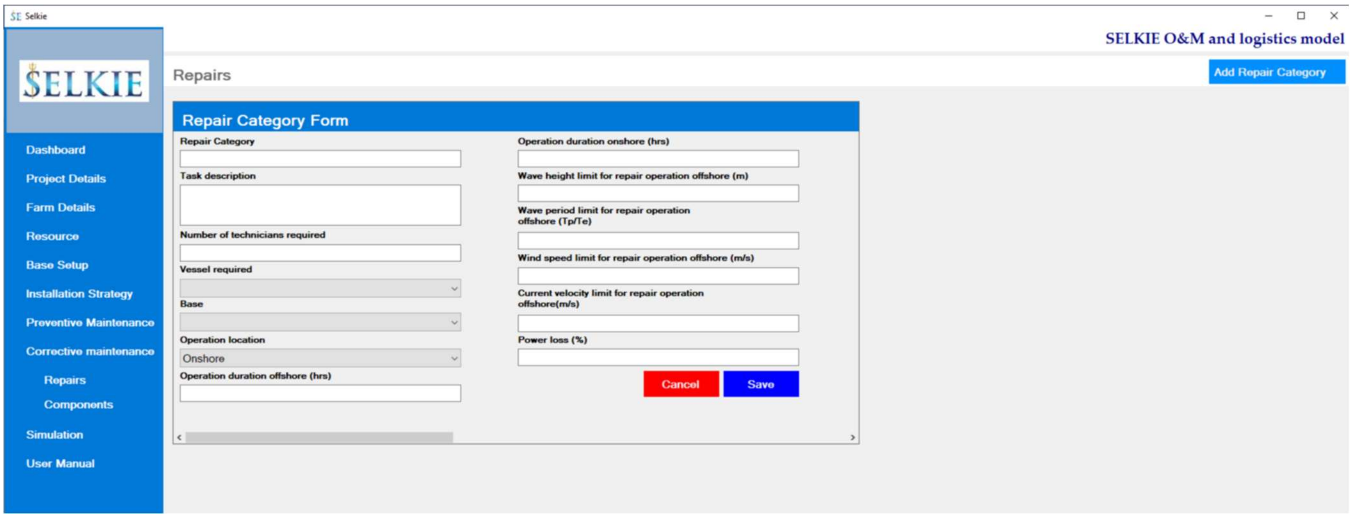



*Figure 4.25 Add Repair Category - model screen*

| Field | Task name | Task description | No. of technicians required | Vessel required | Base | Operation location | Operation duration offshore | Operation duration onshore | Wave height limit for repair operation offshore | Wave period limit for operation offshore | Wind speed limit for repair operation offshore | Current velocity limit for repair operation offshore | Power loss |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Unit | text | text | integer | select | select | select | hrs | hrs | m | s | m/s | m/s | % |
| Description | Name of repair | Additional details of repair (reference only) | No. of technicians required to carry out the operation. | To specfiy details under vessels/equipment | Select base the vessel comes from and/or repair occurs | Does the repair take place offshore or must the device be towed to shore for maintenance | Operation duration offshore e.g. if operation onshore this could represent the time required to detach the device to tow to shore | Operation duration onshore if applicable | This is a general wave height limit for completing operation offshore | This is a general wave period limit for completing operation offshore | General wind speed limit for completing operation offshore | General current velocity limit for completing operation offshore | Power loss when PM is being undertaken i.e. if the turbine is fully stopped until the repair is complete, the power loss is 100 % |
| Data limits | Min 1 - max 200 | Min 0 - max 200 | Min 0 - max 100 | Dropdown list | Dropdown list | Dropdown list | Min 0.00 - max 1000.00 | Min 0.00 - max 1000.00 | Min 0.00 - max 100.00 | Min 0.00 - max 100.00 | Min 0.00 - max 100.00 | Min 0.00 - max 100.00 | Min 0 - max 100% |
| Input | | | | | | | | | | | | | |
| Input | | | | | | | | | | | | | |
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| Input | | | | | | | | | | | | | |
| Input | | | | | | | | | | | | | |
| Input | | | | | | | | | | | | | |

*Figure 4.26 Repair categories - inputs*

#### *4.1.9.2 Components*

Figure 4.27 and **Error! Reference source not found.** display the model screen when you select the “Components” tab and “Add Components”. Figure 4.28 provides further detail about the inputs required.

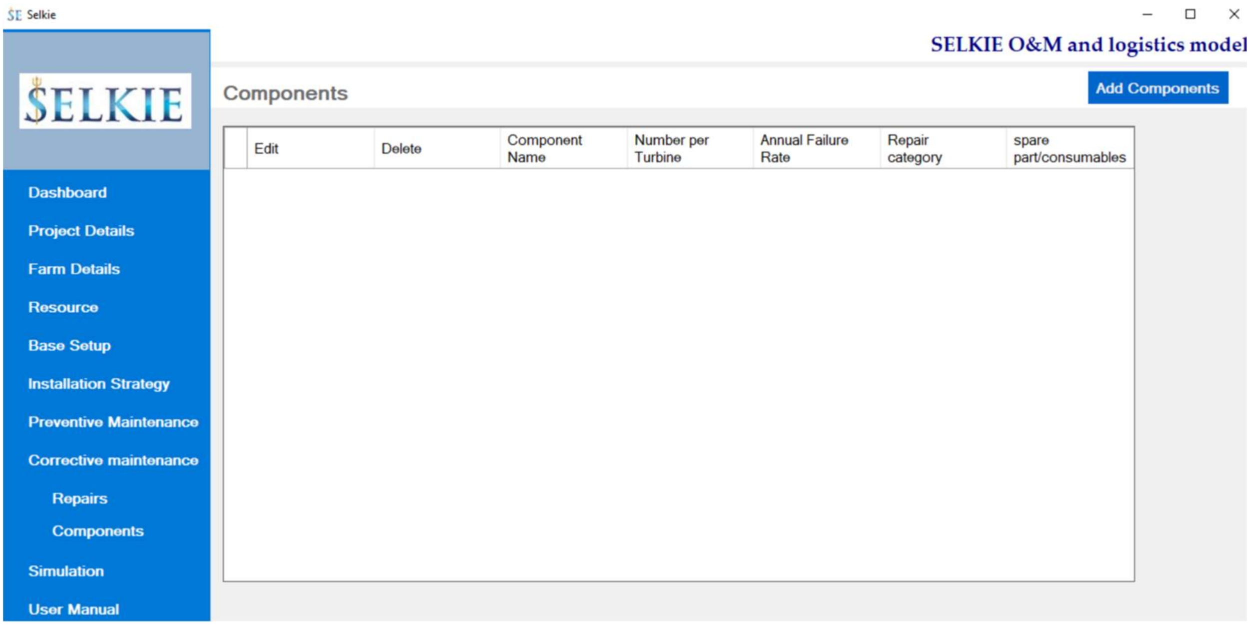


*Figure 4.27 Components - model screen*

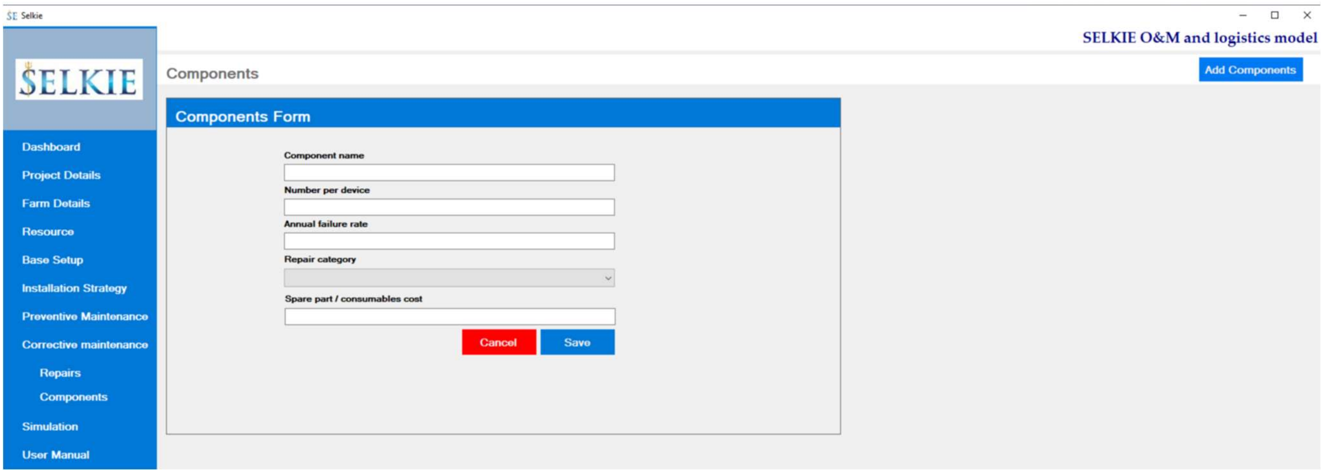


*Figure 4.28 Components - inputs*

## 4.2 Simulation

Once you have loaded a project or input and saved a new project, the user can select the "Simulation" tab as shown in Figure 4.29 and select the "Start Simulation" button. This will lock the project to avoid further changes being made while a scenario is in process and check the inputs to ensure nothing vital is missing. A progress bar will then show the model simulating installation tasks and O&M tasks, providing time taken and progress message updates as well as identifying how many iterations out of the max specified have been completed. A simulation in progress is shown in Figure 4.30.

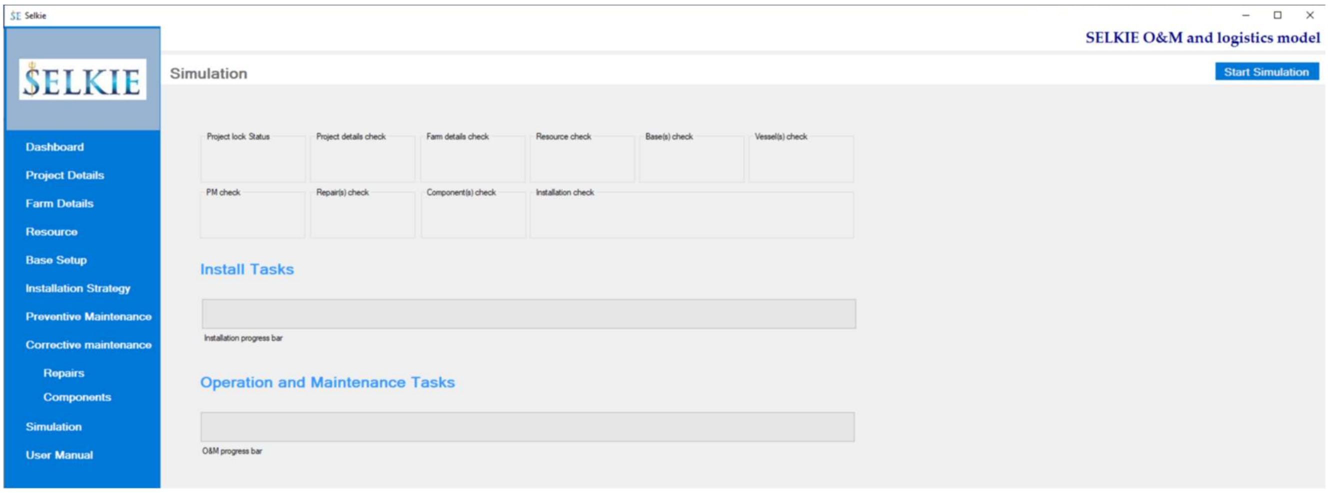


*Figure 4.29 Simulation - model screen*

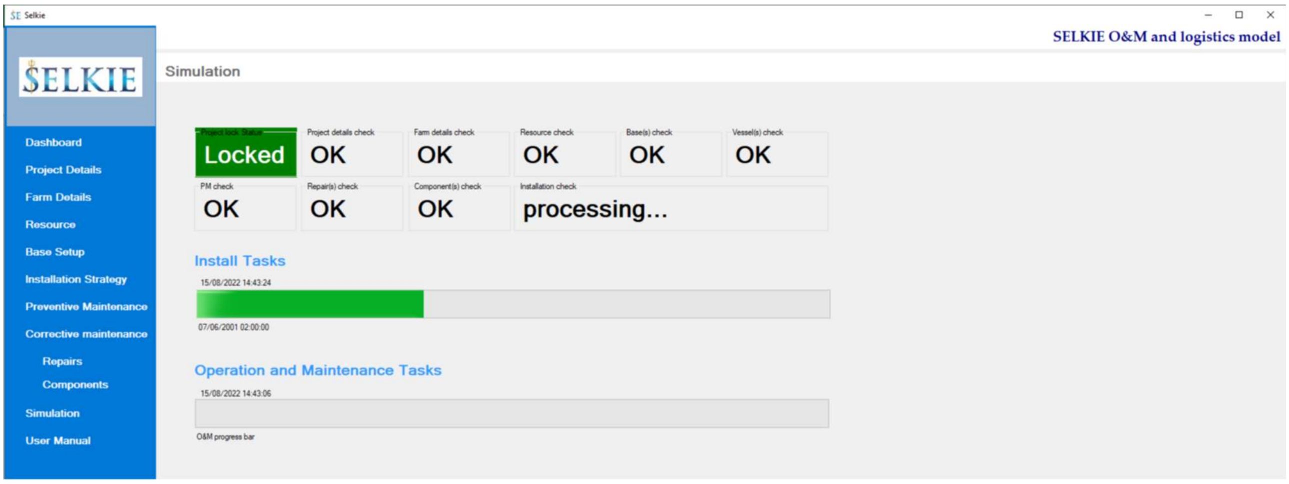


*Figure 4.30 Simulation - processing - model screen*

## 4.3 Outputs

Once completed, the user can export results using the "Export Reports" button as shown in Figure 4.31. This allows the user to save to any folder, including (but not restricted to) the "Reports" folder in their Roaming SELKIE folder created on set-up (Section 3).

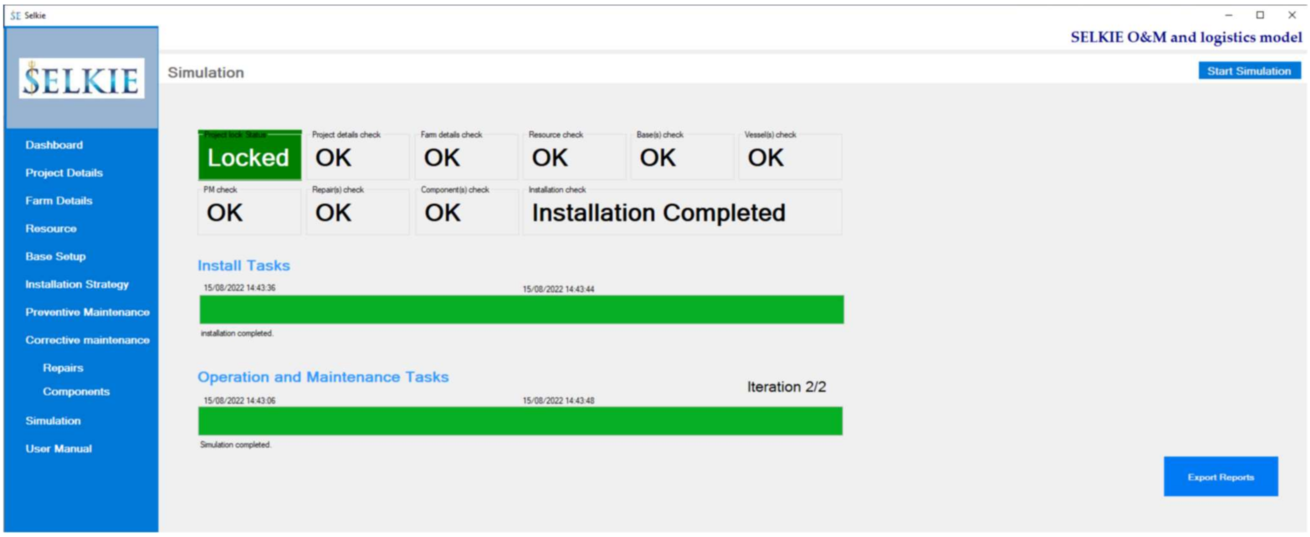


*Figure 4.31 Simulation - Export Results – model screen*

Results are exported as an excel file with the project name and includes 4 sheets:

Inst_Yearly_Results = the yearly results per iteration

| Iteration no. | Ye ar | Base Costs | Vessel fixed/rental Costs | Tech Costs | Vessel fuel costs | Total installation cost |
|---|---|---|---|---|---|---|

Inst_Device_Results = details of installation activities per iteration

| Iteration no. | Device Id | Device type | JOB | Start | End | Status | Install time in hrs |
|---|---|---|---|---|---|---|---|

O&M_Results_AnnualAverage = annual average results per iteration

| Total O&M cost | Vessel Fuel Costs | Vessel fixed/rental Costs | Tech Costs | Base Costs | Spare parts/repair Costs | Additional O&M Costs |
|---|---|---|---|---|---|---|

| Energy Theoretical | Energy Produced | Energy-based Availability | Total hours | Downtime | Time-based Availability | Income |
|---|---|---|---|---|---|---|

OM_Results_Yearly = yearly OM results per iteration

| Iteration no. | Ye ar | Total Annual O&M cost | Vessel Fuel Costs | Vessel fixed/rental Costs | Tech Costs | Base Costs | Spare parts/repair Costs |
|---|---|---|---|---|---|---|---|

| Additional O&M cost | Energy Theoretical | Energy Produced | Energy-based Availability | Total hours | Downtime | Time-based Availability | Income |
|---|---|---|---|---|---|---|---|

# 5 Processing logic

This section is the user requirement specification created for model development and providing the detailed step by step processing logic.

## 5.1 Installation

### 5.1.1 Key assumptions

1. Installation activities can occur 24/7.
2. Technician shifts are limited to 12 hours; therefore, if a task duration exceeds 12 hours, 2 sets of crews are needed. The model will automatically update the technicians required.
3. It is assumed that if a task exceeds 12 hours, the vessel selected can remain offshore for the time required to complete the activity.
4. The user can specify a number of items to be installed per vessel trip but this must take place within one operation/WW. The model will automatically update the installation operation duration as required.
5. The user can specify to install 2 items: the substructure/moorings and anchors and the device. The model will always install the substructure first for either fixed/floating devices. The user can specify only one installation task if preferred.

### 5.1.2 Input analysis and checks

Based on input data, the model randomly mixes up the years of data provided by the user per iteration using a bootstrap method to generate a synthetic times series for Monte Carlo (MC) simulations.

It will generate a data time series for installation based on the estimated installation time input by user.

Based on the user inputs it will generate an installation task list specifying for each task:

1. The substructure/device(s) to be installed – note this depends on the number to install/remaining to be installed. If only one device to install or remaining to install but user has specified a vessel can transport two, then only one device is assigned to task.
2. The transit time from port to site/site to port considering the vessel type selected speed and distance from the base selected. Convert transit speed (knots) to km/hr and calculate with following equation:

$$Transit\ time = \frac{Distance\ from\ shore\ (km)}{Transit\ speed\ (\frac{km}{hr})}$$

3. The operation duration to install substructure/device(s)[2] with following equation:

$$Total\ operation\ duration = (duration\ per\ item\ x\ number\ of\ items\ to\ install) +$$

[2] Hereafter described as item

$$\left(\frac{Distance\ between\ items}{Transit\ speed}\ x\ (number\ of\ items\ to\ install - 1)\right)$$

4. Total task duration = Transit time + Total operation duration + Transit time
5. WW will be the weather limits specified for the operation duration considering significant wave height (Hs); wave period (Tp); wind speed (Uw); current velocity (V) across the total task duration.
6. Based on installation task list, the model will ensure the strategy is viable considering the resources available (vessels, technicians, base) as follows:
   i) Are there any vessels of the type specified available?
   ii) Is the task duration more than 12 hours (technician shift time - hardcoded)? If so, double the number of technicians required for each task as they will need to change crews during the task.
   iii) If technicians are required, are the number needed available at the base selected?
   iv) Does the vessel selected have capacity for the number of technicians required?
   v) If no to 1, 3 and 4, model should cancel simulation and output the errors respectively [1. not enough vessels; 3. not enough technicians; 4. vessel does not have crew capacity].

### 5.1.3 Processing

Installation activities can begin from the first day of the month installation activities are set to begin.

For each task to be completed, the model will check:

1. When is the next WW available for this task?

*Note if no WW are available in a single year, there is likely to be an issue with the strategy. The simulation stops and the following error message is displayed [no WWs available, check inputs to reduce duration/weather restrictions].*

2. Is there a vessel available for the identified WW? If purchased then just a case of checking if there is a vessel free; if rented for a season, need to check if it is within season and there is a vessel free. Hire as required is not available for installation activities.
3. Are there enough technicians available at the base for this WW?
4. If yes to 2 and 3, assign vessels and technicians to task for task duration.
5. If no to 2 and/or 3, the model will move to the next WW and check again. This should allow the model to assign as many tasks as possible to a single WW.

To calculate results:

1. Vessels: track which vessel is assigned.
2. **Vessels rented per season or purchased have fixed annual costs.** Rented per season applies If rented per season, track the annual cost of the season plus one annual mobilisation cost. If purchased, track the annual running cost. For purchased and seasonal rental, only track the costs for vessels used in a given year and during the installation period.

3. **For all vessel scenarios track vessel fuel usage** hours, using fuel consumption and cost per litre to calculate overall fuel cost at the end of each year during the installation period.
4. **Bases and technicians: these are calculated using fixed costs. Therefore, track the annual costs of** the base and technicians only for those utilised that year and during the installation period.
5. Track the **items installed** and **when each task began and when it was completed** (i.e. the WW utilised).

If installation activities exceed the installation time available, the model will add an additional year until installation is complete.

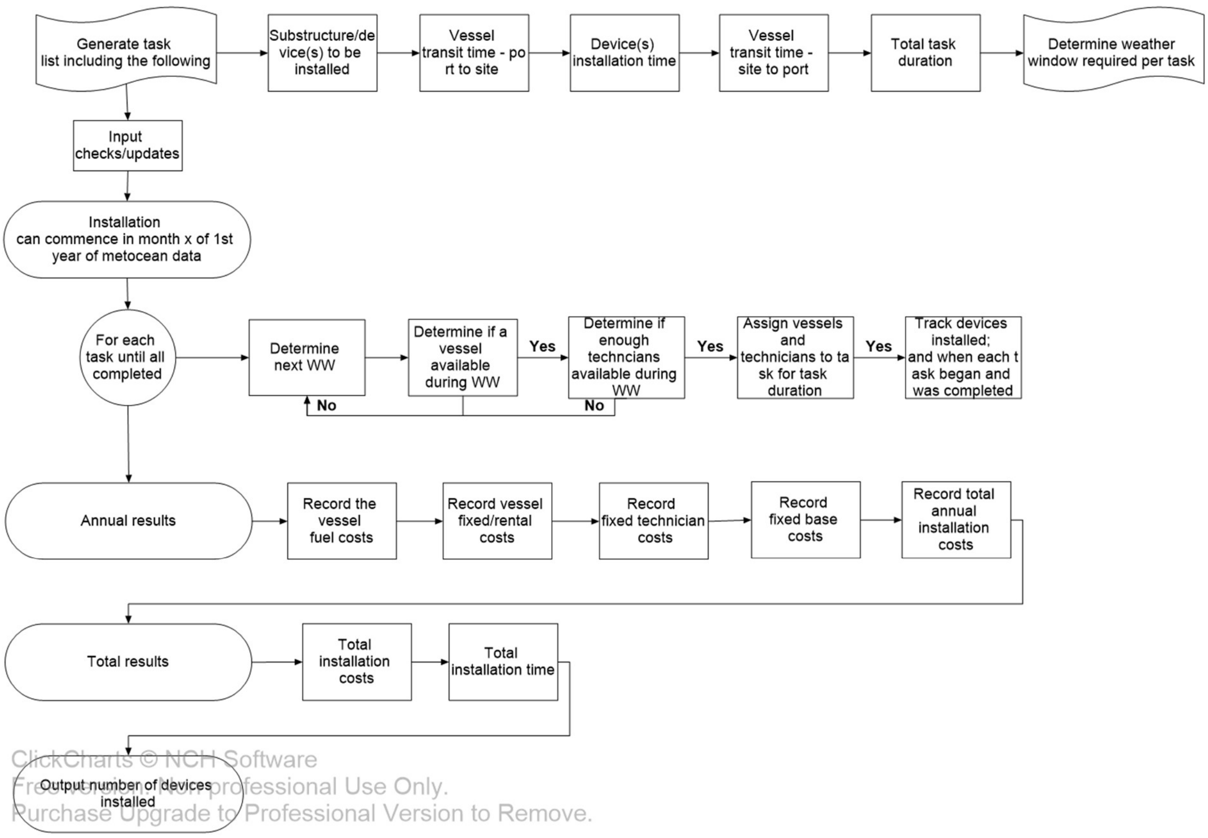


*Figure 32 Installation processing logic*

## 5.2 O&M activities

The O&M model can consider a range of Preventive Maintenance (PM) and Corrective Maintenance (CM) tasks. The former are regularly scheduled activities, while the latter are based on an annual failure rate.

### 5.2.1 Key assumptions

1. The model will install all devices before proceeding to O&M activities.
2. For O&M tasks, work can be undertaken either 24/7 or from 7am-7pm (during daytime). The user determines which by specifying whether a given vessel can undertake "night

work" i.e. operation 24/7. This will help ensure the majority of tasks take place during daylight hours.

3. Technician shifts are limited to 12 hours; therefore, if a task duration exceeds 12 hours, 2 sets of crews are needed. The model will automatically update the technicians required.
4. Only one maintenance operation will be completed per vessel i.e. a vessel must complete a task and return to shore before the next operation is undertaken. Once the repair/maintenance is completed, the assigned technicians and vessels become available again for the next task.
5. The model will attempt to repair any failures and complete all PM tasks. While not completing repairs will impact power production, failure to complete PM tasks will not currently impact the device performance.
6. Power loss %:

   a) For offshore maintenance, the power loss % applied during CM activities occurs from when a component fails to the end of the last offshore maintenance operation for that task (i.e. component is fixed). The % loss for PM activities occurs from the start of the first offshore maintenance operation (i.e. maintenance begins) to the end of the last offshore maintenance operation (i.e. maintenance complete).
   b) For onshore maintenance, the power loss % applied during CM activities occurs from when the component fails to the start of the first offshore maintenance operation (i.e. device is retrieved). The device then has 100% power loss until the end of the last offshore maintenance operation for this task i.e. the device is reinstalled. The power loss % applied during PM activities is 100% from the start of the first offshore maintenance operation (i.e. device retrieved) to the end of the last offshore maintenance operation (i.e. device reinstalled).
7. Only one maintenance activity can occur on a device at a time.
8. Any tasks due up to one month before the end of the project lifetime should be removed from the list.

### 5.2.2 Input analysis and checks

Based on input data, the model randomly mixes up the years of Metocean data per iteration using a bootstrap method to generate a synthetic times series for MC simulations.

This will generate a data time series for O&M based on the project lifetime input from the user.

Once installation has been completed the model will check the number of months it will take to fully commission the farm i.e. how long until it is operational. This will determine when the O&M model can commence analysis i.e. the first day of the month following completion of commissioning.

For CM, the model begins by determining a randomised list of failures based on the failure rate input by the user for each component per device and for the number of devices in a farm. Note the user can specify the number of components per device. Therefore, the model will need to generate failures for each component.

Failure times are generated as follows:

- The failure rate is used to determine the meantime to failure (MTTF I in hours as follows: MTTF = (1/Failure rate per year)*(hours per year i.e. 8760)[3]
- Then the inverse of normal cumulative distribution function is used to randomise failures per iteration. In excel this is NORMINV=(Rand(); MTTF;Stdev). The standard deviation is set to 10% in the model.

Based on the failure list, the model will generate an O&M task list of all CM activities to be completed. It will then determine the PM tasks to be completed considering the frequency of PM tasks per device as defined by the user e.g. annual inspection or 5 yearly overhaul the frequency would be 1 or 0.2 respectively per device for a 20 year project. These tasks are added to the repair list set for when the PM season begins as specified by the user.

For each task (CM/PM) the model will specify:

1. The component to be maintained (Only specified for CM, blank for PM)
2. The device to be maintained.
3. The repair category CM or PM category.
4. The technicians required.
5. The vessel required.
6. The base assigned.
7. The power loss %.
8. The spare parts & consumables cost.
9. The operation location (onshore/offshore). For tidal and floating wave, a lot of maintenance activities are likely to occur onshore. Therefore, the model allows the user to specify the repair duration and where the repair occurs i.e. offshore or onshore. This is also true for PM tasks.
10. If offshore, the model checks whether night work is possible for the vessel selected.

a. If yes, maintenance can occur 24/7 and therefore, the full operation should be completed within 1 task. The duration is defined as follows:

    i. The transit time from port to site/site to port considering the vessel type selected transit speed and distance from the base selected. Convert transit speed (knots) to km/hr and calculate with following equation:

$$Transit\ time = \frac{Distance\ from\ shore\ (km)}{Transit\ speed\ (\frac{km}{hr})}$$

    ii. The operation duration offshore to service the device.
    iii. Total task duration = i + ii + i.
    iv. The model then determines the WW requirements/WWs available based on the weather limits specified for the offshore operation considering the significant wave height (Hs); wave period (Tp); wind speed (Uw); current velocity (V) applied across the total task duration (i.e. including vessel transit).

[3] Ignore leap years for this equation

b. If no, then offshore operations must be completed between 7am-7pm i.e. within 12 hours. Therefore, the model determines the total operation duration as above (a. iii) and checks if the duration is more than 12 hours (max daytime working and technician shift).

i. If yes, the model breaks the operation down into tasks, each of which is not longer than 12 hours (including the vessel transit time). These tasks must occur consecutively and are dependent on the previous being completed before the next can begin. The task duration and WW requirements are established for each as per a. i-iv.

11. If onshore, the model checks whether night work is possible for the vessel selected.

a. If yes, the model creates 3 consecutive tasks as the device must be Retrieved; Onshore maintenance completed; and the device is re-installed. Each task is dependent on the previous task being completed and each task must be completed in full during a single WW since operations can occur 24/7 offshore i.e. night work is possible.

The operation duration to retrieve/reinstall the task is defined as follows:

i. The transit time from port to site/site to port considering the vessel type selected transit speed and distance from the base selected. Convert transit speed (knots) to km/hr and calculate with following equation:

$$Transit\ time = \frac{Distance\ from\ shore\ (km)}{Transit\ speed\ (\frac{km}{hr})}$$

ii. The operation duration offshore to service the device.

iii. Total task duration = i + ii + i.

iv. The model then determines the WW requirements/WWs available based on the weather limits specified for the offshore operation considering the significant wave height (Hs); wave period (Tp); wind speed (Uw); current velocity (V) applied across the total task duration (i.e. including vessel transit).

The onshore operation duration is defined by the user. There are no weather restrictions associated with this since it occurs onshore.

b. If no, then offshore operations must be completed between 7am-7pm i.e. within 12 hours. The model determines the total operation duration for the offshore task as above (a. iii) and checks if the duration is more than 12 hours (max daytime working and technician shift).

i. If yes, the model must create 3 consecutive tasks to retrieve, maintain onshore and reinstall the device and then break each of the offshore operations down further into tasks not more than12 hours (including the vessel transit time). These tasks must occur consecutively and are dependent on the previous being completed before the next can begin. The task duration and WW requirements are established for each as per a. i-iv.

The task list is then re-ordered time-sequentially but ensures that consecutive tasks (tasks that must happen in sequence) remain together.

The model checks to ensure each task is viable considering the resources available (vessels, technicians, base):

1. Are there any vessels of the type specified available?
2. Is the task duration longer than 12 hours (technician shift time - hardcoded)? If so, double the number of technicians required for each task as they will need to change crews during the task.
3. If technicians are required, are the number needed available at the base selected?
4. Does the vessel selected have capacity for the number of technicians required?

If no to 1; 3 and 4, simulation stops and gives the following error [not enough vessels; not enough technicians; vessel does not have crew capacity].

### 5.2.3 Processing

Particularly with a multi-device array, it is likely that a significant number of PM tasks will be due to occur simultaneously and will probably overlap with CM tasks. A number of failures may also occur on a single device when maintenance may already be underway etc. Therefore, the O&M task list will be updated during the simulation based on the following logic:

- If PM is due on a device but a CM fault occurs before PM can occur (e.g. waiting for a weather window), the CM fault takes priority. The PM tasks due date is re-scheduled for when the device is fixed. This should still be within the PM season. If PM tasks are not completed within the season, then the model would need to prioritise that task as soon as possible at the start of the next season. The reason it does not just cancel the task is that some PM may only happen halfway through a project lifetime (e.g. a half-life refit) so you would be essentially cancelling a very important task. However, for regular maintenance (e.g. annual), this could lead to quite a build-up of PM tasks. Therefore, the model assumes that if another PM task of the same type for the same device is due within 31 days of the last PM task finishing, then it can be cancelled as the previous PM operation has essentially replaced it.
- If a failure occurs while maintenance (CM or PM) is already underway on a device, that failure should be deleted as the device is already down for maintenance so this wouldn't have occurred.
- Where multiple failures occur for different components on a single device (i.e. same hour), the model should select the component causing the greatest power loss to service first. CM for subsequent failures occur in separate tasks (only one maintenance activity can occur on a device at any one time).

O&M activities can begin from the first day of the month O&M activities are set to begin.

For each task to be completed, the model will check

1. If vessel is to be hired as required, mobilise vessel, noting when it will be available at port considering the lead time specified by user. The vessel will wait at port until a WW is available. Day rates are applied from time vessel is available at port until end of task and a mobilisation cost is added each time vessel is hired, unless it's been no more than a week since it was last hired (otherwise it won't charge to mobilise again so soon after last time). If it has not been more than a week since last hired, also assume next lead time is zero. The week is hardcoded into the model.

2. When is the next WW available for this task? If vessel is hired as required, ensure only check for windows after vessel has arrived at port to skip step 3.

*Note if no WW are available in a single year, there is likely to be an issue with the strategy. The simulation should be cancelled, and an error message output as follows [no WWs available, check inputs to reduce duration/weather restrictions]*

3. Is there a vessel available for the identified WW? If purchased, then check if there is a vessel free; if rented for a season, check if the required time is within the season and there is a vessel free.
4. Are there enough technicians available at the base for this WW?
5. If yes to 2 and 3, assign vessels and technicians to task for task duration.
6. If no to 2 and/or 3, the model will move to the next WW and check again. This should allow the model to assign as many tasks as possible to a single WW.

The next failure for a component should be added to the list once the previous failure has been fixed.

To calculate results:

1. Vessels: track which vessels have been assigned.

**If hire as required**, the model tracks vessel usage hours for each task assigned from when it is made available at port following lead time (i.e. time required for vessel to get to port) until end of O&M task. Apply the rental day rate to this time and add a mobilisation cost each time hired unless it has only been no more than a week since the last hire event ended. Track the annual usage and number of times mobilised each year. User can hire up to max of the number specified by user for this vessel type.

**Vessels rented per season or purchased have fixed annual costs.** If rented per season, the model tracks the annual cost of the season plus one annual mobilisation cost. If purchased, it tracks the annual running cost. For purchased and seasonal rental, it only tracks the costs for vessels used in a given year and during the O&M period.

**For all vessel scenarios the model tracks vessel fuel usage** hours, using fuel consumption and cost per litre to calculate overall fuel cost at the end of each year during the O&M period.

2. **Bases and technicians**: these are calculated using fixed costs. The model tracks the annual costs of the base and technicians only for those utilised that year and during the O&M period.
3. **Tracking the devices serviced including their shutdown time**, **restart time**, **% power loss during each shutdown**; **when each task began and when it was completed** (i.e. the WW utilised). At the end of the simulation, the model should compare the shutdown time, restart time and % power loss for a task against the Metocean data to determine the downtime hours and energy production.

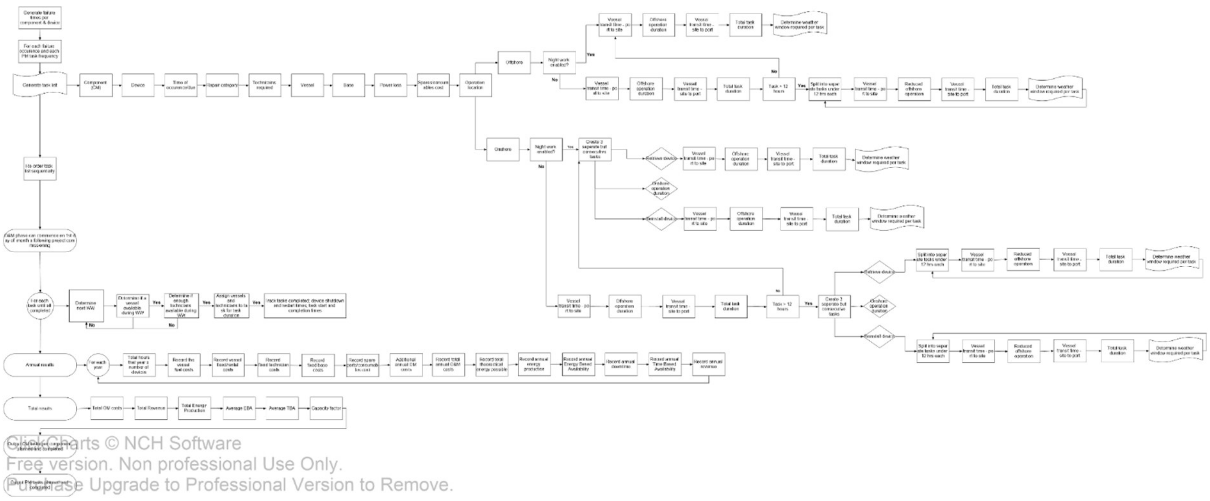


*Figure 33 O&M processing logic*

# 6 SELKIE format tools

In addition to the main installation and O&M tool, we have provided 2 tools developed in Matlab to help users arrange their Power Matrix and Metocean data into the format required by the SELKIE model.

These tools have been compiled as standalone executables; but in order to run any Matlab program on a machine that doesn't have Matlab installed you will need to install the Matlab Compiler Runtime (MCR). These tools were developed using Matlab R2015a (8.5) and will therefore require installation of the corresponding (free) runtime software via [MATLAB Runtime - MATLAB Compiler - MATLAB (mathworks.com).](MATLAB Runtime - MATLAB Compiler - MATLAB (mathworks.com)) The formatting tools comprise the following: Excel input files “Metocean_data_input” and “PM_input” containing sample information based on the Pelamis P2 power matrix and FarrPoint Metocean data [1] [2].

Matlab executables “SELKIE_Metocean_data_format_tool” and “SELKIE_PowerMatrix_format_tool”. Excel template files that show the format required by the SELKIE tool “Metocean_data_template” and “PM_data_template”.

To use the tools, put data in the input files according to the sample data provided. Double click the appropriate executable and wait for the progress bar to show that processing is complete.

Output will be provided as a new, timestamped excel file in the correct format, ready for use in the SELKIE tool.

Users can also use the template files directly to manually prepare inputs for the SELKIE tool.

# 7 Timeline and model application

Initial coding was completed in May 2021. Extensive validation and testing followed using realistic pilot case studies based on the OEBuoy OE12 30kW device deployed at SmartBay and the Sabella PHARES project (two D15 500kW devices).

The final version will be presented during a user training course in 2022 including a sample case study based on the Pelamis2 device and FarrPoint metocean data provided as part of the Wave Energy Scotland model [1] and summarised in Gray et. Al [2].

It should be noted that this model will interact with the GIS techno-economic model developed in WP4 and this will be described in the following section.

# 8 Interaction with WP4 GIS Techno-Economic tool

There are two principal interactions between WP8's O&M and Logistics tool, and WP4's GIS Techno-economic tool. WP4 will give WP8 metocean data for the case study sites listed in D8.3-8.5. WP8 will send WP4 the results of its optimizations of the pilot and array-scale case studies of Wave and Tidal energy farms at each location, so that WP4 may conduct full LCOE analyses.

# Bibliography


[1] 29 10 2020. [Online]. Available: https://library.waveenergyscotland.co.uk/other-activities/design-tools-and-information/tools/om-simulation-tool/wes-om-tool-and-user-guide_rev2/.

[2] A. Gray, B. Dickens, T. Bruce, I. Ashton and L. Johanning, “Reliability and O &M sensitivity analysis as a consequence of site specific characteristics for wave energy converters,” *Ocean Engineering,* vol. 141, pp. 493-511, 2017.

## Appendix 1

## On-line Questionnaire

The SEKLIE project is developing a decision-support tool that will allow users to 1) simulate operations across the lifecycle considering uncertain factors e.g. weather and failures and their impact on the costs and duration of a project; 2) optimise the logistics required for the installation and Operation and Maintenance (O&M) phase e.g. port, offshore vessel fleet, activity schedule etc. This survey seeks to identify what strategies the tool should be able to test and gather information to form generic case-studies, which are of most interest to industry. Therefore, we would greatly appreciate participation from experts across the Offshore Renewable Energy supply chain. Please provide as much detail as possible/relevant to you. We would greatly appreciate any figures or rough ranges/percentages, but if that is not possible, general statements are still very much appreciated. Your feedback may be anonymous. If you choose to provide your contact email, this will be kept confidential within the consortium and only used for the purpose specified (i.e. follow up discussion on topic). The survey will be open until the 1st December 2020. Information provided will be stored on a secure site or partners' desktop computer for the duration of the SELKIE project.

Top of Form

- GENERAL - 1. What is your area of expertise?

[Control]Wave energy
[Control]Tidal energy
[Control]Offshore wind
[Control]Oil & Gas
[Control]Device manufacturing
[Control]Transport and logistics
[Control]Installation
[Control]O&M
[Control]Other - please specify

- GENERAL - 2. Would you be willing to be contacted for a follow-up discussion on this topic?

[Control]Yes[Control]No

- GENERAL - 3. If yes to the above, please provide your email address to be added to our contact list.
- SUPPLY-CHAIN - 4. What are the major obstacles to deploying wave or tidal energy arrays and how could these obstacles be overcome in future? (if applicable, please include improvements in supply chain/ licensing/ governance etc.)

[Control]

- SUPPLY-CHAIN - 5. What are the key port requirements for installing/decommissioning wave and tidal energy devices e.g. space, transport links?

[Control]

- SUPPLY-CHAIN - 6. What are the key port requirements for O&M of wave and tidal energy devices e.g. space, transport links?

[Control]

- SUPPLY-CHAIN - 7. What developments and investment may be needed for existing Irish/Welsh ports to cater for the wave and tidal industry?

[Control]

- TECHNOLOGY - 8. What is your device or preferred concept currently in development/deployed (name or technology type e.g. oscillating water column)

[Control]

- TECHNOLOGY - 9. Is the device

[Control]wave - fixed[Control]wave - floating[Control]tidal - fixed[Control]tidal - floating[Control]Other

- TECHNOLOGY - 10. If fixed, please specify foundation type e.g. gravity, monopile etc.

[Control]

- TECHNOLOGY - 11. If floating, please specify mooring and anchor system e.g. mooring lines, number, anchor type etc.

[Control]

- SITE SELECTION - 12. What (if any) are the ideal site conditions for your preferred concept e.g. water depth, distance from shore?

[Control]

- SITE SELECTION - 13. What (if any) are the seabed restrictions (e.g. seabed type)?

[Control]

- ARRAY DESIGN - 14. What would be the preferred installed capacity (MW) of the first arrays (e.g. a small Offshore Wind Farm would be 100MW)?

[Control]

- ARRAY DESIGN - 15. What are the space requirements for the device i.e. distance between devices?

[Control]

- INSTALLATION - 16. What is the installation strategy for the device (please provide a brief description of the process)?

[Control]

- INSTALLATION - 17 a. What are the vessels and equipment required?

[Control]

- INSTALLATION - 17 b. What are the main costs (where possible please specify figures or ranges)?

[Control]

- INSTALLATION - 17 c. What is the time required to install? (where possible, please break down into the different operations e.g. anchor installation, mooring connection etc.)

[Control]

- INSTALLATION - 17 d. What are the weather restrictions e.g. max significant wave height/tidal current/wind speed? (where possible, please provide for the different activities e.g. vessel transit, foundation/mooring installation etc.)

[Control]

- INSTALLATION - 18. What are the actual or estimated total installation costs per MW?

[Control]

- INSTALLATION - 19. What are the main installation challenges?

[Control]

- INSTALLATION - 20. If you have installed a device, what were the major lessons learned and what would you do differently the next time?

[Control]

- INSTALLATION - 21. If you have installed a device, can you comment on the vessel availability and expenses (i.e. were vessels in short supply, did this create delays, what was the day rate/mobilisation costs etc.)

[Control]

- INSTALLATION - ANY OTHER COMMENTS

[Control]

- O&M - 22. What is the O&M strategy for the device (please provide a brief description e.g. tow back to shore for major repairs, onsite for minor repairs)?

[Control]

- O&M - 23 a. What are the vessels and equipment required?

[Control]

- O&M - 23 b. What are the main costs (where possible please specify figures or ranges)?

[Control]

- O&M - 23 c. Can you specify the main maintenance operations for this device and their estimated durations? (corrective/preventive e.g. gearbox repair, annual inspection etc.)

[Control]

- O&M - 23 d. What are the weather restrictions e.g. max significant wave height/tidal current/wind speed? (Where possible, please provide per operation e.g. towing, blade repair etc.)

[Control]

- O&M - 24. What are the actual or estimated annual O&M costs per MW?

[Control]

- O&M - 25. What are the main O&M challenges?

[Control]

- O&M - 26. If you have maintained a device, what were the major O&M lessons learned and what would you do differently the next time?

[Control]

- O&M - 27. If you have maintained a device, can you comment on the vessel availability and expenses (i.e. were vessels in short supply, did this create delays, what was the day rate/mobilisation costs etc.)

[Control]

- O&M - ANY OTHER COMMENTS

[Control]