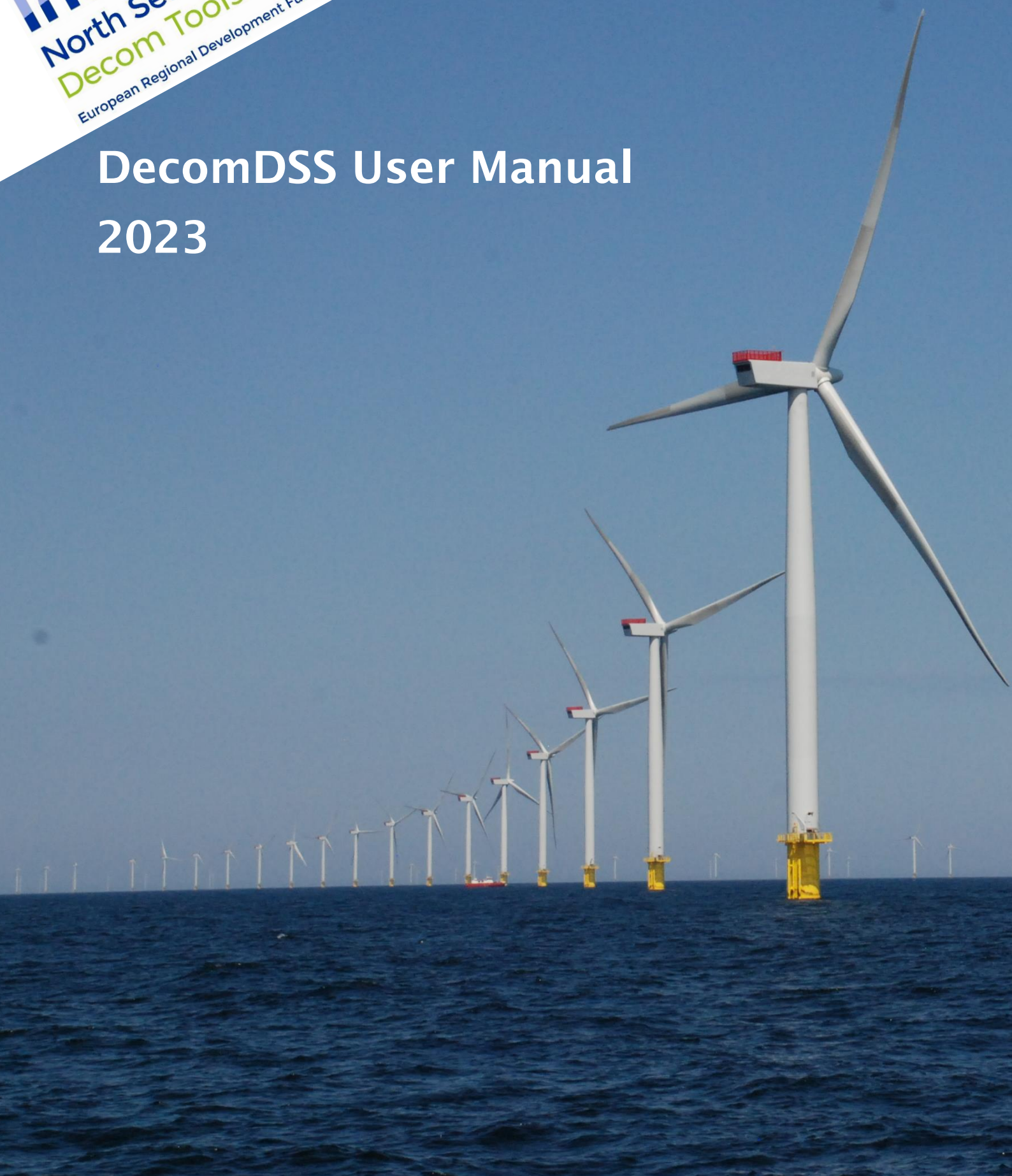


DecomDSS User Manual 2023



Project Acronym: **DecomTools**

Reference Number: **Interreg North Sea Region– Project Number: 20180305091606**

Project Title: **Eco-Innovative concepts for the end of offshore wind energy farms lifecycle**

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Project Partners:



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1 Introduction

The DecomDSS tool is a decision support system which allows its users to

- Define an offshore windfarm.
- Define/Set available resources.
- Define different removal scenarios.
- Evaluate a removal scenario for its Cost and Emission.

DecomDSS is a user-friendly tool with the following main features:

- Expandable to different levels of detail.
- Can be used for different removal scenarios.
- It is generic and can be used for different types of windfarms, types of wind turbines, etc.
- Expandable to include new set of data as new technologies emerge.

The graphical user interface (GUI) of DecomDSS has three tabs, namely,

- Windfarm Components
- Define Removal Scenario
- Analyse Removal Scenario

These three tabs, respectively, allow for

- showing the components of the windfarm under study at different levels; the dependency of the components, and the attributes of the components,
- defining a wide range of removal scenarios by combining components together, using different cutting/removal techniques, and partial decommissioning, and
- evaluating a defined removal scenario with respect to cost and emission.

2 Windfarm components, their dependency, and attributes

DecomDSS software reads the Windfarm input file, where all components of a windfarm are defined using *component.parent* protocol [1]. Then it finds the level of each component, finds its dependants and groups components in different levels. The *component.parent* data structure makes the data protocol expandable with no limitation in the level of detail/dependency.

2.1 Showing components level-by-level

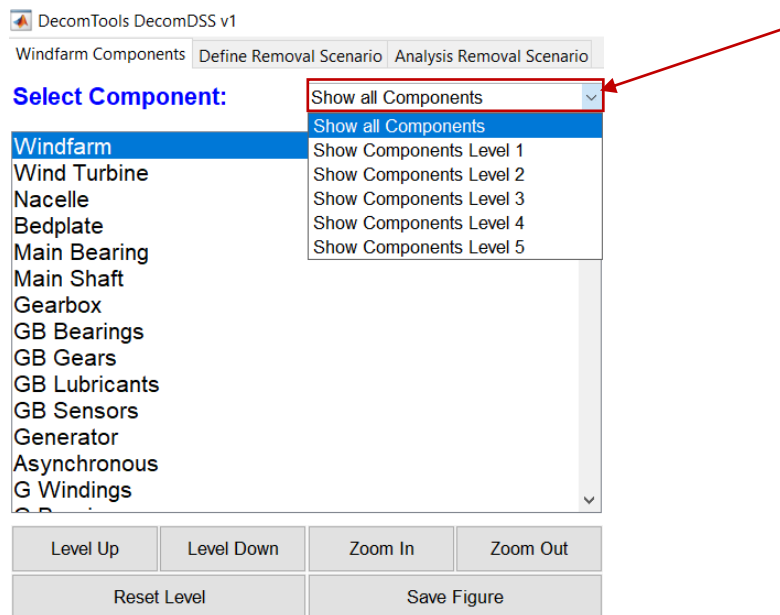


Figure 1-Drop-down menu, allowing to show and select all components or the components at a certain level

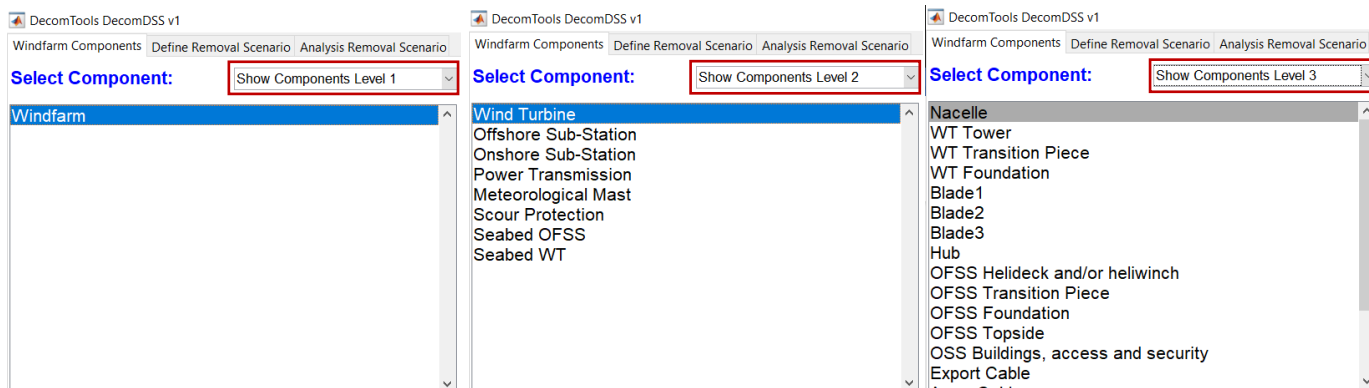


Figure2-Left to right, components at Level 1 (only Windfarm), components at Level 2, and components at Level 3

2.2 Level of detail/dependency

DecomDSS finds dependants of each component and shows them by three levels of detail by default. Levels are colour coded.

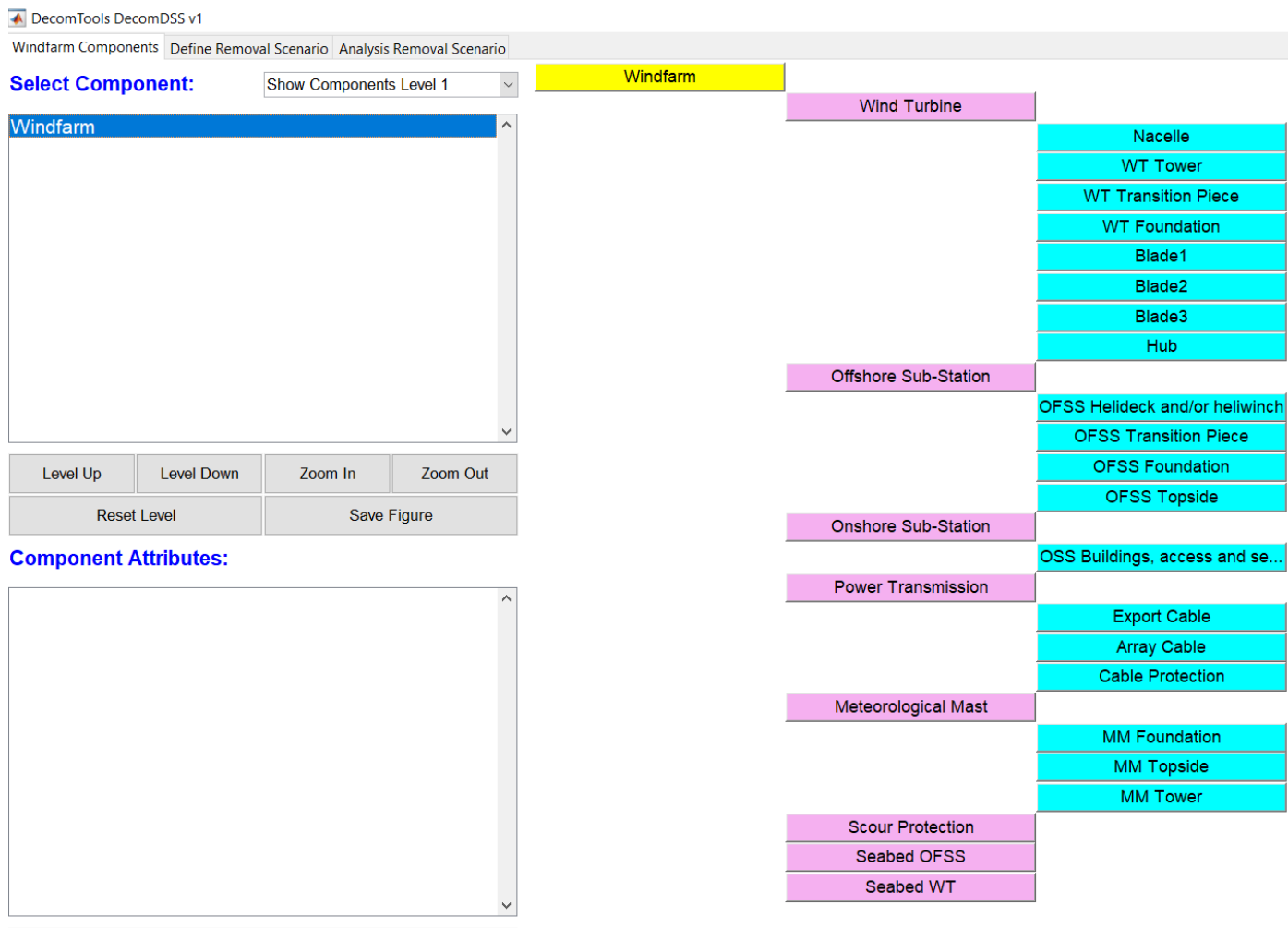


Figure 3-Starting from Windfarm, the selected component at Level 1, showing **three** levels of dependency (three levels by default)

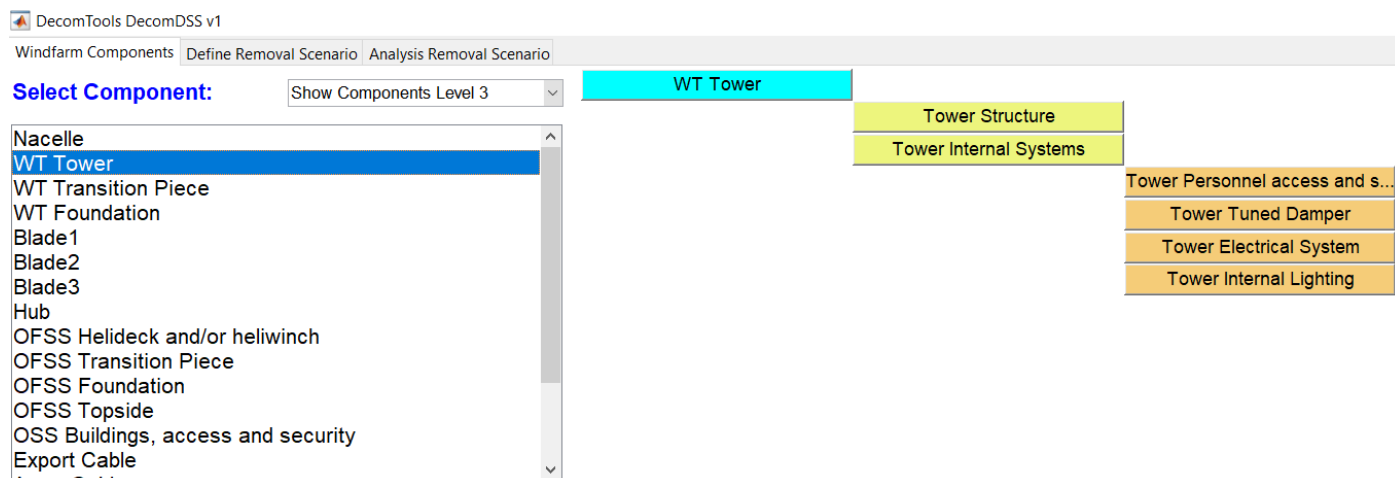


Figure 4-Starting from WT Tower, the selected component at Level 3, showing three levels of dependency

DecomTools DecomDSS v1
Windfarm Components
Define Removal Scenario
Analysis Removal Scenario

Select Component:
Show Components Level 2

Wind Turbine
Offshore Sub-Station
Onshore Sub-Station
Power Transmission
Meteorological Mast
Scour Protection
Seabed OFSS
Seabed WT

Level Up
Level Down
Zoom In
Zoom Out
Reset Level
Save Figure

Component Attributes:

Restart DecomDSS

Wind Turbine

Nacelle

Bedplate
Main Bearing
Main Shaft
Gearbox
Generator
Power Take-off System
Power Control System
Yaw System
Auxiliary Systems
Nacelle Cover
Condition Monitoring System

WT Tower

Tower Structure
Tower Internal Systems

WT Transition Piece


Crew access and platform
Internal platforms
Davit crane
J-tubes, I-tube or monopile ent...
Corrosion Protection System

WT Foundation


Monopile Structure

Blade1
Blade2
Blade3
Hub

Pitch System
Rotor Spinner
Rotor Auxiliary Systems



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Figure 5-Starting from Wind Turbine, the selected component at Level 2, showing three levels of dependency

2.3 Changing the level of dependency to show

The level of details can be changed by using Level Up (more detailed) and Level Down (less detailed) buttons.

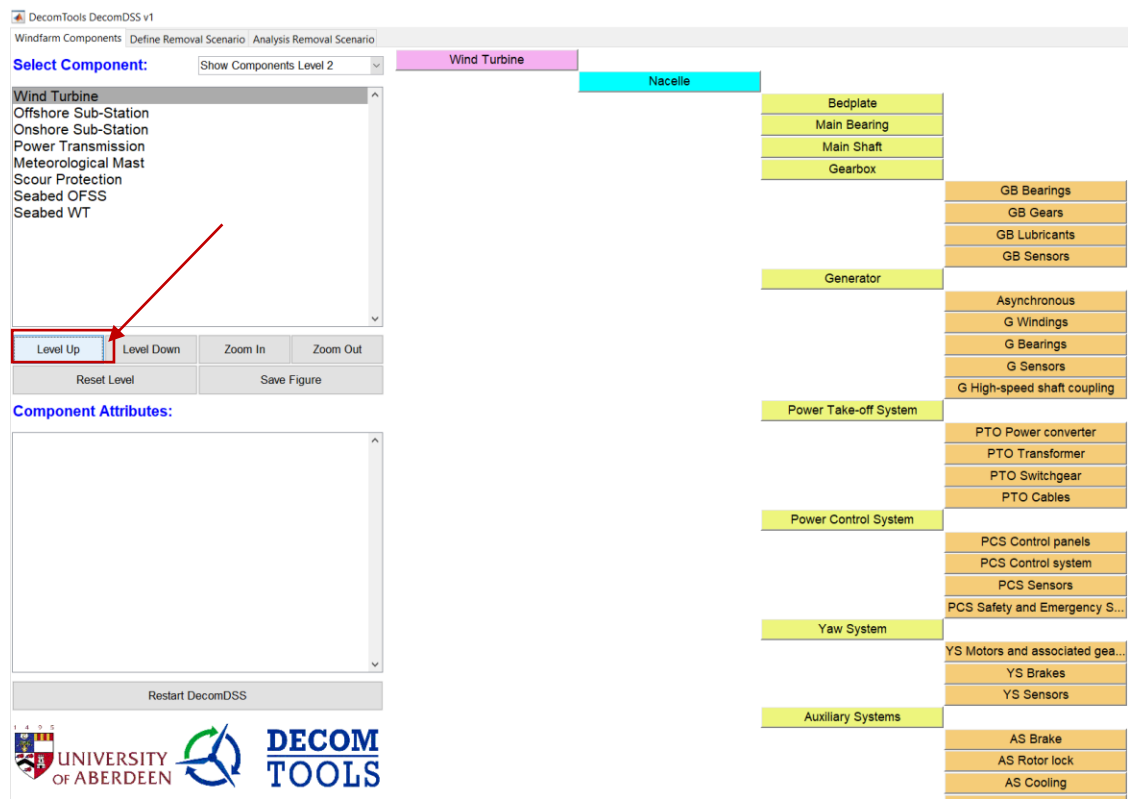


Figure 6-Starting from Wind Turbine, the selected component at Level 2, showing **four** levels of dependency

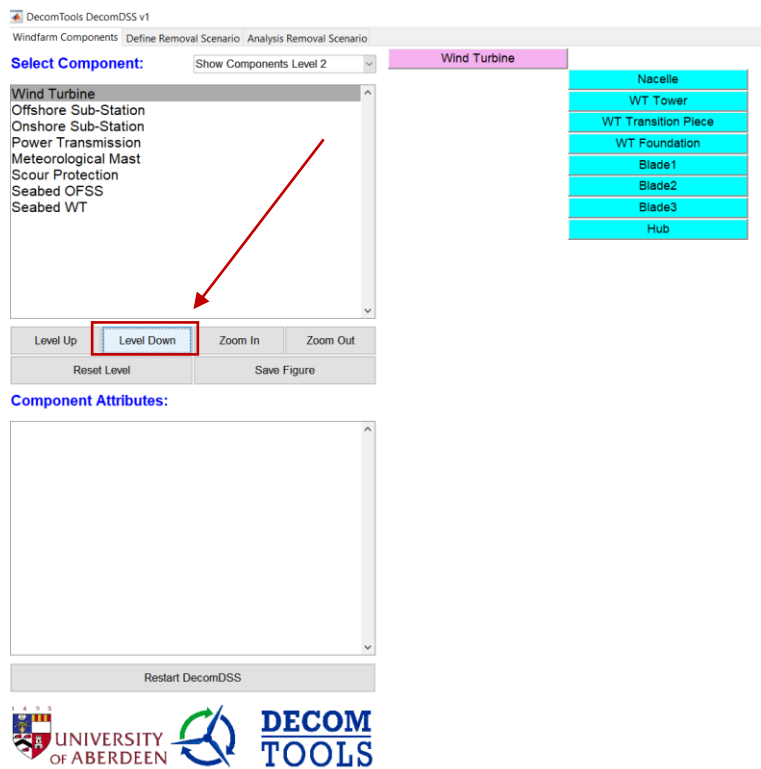


Figure 7-Starting from Wind Turbine, the selected component at Level 2, showing **two** levels of dependency.

2.4 Zoom in/out

In cases, where all dependencies cannot be shown on the GUI, Scroll, Zoom In and Zoom Out buttons can be used to fit the components in the screen.

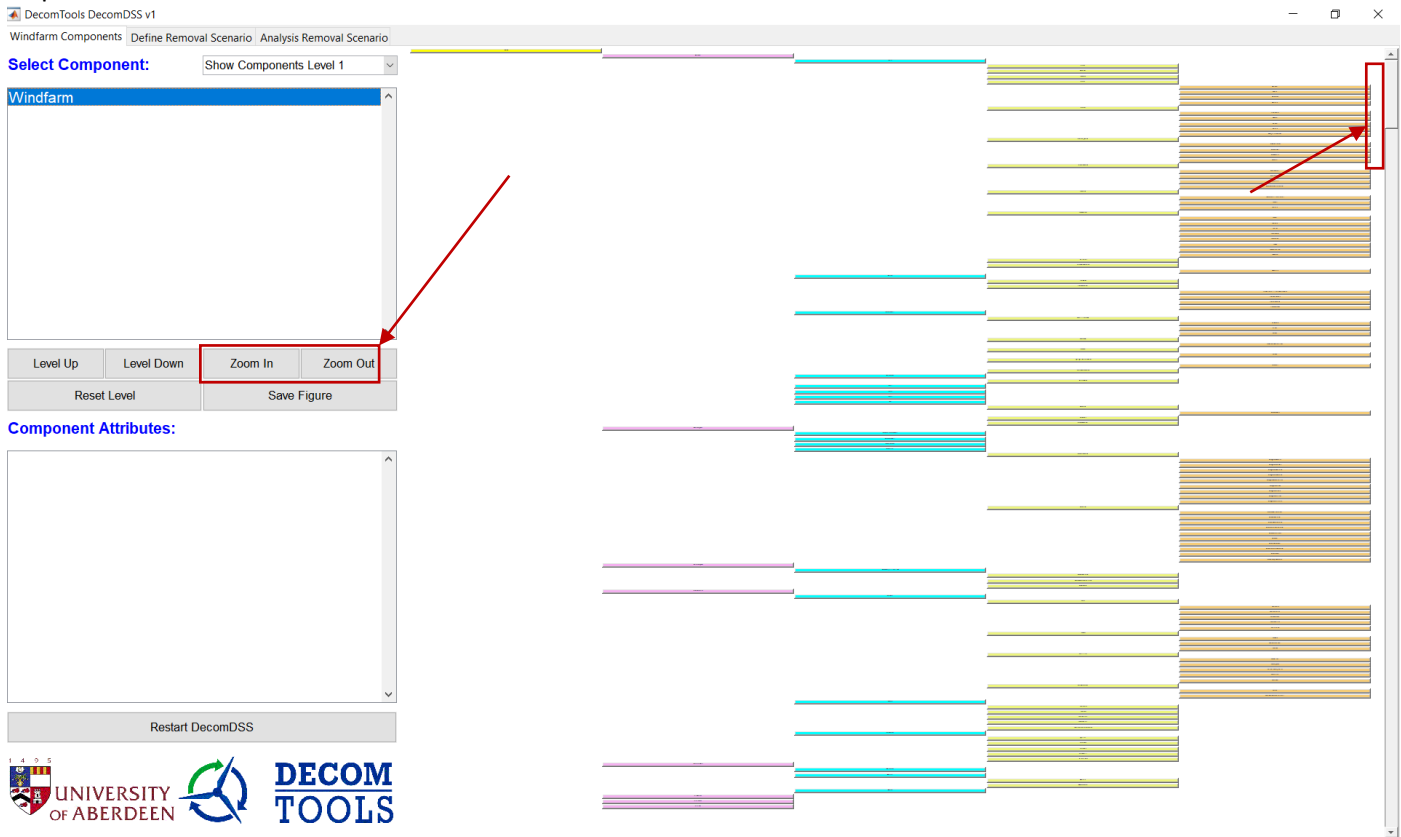


Figure 8-Zoom In, Zoom Out and Scroll

2.5 Save Figure

Button Save Figure saves the part of windfarm which is shown on GUI in a high-quality *tiff* format with a name generated automatically based on the time and date of generation.

Note: If you are using dual monitors, ensure that the GUI is entirely displayed on the main monitor before saving the figure.

2.6 Components attributes

Each component is associated with a list of attributes, which have been saved in the input file. Attributes are shown in the 'Component Attributes:' list box by clicking on each component. Attributes include (but not limited to):

- Component name as in the input file (e.g. Wind Turbine)
- Actual name (e.g. Siemens SWT=3.6-107)
- Parent
- Level (calculated automatically)
- Code (unique code assigned to each component automatically)
- Number of identical components of that type on the parent (e.g. 3 for hydraulic cylinder on pitch control system)
- Total number of that components in the entire of windfarm
- Dimensions (rectangular/box dimensions)
- Mass

- Mass of each type of material in the component (calculated based on the percentage of each type of material in the input file)
- Connections to other components, and for each connection its type and characteristics, and possible cut/removal techniques and their characteristics
- Any function used in calculations (e.g. thrust and power coefficient curves for wind turbine)

Not all components are defined by the same set of attributes. Depending on the type of components different attributes are defined.

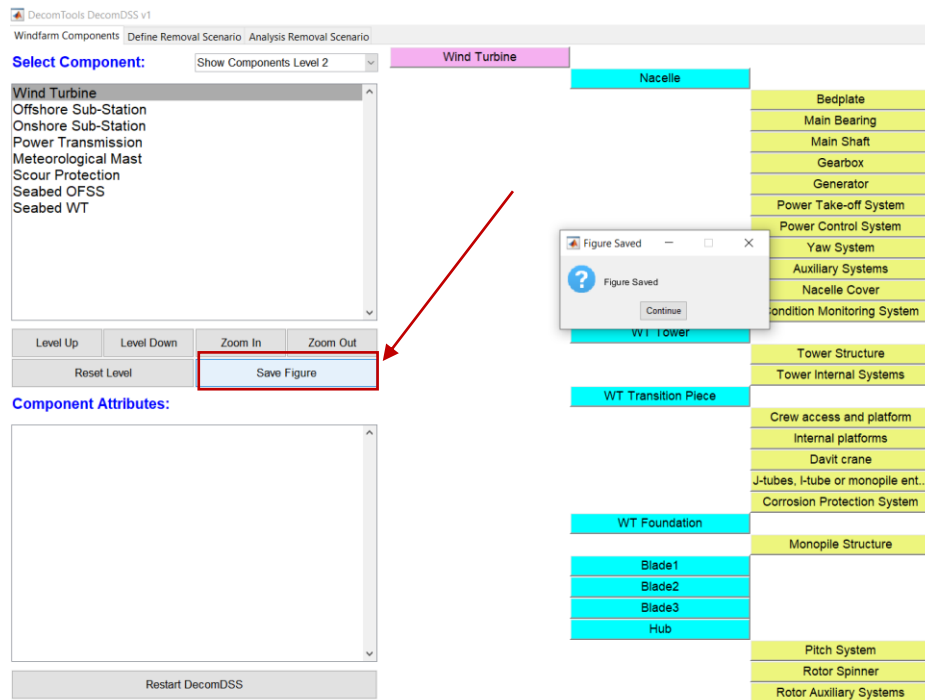


Figure 9-Save Figure in the subfolder DecomDSS

DecomTools DecomDSS v1

Windfarm Components Define Removal Scenario Analysis Removal Scenario

Select Component: **Windfarm**

Windfarm

- Wind Turbine
 - Nacelle
 - WT Tower
 - WT Transition Piece
 - WT Foundation
 - Blade1
 - Blade2
 - Blade3
 - Hub
- Offshore Sub-Station
 - OFSS Helideck and/or heliwinch
 - OFSS Transition Piece
 - OFSS Foundation
 - OFSS Topside
- Onshore Sub-Station
 - OSS Buildings, access and secu...
- Power Transmission
 - Export Cable
 - Array Cable
 - Cable Protection
- Meteorological Mast
 - MM Foundation
 - MM Topside
 - MM Tower
- Scour Protection
- Seabed OFSS
- Seabed WT

Component Attributes:

Component: WT Tower

Parent: Wind Turbine
Level: 3
Code: 0,1,2

>No. of Identical Components on Parent= 1
>Total No. of Components in WF= 88
>Dimensions (m)= 80,5,5
>Mass (kg)= 255000
>Materials:
Steel: 255000 kg
>Connections:
C1: Nacelle
Type: Bolted
Removal(s):
R1: Unbolt(120)
C2: WT Transition Piece
Type: Bolted
Removal(s):
R1: Unbolt(100)
R2: Plasma(5,0.04)

Figure 10-Attributes of each component is shown in the attribute list box by clicking on the component. Example: attributes of WT Tower

3 Defining Removal Scenarios

Adopting a component-parent protocol for defining a windfarm and having connections defined as an attribute to each component allows us to define various removal scenarios.

The Tab '**Define Removal Scenario**' is made of four sections, namely, Connection Tree Diagram, Connections, Cut Method, and Cut & Lift Order.

3.1 Connection Tree Diagram

In connection tree diagrams, each node shows a component, and each line is a connection to be removed (cut and lift operation). Connection Tree Diagrams are made for separate assemblies and only one of the identical assemblies are shown in the connection tree diagrams. In Figure 11, there are two connection tree diagrams, one for wind turbines (left-only one wind turbine is shown) and one for offshore substation (right). Connection tree diagrams change as components are combined by the user through 'Connections' section.

3.2 Connections

Connections section allows the user to define different removal scenarios by combining components. Each item in the list has the generic form of **A*B**, where **A** and **B** are two components to be separated and ***** stands for the connection between the two components which needs to be removed. By clicking on each item in the list the two components become one component (shown by **A&B**) which will be removed with one lift operation. Example below shows how by clicking on the first item in Figure 12 (**Blade1*Hub**) they become one single component (**Blade1&Hub**), which is now connected to the Nacelle (**Blade1&Hub*Nacelle**).

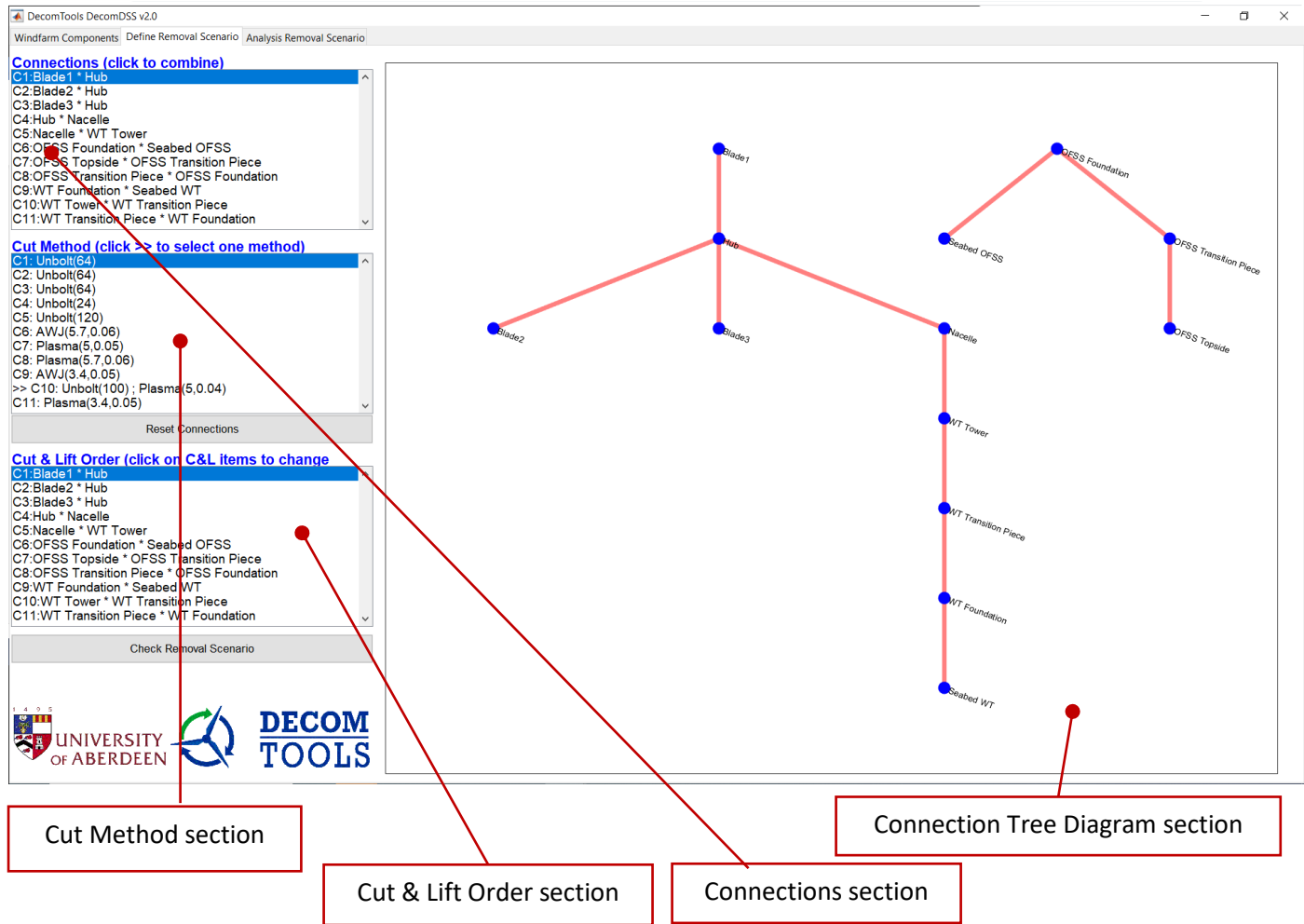


Figure 11- Four sections of Define Removal Scenario Tab

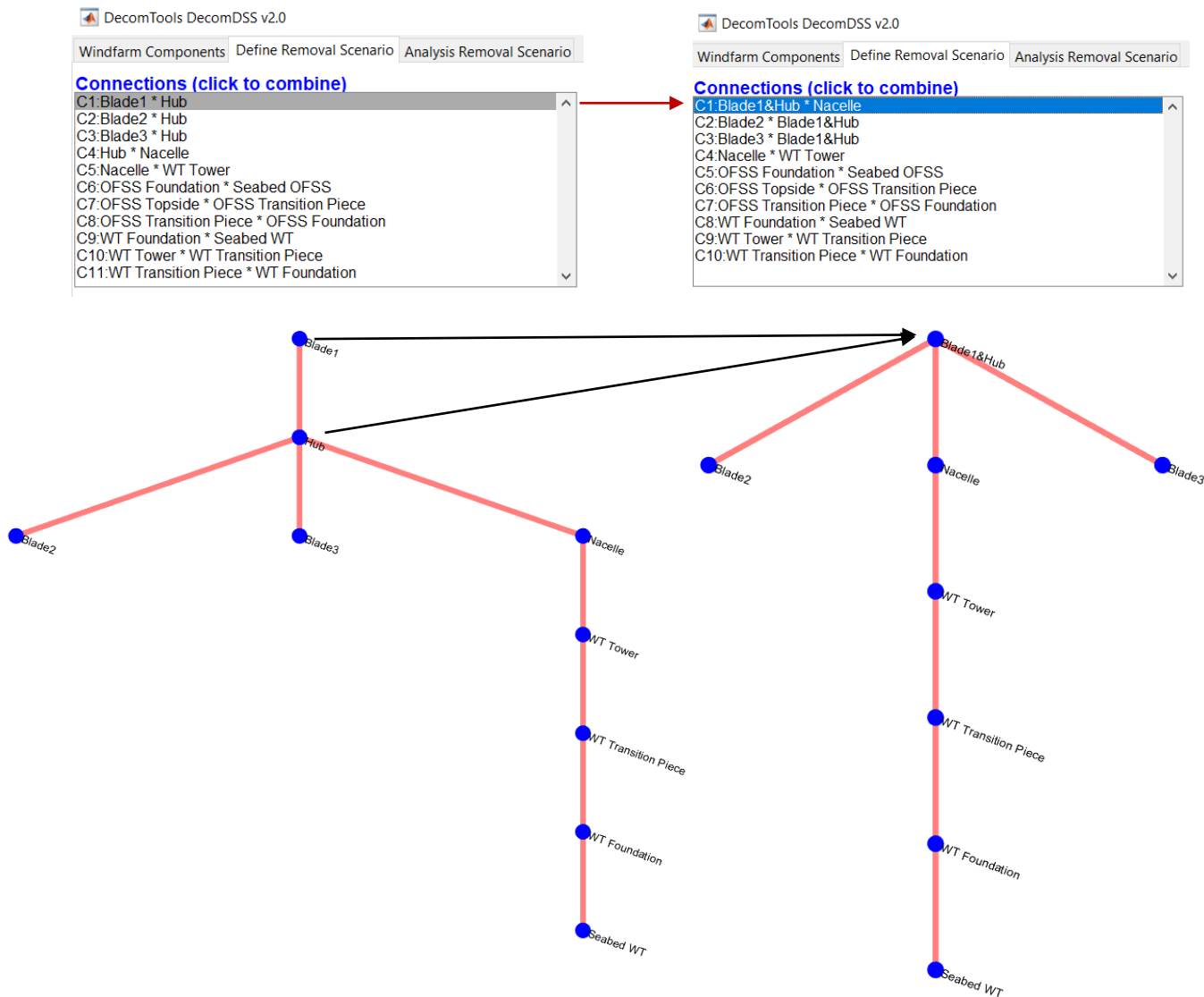


Figure 12- Defining different removal scenarios by combining components; Example: combining Blade 1 and Hub

Figure 11 shows the removal scenario of 'Complete removal of wind turbines and substations, in which blades are removed one by one'. Figure 12 shows the removal scenario of 'Complete removal of wind turbines and substations, in which two blades are removed from hub one by one, while the third one remains attached to the hub and the assembly is removed from Nacelle in a single cut and lift'.

Figures 13 shows how to generate the removal scenario of 'Complete removal of wind turbines and substations, in which the rotor is removed with one cut and lift operation'. In this scenario three blades and hub are treated as a single component. To form this combination first **Blade1** and **Hub** are combined to form **Blade1&Hub**, then Blade1& Hub are combined with **Blade2** to form **Blade2&Blade1&Hub**, and finally, are combined with **Blades3** to form a single component of **Blade3&Blade2&Blade1&Hub** which is connected to Nacelle (**Blade3&Blade2&Blade1&Hub*Nacelle**) and is removed with a single cut and lift.

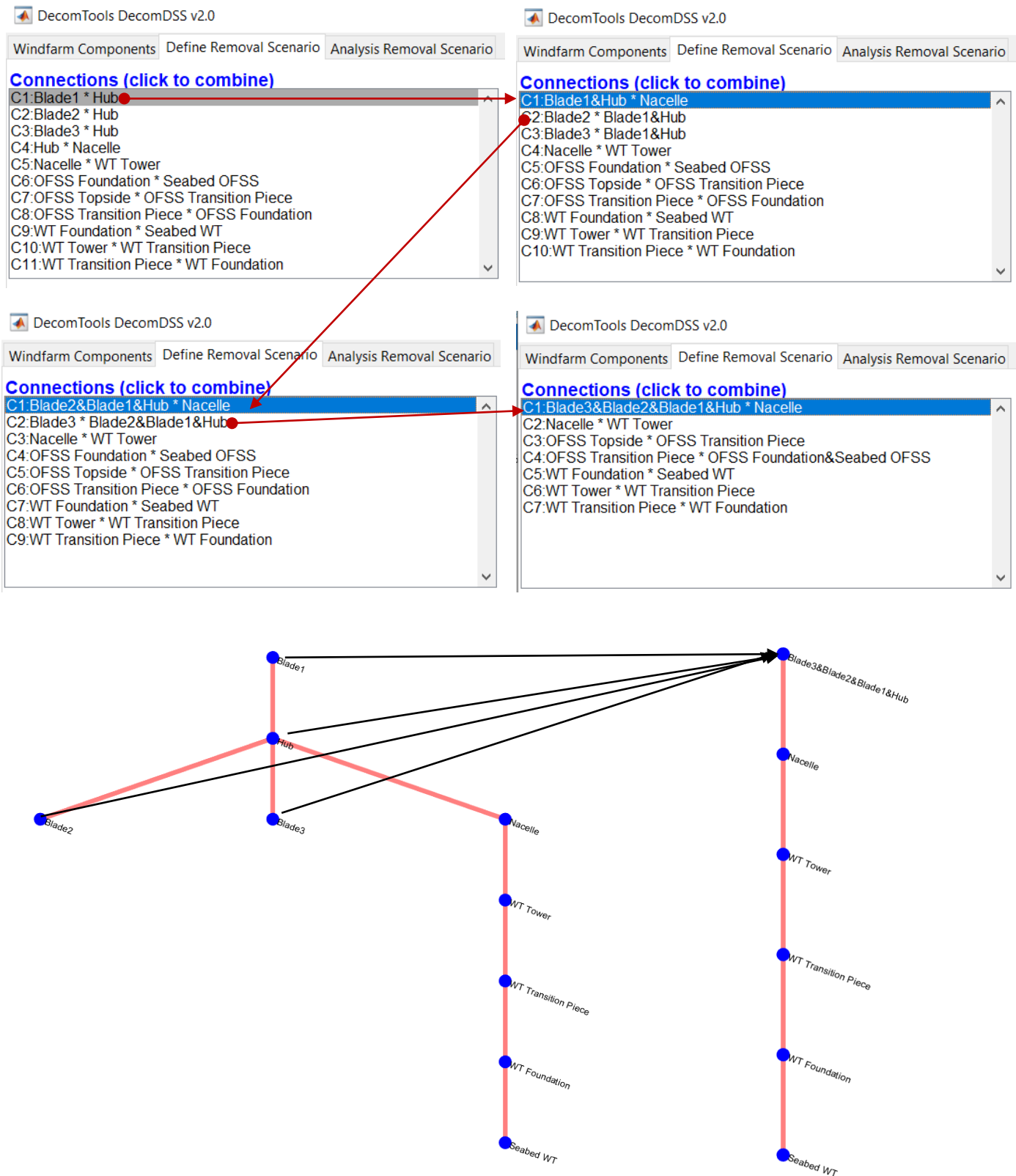


Figure 13- Defining removal scenario of complete removal of wind turbines and substations, in which the rotor is removed with one cut and lift operation.

The removal scenario of ‘*Partial removal of substations leaving foundations in situ and completed removal of wind turbines*’. In this scenario offshore substation foundation ‘**OFSS Foundation**’ is combined with the offshore substation seabed ‘**Seabed OFSS**’ to make one component ‘**OFSS Foundation& Seabed OFSS**’, hence remains in situ.

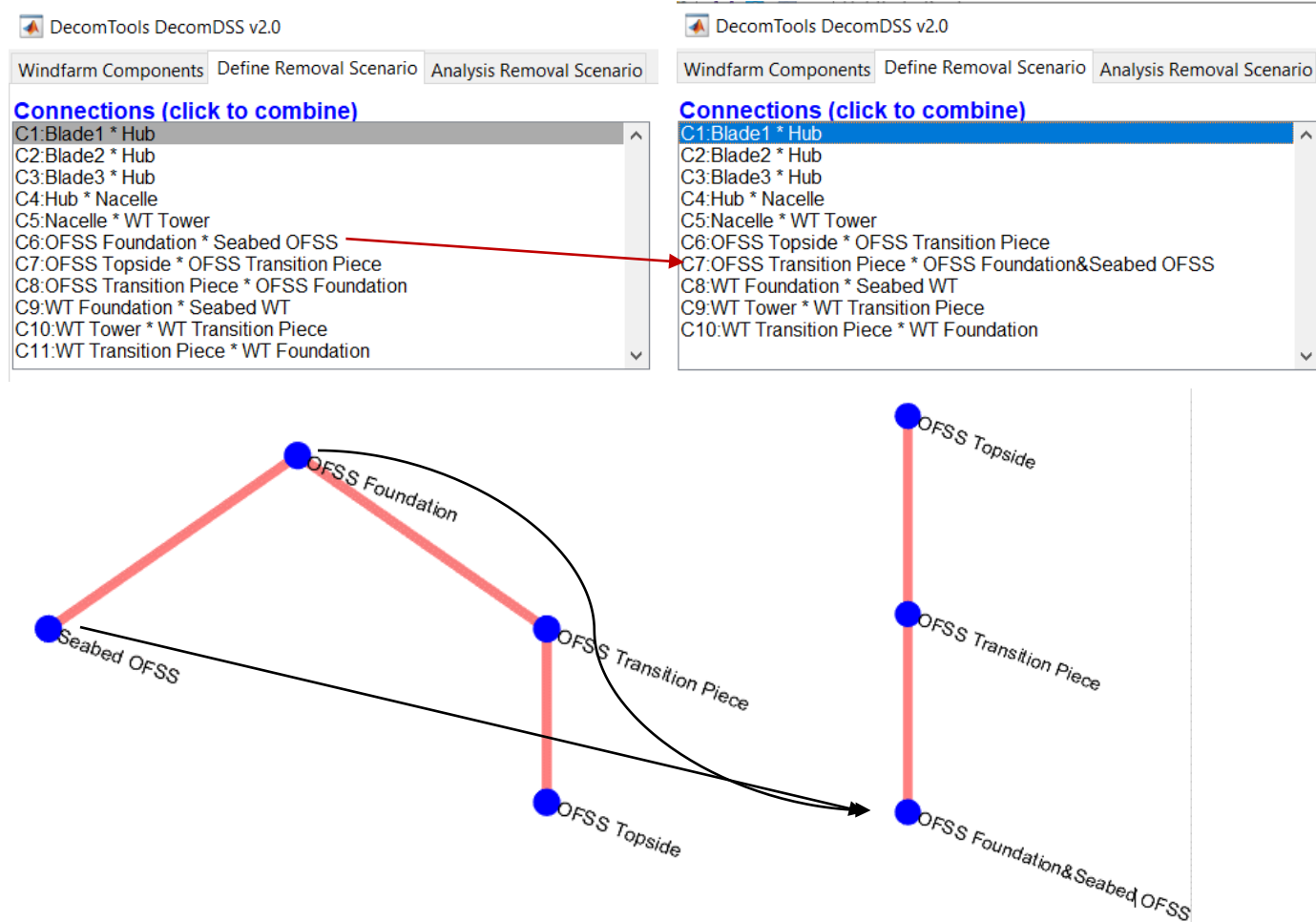


Figure 14- Defining removal scenario of partial removal of substations leaving foundations in situ and completed removal of wind turbine.

3.3 Cut Method

Cut Method section allows the user to define different removal scenarios by selecting different cutting methods, if available. For instance, in the Windfarm file of Figure 11, two methods of **Unbolt** and **Plasma Cut** are defined for separating **WT Tower** from **WT Transition Piece** (see Figure 15 below).

It should be noted that in Cut Method list-box all connections with more than one available cut methods are identified by '>>'. By clicking on connections identified by '>>' in Cut Method list-box, a question box appears asking the user to choose one of the available cut methods (see Figure 15 below).

The numbers shown in front of each cut method are the dimensions and sizes which are defined as attributes of connections in the Windfarm file. These values are used for calculating the removal time and from there the overall time, cost and emission. The user can override/edit these values in the third Tab ‘**Analysis Removal Scenario**’ as explained in Section ***.

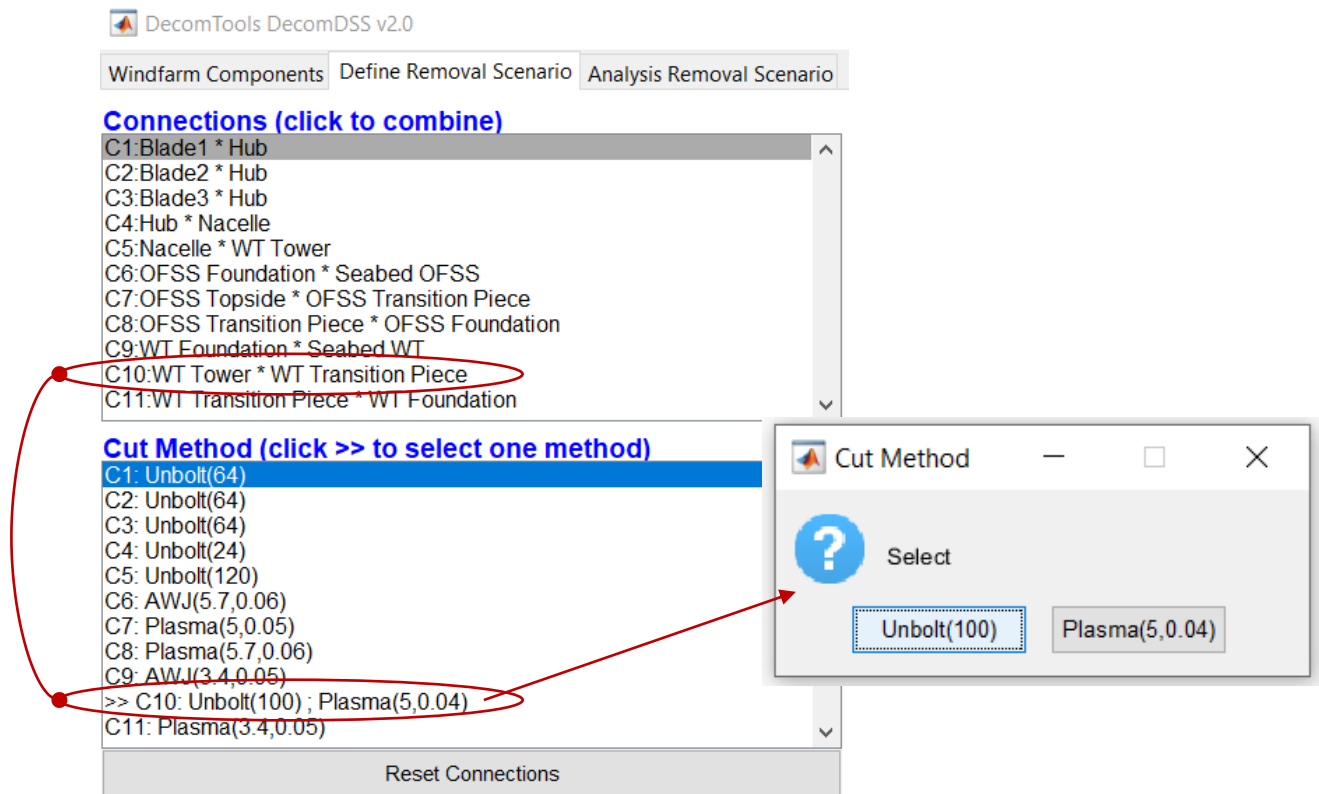


Figure 15-Selecting one cut method when more than one is available.

3.4 Cut & Lift Order

After defining a scenario and selecting cut methods, the user needs to use the 'Cut & Lift Order' list-box to generate a logical order for the removal (cut and lift) events. This can be done simply by clicking on the items in the list-box and moving them up in the list.

Once the user is finished with defining a removal scenario, selecting the cut methods, and putting the operations in a logical order, they need to click on 'Check Removal Scenario' button which runs a check for the scenario and prompts errors and warnings if the removal scenario is not defined properly. Figure 16 shows the errors and warnings that are prompt if the user clicks the 'Check Removal Scenario' button without selecting a single cut method, the order is not logical, there is a missing data in the Windfarm file, or the weight of component (or an assembly) to be lifted is greater than the crane capacity. In this figure, the Cut & Lift order is not logical (logical in green illogical in red): Blade1, Blade2, Blade3, Hub, Nacelle, OFSS Foundation, OFSS Topside, OFSS Transition Piece, WT Foundation, WT Tower, WT Transition Piece.

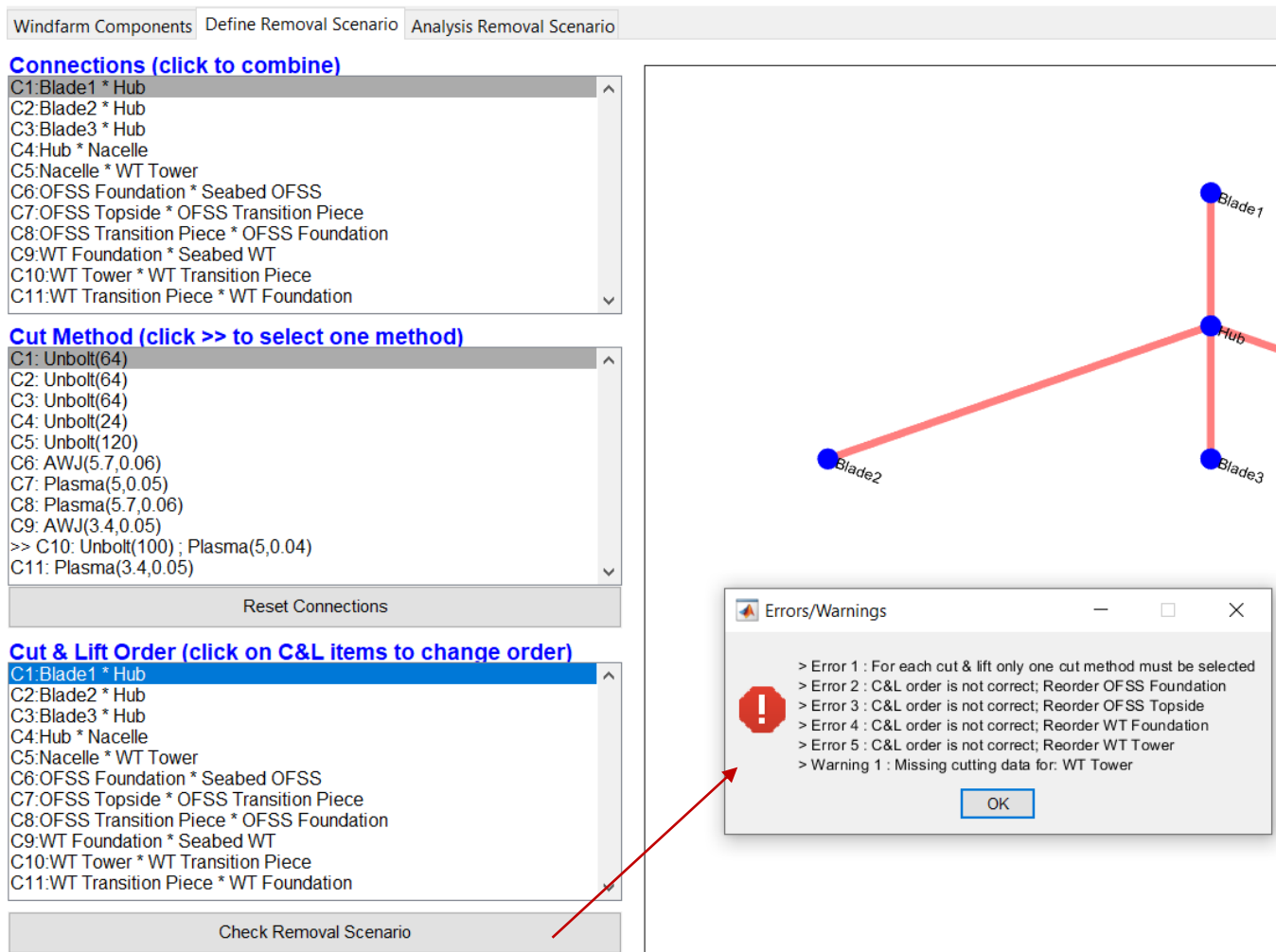


Figure 16-Checking the defined removal scenario.

Figure 17 shows a valid removal scenario after selecting 'Unbolt' as the separation method of WT Tower and WT Transition Piece and after rearranging the Cut & Lift Order to Blade1, Blade2, Blade3, Hub, Nacelle, WT Tower, WT Transition Piece, WT Foundation, OFSS Topside, OFSS Transition Piece, and OFSS Foundation. By clicking 'Check Removal Scenario' button, the software activates the third tab '**Analysis Removal Scenario**'.

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Windfarm Components Define Removal Scenario Analysis Removal Scenario

Connections (click to combine)

- C1: Blade1 * Hub
- C2: Blade2 * Hub
- C3: Blade3 * Hub
- C4: Hub * Nacelle
- C5: Nacelle * WT Tower
- C6: OFSS Foundation * Seabed OFSS
- C7: OFSS Topside * OFSS Transition Piece
- C8: OFSS Transition Piece * OFSS Foundation
- C9: WT Foundation * Seabed WT
- C10: WT Tower * WT Transition Piece
- C11: WT Transition Piece * WT Foundation

No error: no weight is greater than the crane capacity.

Cut Method (click >> to select one method)

- C1: Unbolt(64)
- C2: Unbolt(64)
- C3: Unbolt(64)
- C4: Unbolt(24)
- C5: Unbolt(120)
- C6: AWJ(5.7,0.06)
- C7: Plasma(5,0.05)
- C8: Plasma(5.7,0.06)
- C9: AWJ(3.4,0.05)
- C10: Unbolt(100)
- C11: Plasma(3.4,0.05)

No error: only one cut method is assigned to each connection.

Reset Connections

Cut & Lift Order (click on C&L items to change order)

- C1: Blade1 * Hub
- C2: Blade2 * Hub
- C3: Blade3 * Hub
- C4: Hub * Nacelle
- C5: Nacelle * WT Tower
- C10: WT Tower * WT Transition Piece
- C11: WT Transition Piece * WT Foundation
- C9: WT Foundation * Seabed WT
- C7: OFSS Topside * OFSS Transition Piece
- C8: OFSS Transition Piece * OFSS Foundation
- C6: OFSS Foundation * Seabed OFSS

No error: cut & lift operations have a logical order: Blade1, Blade2, Blade3, Hub, Nacelle, WT Tower, WT Transition Piece, WT Foundation, OFSS Topside, OFSS Transition Piece, OFSS Foundation

Check Removal Scenario

When there is no error, clicking this button activates the Analysis Removal Scenario tab.

Figure 17- A valid removal scenario.

4 Analysis Removal Scenarios

Once a removal scenario is defined and its validity was checked by the software, the Analysis Removal Scenario tab is activated as shown in Figure 18. The table has 9 columns, showing the name and mass of components to be removed, cut method, connection dimensions (or number of bolts, where applicable), removal speed, positioning time, removal time, the number of that component in the windfarm, and barge vessel capacity if loaded by that component only. The table is populated using the inputs in the previous tab for defining removal scenario, the built in models for calculating cutting speed, and the data in the Windfarm file.

Connection dimensions (or number of bolts, where applicable) can be edited by the user. Removal speed is calculated using these data and the built-in models. The user can override these values as well. Positioning time, although populated by some default values, strongly depend on the logistic and the user needs to edit the default values for the project at hand.

The data in barge vessel capacity column are also based on the data in the Windfarm file, but the user can override and edit the data before calling for a deterministic analysis. Clicking the **Deterministic Analysis** button calls the cost and emission models developed for this software [2], [3] and [4] and calculate the total removal time (in days), total number of tugboat/ barge vessel trips to shore for unloading the decommissioned parts, and the total cost and CO₂ emission of the removal operation.

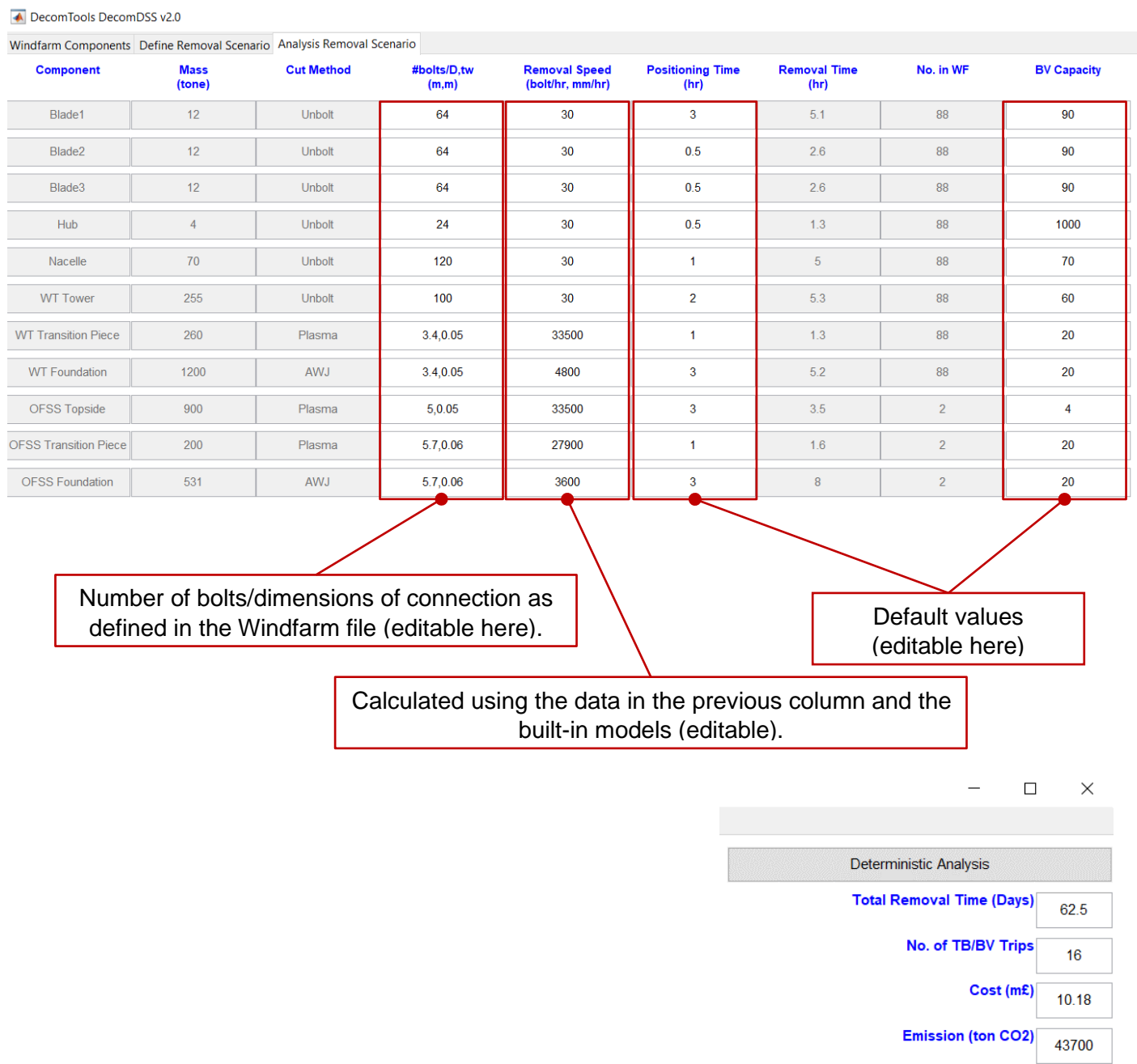


Figure 18- Analysis Removal Scenario tab

References:

- [1] Shahin Jalili, Alireza Maheri, Ana Ivanovic (2022) 'Cost and Emission Analyses of Decommissioning of Offshore Wind Farms Using Reverse Installation Method: Cases of Lincs Limited, Gunfleet Sands, and Horns Rev I Wind Farms', DecomTools deliverable available from [DecomTools, Interreg VB North Sea Region Programme](#)
- [2] Shahin Jalili, Alireza Maheri, Ana Ivanovic (2022) 'Cost Modelling for Offshore Wind Farm Decommissioning', DecomTools deliverable available from [DecomTools, Interreg VB North Sea Region Programme](#)
- [3] Alireza Maheri , Shahin Jalili (2021), 'A Decision Support System for Decommissioning of Offshore Windfarms: The Data Platform, IEEE Explore <https://doi.org/10.1109/EFEA49713.2021.9406248>
- [4] Callum Milne, Shahin Jalili, Alireza Maheri (2021), 'Decommissioning cost modelling for offshore wind farms: A bottom-up approach', Sustainable Energy Technologies and Assessments, vol. 48, 101628, <https://doi.org/10.1007/s00521-021-06519-0>