Simulation Analysis

Comparison of various logistical concepts for offshore wind farm decommissioning

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List of Abbreviations

CLV	Cable Laying Vessel
DecomToolV	DecomTools Vessel
DES	Discrete Event Simulation
FV	Feeder Vessel
F_PbP	Feeder Part-by-Part
F_BunnyEar	Feeder Bunny Ear
F_Star	Feeder Star
HR1	Horns Rev 1
IV	Installation Vessel
MM	MetMast
OHVS	Offshore High-Voltage Substation
OWF	Offshore Wind Farm
OWT	Offshore Wind Turbine
P_PbP	Pendulum Part-by-Part
P_BunnyEar	Pendulum Bunny Ear
P_Star	Pendulum Star
WTIV	Wind Turbine Installation Vessel

1 Introduction

Most wind turbines are designed and certified for a service life of 20 to 25 years. After this period they must be decommissioned or have their accredited service life extended, often accompanied by repowering. While procedures for decommissioning and repowering of onshore wind farms are known, experience with offshore wind farms (OWF) is limited. There is no overall sustainable end-of-life approach to OWF. The transnational project "*DecomTools*" closes this gap by developing eco-innovative concepts, green products and various demonstration pilots in the areas of logistics, safety, vessel design as well as in up- and recycling. These new innovations help the entire industry to achieve a better eco-balance.

The pioneer OWFs in the North Sea Region are increasingly reaching the critical stage. The market analysis developed by Kruse (2019) shows that two decommissioning cycles can be expected in the North Sea region in the coming years. The first cycle with a smaller number of wind turbines to be decommissioned is already ongoing. The second cycle will start at the end of this decade, with a large amount of wind turbines to be decommissioned in almost all North Sea littoral states. While the first cycle is as a test case for different decommissioning strategies, the high volumes in the second cycle require mature solutions. To have enough preparation time, detailed simulations and analysis are need to be addressed now to define sustainable decommissioning logistic strategies.

This simulation analysis is based on the simulation models created in work package 5, deliverable 2. The models were created with the software "Plant Simulation" (Version 16) from Siemens. This is a "Discrete Event Simulation Software" for modeling, simulation and analysis of logistic systems (Siemens, 2022). Discrete Event Simulation (DES) is a simulation method for representing real systems, which can be divided into logical, temporally subdivided or sequential processes (Allen M, 2015). In the course of the development work, eight different simulation models were developed and implemented, which concretize different logistics strategies and dismantling configurations. These are presented in more detail below, including their results and their generated data. In addition to the dismantling of the offshore wind turbines, all models also include associated processes such as the pre-decommissioning activities, the removal of the offshore cables, and the dismantling of the MetMast (MM) as well as the offshore high-voltage substation (OHVS).

2 Offshore Logistic Strategies and Dismantling Configurations

A logistics strategy can be defined as a set of principles, settings and factors to consider planning, goals and relationships along a supply chain (Hill, 2017). The supply chain of offshore decommissioning can be divided into five different steps.

The first step is the offshore operation or are scenarios to decommission an OWT. Regarding the dismantling scenarios, three configurations can be identified. The product process model in Figure 1 shows the main components of offshore wind turbines and the configurations in which they can be dismantled. These dismantling configurations represent the (offshore) base of the developed simulation models.

The Star configuration describes the dismantling of the entire rotor including the three blades and the hub, followed by the nacelle, tower and substructure. The next operation involves the dismantling of the remaining two rotor blades, including the hub and the nacelle. The final dismantling operation consists of the removal of the substructure. In both removal configurations, 4 lifting operations are required.

The part-by-part removal provides a step-by-step dismantling of the individual components. The rotor blades are removed individually, followed by the nacelle incl. hub, tower and substructure, resulting in 6 lifting operations.

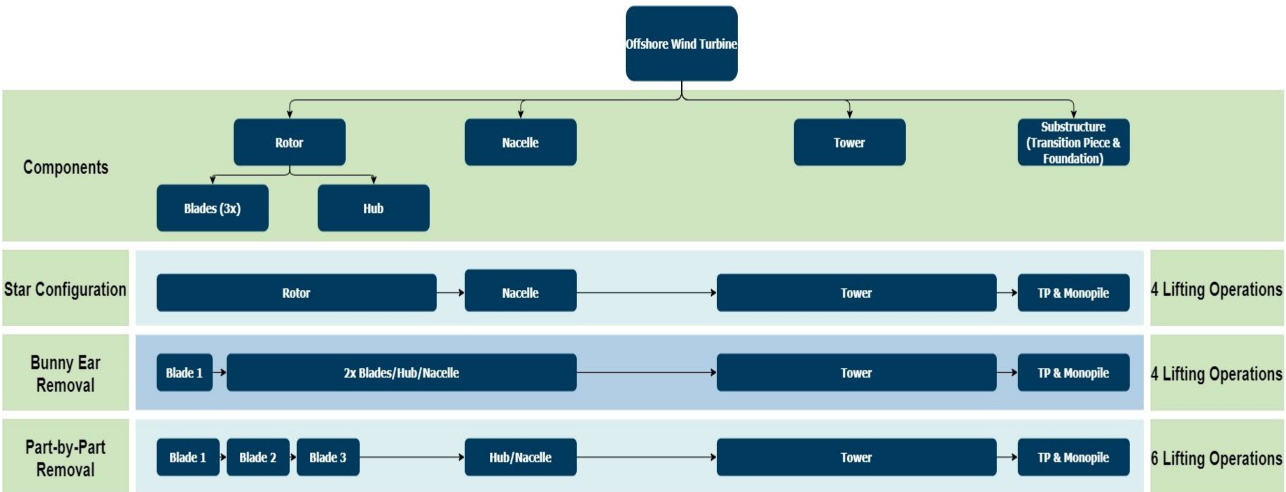


Figure 1: Product-Process-Model of main configurations for the dismantling process

In the second step, the dismantled components of a wind turbine are transported to the port. In terms of the supply chain for offshore decommissioning, two main logistics strategies can be defined: the pendulum system and the feeder system. The pendulum system describes a ship shuttle service between a port and the OWF. Here the installation vessel also performs the transport of the decommissioned components to the port. In the feeder system, on the other hand, the Installation-Vessel remains at the wind farm and a smaller vessel (feeder vessel) transports the components to the port.

At the port, the wind turbine components are unloaded and processed into smaller elements and prepared for further transport on shore in a third step. In the fourth step the materials are then transported to the hinterland by truck or rail to the recycling facilities, where the wind turbine components are recycled or repurposed in the final step.

3 The Logistic Simulation Model of the entire supply chain

To obtain useful optimization potential for decommissioning logistics, the offshore logistics strategies and dismantling configurations described in Chapter 2 have been mapped into different Plant Simulation Networks.

For clarity, the models consist of several networks. These are PlantSimulation modules, which enable the hierarchically structured construction of models.

The main network contains six subnetworks. These include the network for the offshore wind farm, a network for saving the simulation results, and four port networks.

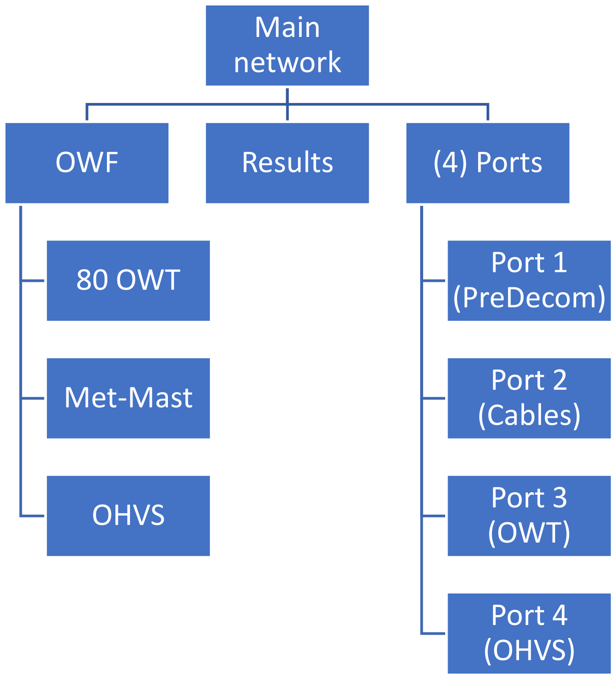


Figure 2: Network Levels

The OWF network is further composed of 82 subnetworks. Of these, 80 networks each represent one OWT. The remaining two networks represent the MetMast and the OHVS.

While the MM and OHVS networks are divided into topside and substructure removal, the OWT networks contain several process steps. These process steps are analogous to the dismantling configurations described in the previous chapter.

The offshore dismantling process is generally divided into several phases in which different types of vessels are used.

The pre-decommissioning stage comprises all activities to prepare the construction site for dismantling. This includes, for example, the seabed survey, the removal of hazardous materials and the removal of the wind turbines from the grid, including the cutting operations of cables and the installation of buoys at the cut ends. The second phase involves the recovery of all offshore cables (Inner Array Cables and Export Cable). This is followed by the dismantling of the wind turbines, the MetMast and the OHVS (Figure 3).

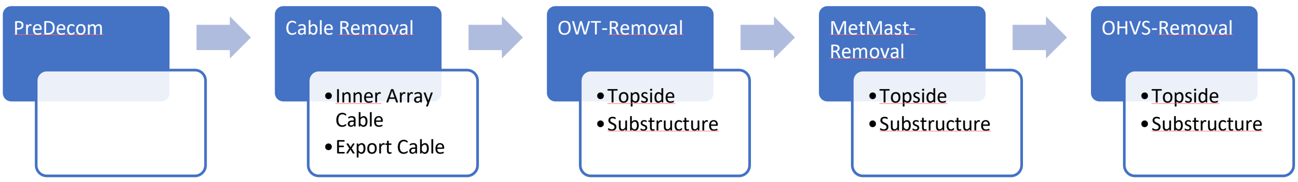


Figure 3: Offshore Process Overview

In addition to the offshore logistics, the simulation models also depict the onshore handling of the components. To consider different ports in terms of their activities and their geographical location a generic port-network was established. It consists of several sub-networks which are divided into “PreDecommissioning”, “Cable Removal”, “OWT Removal” and “OHVS Removal”. Accordingly, their operating principle and structure are similar. The components are unloaded from the ships, transported to a laydown area, and distributed further. They are then dispensed either to a station for further disassembly or for direct preparation for inland transportation by barges and trucks.

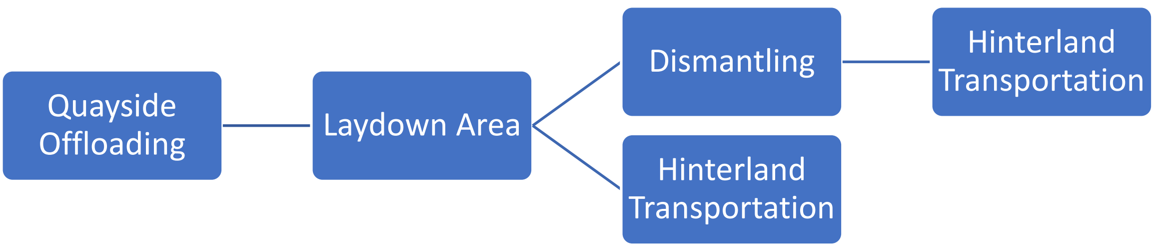


Figure 4: Onshore Process Overview

The results-network stores all data generated during the simulation. This information includes transit times, costs, and CO_2 emissions along the entire supply chain as well as more specific information on start and end times of the individual process phases including standby, transit and working times, etc.

4 Input Parameters and Model Descriptions

In the following chapter, the different input parameters of the simulation models will be specified in more depth. Furthermore, the models are considered in detail with regard to their structure and their special features.

4.1 Input Parameters

In terms of parameters, a large number are taken into account, which will be described in more detail in the following.

The wave height and the wind speed are to be mentioned as the main variables of weather influence on the offshore dismantling process. Our basis for this are data sets from the Danish Coastal Authority. The Danish Coastal Authority, which has positioned several sensors along the Danish North Sea coast, collects weather and wave information.

Based on these values, wind and wave information was defined in a 24-hour format for about 2 years (2018 and 2019) and used as a basis for the simulation.

All deployed vessels can be assigned specific attributes in advance via a table.

These attributes include day rates, fuel consumption in various modes, and speeds. The day rates plus fuel costs (average 650 €/ton at the time of simulation), average speeds and permissible wave heights and wind speeds are listed as examples in Table 1 and Table 2 for the Base Study.

It should be noted at this point that, as part of the project, consideration was given to possible optimized vessels in the dismantling process. In this context, a ship model was developed, which can be used both as a feeder vessel as well as a (de-)installation vessel. For example, it would be capable of recovering the cables and removing the monopiles as well as storing dismantling segments of the offshore wind turbines, taking into account the CO_2 emissions.

For a deeper insight, please refer to the document titled "DecomTools Vessel Design – An Eco-Sustainable approach to Decommission Offshore Wind Farms by designing a New Ship, new tools and efficient and reliable procedures" on the DecomTools project homepage.

Table 1: Vessel Information - Day rates, Speeds, Max. Wave Heights and Wind Speeds

Stage	Vessel	Day rate [€]	Average Sailing Speed [kn]	Average Infield Speed [kn]	Max. Wave Height [m]	Max. Wind Speed [kn]
PreDecom	Survey-Vessel	100,000	10	1	3	20
Cable Removal	CLV	150,000	10	1	3	20
OWT-Removal	WTIV	200,000	10	1	4	15-20
	FV	50,000	10	1	-	-
OHVS-Removal	IV	200,000	5	1	3	30
	FV	50,000	10	1	-	-

Table 2: Vessel Information - Fuel Consumption in different modes

Stage	Vessel	Fuel Consumption [t/d]			
		Sailing	Operational	Standby	Mobilization
PreDecom	Survey-Vessel	10	4.0	2	0
Cable Removal	CLV	12	10.0	4	0
OWT-Removal	WTIV	16	6.0	4	8
	FV	10	7.5	2	0
OHVS-Removal	IV	16	6.0	4	8
	FV	10	7.5	2	0

The dismantling times in the simulation models are essentially based on the erection times. They were also assigned to the deployed vessels in the form of attributes. For the baseline study, which is based on the Horns Rev 1 wind farm, an erection time and therefore also the deconstruction time of about six days per wind turbine was determined. (Roberto Lacal-Arántegui, 2018)

The Dismantling of OHVS-Topside is estimated to take two days and the removal of the OHVS-Substructure is also estimated to take two days.

Additional process times for different configurations on which the models are based on can be found in Table 3.

Table 3: Dismantling times of OWT through different configurations

Dismantling component	Dismantling time of different configurations [d]		
	Bunny-Ear	Part-by-Part	Star
Hub/Nacelle/2Blade	1.21	-	-
Blade	0.25	1.00	-
Rotor	-	-	0.71
Nacelle	-	1.00	1.00
Tower	1.21	1.00	1.00
Substructure Removal	3.17	3.18	3.18
Total Removal Time	5.84	6.18	5.88

The onshore parameters include the offloading times of the individual components at the quay, the transfers from the quay to the designated laydown area using parameterized means of transport, dismantling times and the transport to the hinterland by barge or truck including the respective distances.

Table 4 displays the duration and offloading of the wind turbine components through different configurations.

Table 4: Offloading and onshore dismantling times through different configurations

Component	Part-by-Part		Bunny-Ear		Star	
	Offloading Time in h	Dismantling Time in d	Offloading Time in h	Dismantling Time in d	Offloading Time in h	Dismantling Time in d
Blade	2	0.67	2	0.67	-	-
Hub/Nacelle /2Blade	-	-	4	14	-	-
Rotor	-	-	-	-	4	2
Nacelle	4	10	-	-	4	10
Tower	4	2	4	2	4	2
Substructure	4	3	4	3	4	3

Table 5 shows the removal (offshore), offloading and onshore dismantling durations for inner array cables and the export cable.

Table 5: Duration of cable removal, offloading time and onshore dismantling time

Component	Inner Array Cable Removal	Export Cable Removal
Days per 1 km	1	1
Offloading time in h	24	24
Dismantling time in d	10	25

The offloading and onshore dismantling durations for OHVS are displayed in Table 6.

Table 6: Offloading and onshore dismantling duration - OHVS

Component	OHVS (Topside)	OHVS (Substructure)
Offloading Time (h)	6	6
Dismantling Time (d)	56	14

Table 7 depicts the different relevant routes and onshore distances

Table 7: Onshore distances

Route	Distance (km)
Quayside ↔ Laydown Area	0.5
Port ↔ Hinterland (Street)	50.0
Port ↔ Hinterland (Waterway)	100.0

The Laydown costs per square meter comes to 0.5 €. Expenses for internal port transportation are composed of a daily rate and fuel consumption. A day rate of 4,5000 € and an average fuel consumption of 35 t per day are expected.

Table 8 shows the Onshore means of transport, fuel consumption and transport costs.

Table 8: Onshore Means of Transport (Generic)

Vehicle	Costs per 1km (€)	Fuel Consumption per 1km (t)
Truck	25	0.3
Inland Vessel	20	0.1

4.2 Basestudy

The base study concretizes the wind farm Horns Rev 1, consisting of 80 OWT, one MetMast, one OHVS, around 40 km inner array cables and 22 km export array cables. This wind farm has been installed about 20km off the Danish coast, west of Esbjerg.

During the baseline study, one vessel was simulated for pre-decommissioning activities, one for cable recovery, three installation vessels and one feeder vessel.

Unlike the other models, it should be emphasized that both the pendulum and feeder systems were used for the erection of HR1. The OWT foundations were placed in the feeder system. The installation vessel remained in the wind farm for this period, while the smaller transport vessel brought the monopiles to the wind farm (MTHojgaard, 2010, S.18; Vattenfall, 2014). In the further course, the OWT top structures (tower, hub, rotor blades) were installed in the Pendulum system. In this phase, two installation ships were used, each carrying 2 turbine sets in the bunny-ear configuration (Modern Powern Systems, 2005).

Analogous to this erection, the dismantling of the wind farm is realized in reverse order in this base line scenario. The first steps include the pre-decommissioning activities and the disconnection of the wind turbines from the power grid. To reduce the risk of jacking operations in the wind farm, the next step is to remove all cables. Subsequently, two vessels will dismantle the topsides of the OWT followed by an installation vessel and a FV for the purpose of dismantling and salvaging the foundations including the transition pieces. The last stage is the dismantling of the OHVS. Again, the topside will be dismantled first before the foundation can be removed.

The onshore processes start as soon as the first components are unloaded at the quayside. These include onward transport to the designated laydown area, from where the components are further distributed. For the portside onshore process, costs for storage are calculated in the simulation, in the same way as CO2 emissions and costs of the transport carriers used. Unfortunately, further cost structures could not be integrated due to the sensitivity of the data. There are two main options for the stored components, either they are further dismantled or transported on as "complete components". The transports to the hinterland are carried out via barge and/or truck depending on the respective capacity of the transport carrier. The assumed costs and fuel parameters can be seen in table 8 of the previous chapter.

4.3 Pendulum-Systems: Part-by-Part-, Bunny-Ear- and Star-Configuration

The logistics simulations of the Pendulum systems are similar to the baseline study, the main parameters, such as number of wind turbines, fuel consumptions, distances, etc. are the same.

The parameters of the simulated ships are also identical. These include the process times, the fuel consumptions, vessel speeds etc. Further, the simulated WTIV was able to carry 2 complete Sets of OWT, analogous to the vessels used in the base study.

However, one major difference is the total number of ships. Since primarily installation vessels are used to shuttle between the wind farm and the port, there are no feeders here, except for the OHVS-Removal.

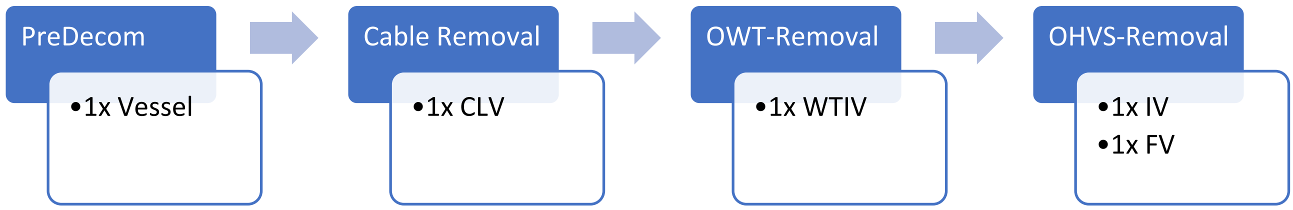


Figure 5: Pendulum-Systems: Stages and simulated Vessels

In addition, the pendulum models assume only one installation vessel, which dismantles the turbines, and not two vessels as in the base study.

On the process level, the pre-decommissioning activities are followed by the removal of the submarine cables. In the next steps, the turbines are dismantled. In the part-by-part configuration, the components are dismantled as individual parts. This results in 6 lifting operations (3x blade, 1x nacelle, 1x tower, 1x substructure). For the bunny-ear configuration and the star configuration, there are 4 lifting operations each. The different dismantling times can be seen in Table 3. The final steps include the disassembly of the OHVS.

With the arrival of the first dismantled components in the port, the onshore processes start here as well. After storage in the laydown area, possible further disassembly occurs. The onshore dismantling times of the respective components differ in the individual dismantling configurations. For example, dismantling the rotor is more time-consuming than dismantling individual rotor blades, which can be seen in Table 4.

4.4 Feeder-Systems: Part-by-Part-, Bunny-Ear and Star-Configuration

In the feeder models, the main parameters regarding the OWF and the ships used are the same as in the baseline study. The total number of ships used in the different phases of the dismantling process along the supply chain is also lower here than in the baseline study. For the OWT dismantling process, only one installation vessel including one FV is thus simulated in these models, as it is shown in the figure 6 below.

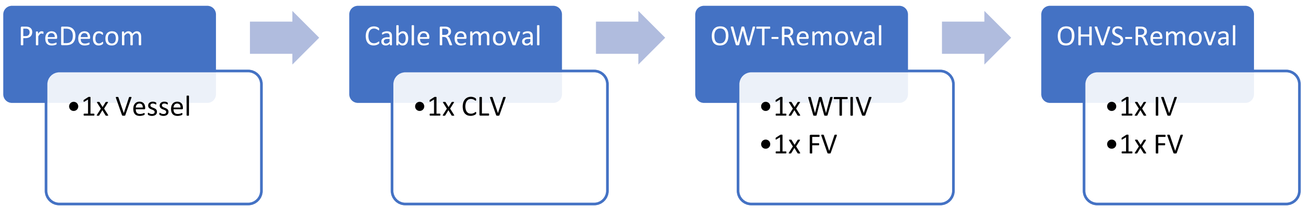


Figure 6: Feeder-Systems – Stages and simulated Vessels

During the OWT dismantling, the installation vessel remains in the wind farm. The dismantled components are brought to the port by the FV.

The land-based processes related to handling, storage, dismantling and onward transportation start when the feeder vessel reaches the port. In the port itself, after storage, the components are dismantled or further transported to the hinterland by simulated truck and barge transports.

5 Results and discussion

In the following chapter, different scenarios are presented with regard to their effects on runtime, costs and CO2 emissions. The results are presented in a separated form. On the one hand, the entire supply chain is observed and, on the other hand, explicitly the offshore processes for dismantling wind farms.

5.1 Scenarios with increasing distances for Complete Supply Chain

In the following, the impacts of parametric changes (here: distance to coast) for the whole supply chain are presented and the different configurations described above are compared.

5.1.1 Runtime

Figure 7 shows the average runtime of different configurations as a function of increasing distances. The baseline study curve ranges from a value of 618 days at 18 kilometres to a value of 1050 at 250 kilometres. The values of this curve remain lower over the increase in distance than the other compared configurations. The feeder Bunny Ear and the feeder Star configuration have the same curve progression. The pendulum Bunny Ear and pendulum Star configuration have a similar curve progression and differ only by about 30 days throughout the increasing distances. Pendulum Part-by-Part and feeder Part-by-Part start with very similar values but diverge towards the end, with feeder Part-by-Part having the lower runtime. The DecomTool vessel (DecomToolV) has the closest runtime compared to the base study. The curve starts with lower values than the feeder Bunny Ear and feeder Star configurations, intersects at 250 kilometres and then rises above the average runtime of the other two configurations. Up to a distance of 250 kilometres, the DecomToolsV comes closest to the base study, which has the lowest average runtimes.

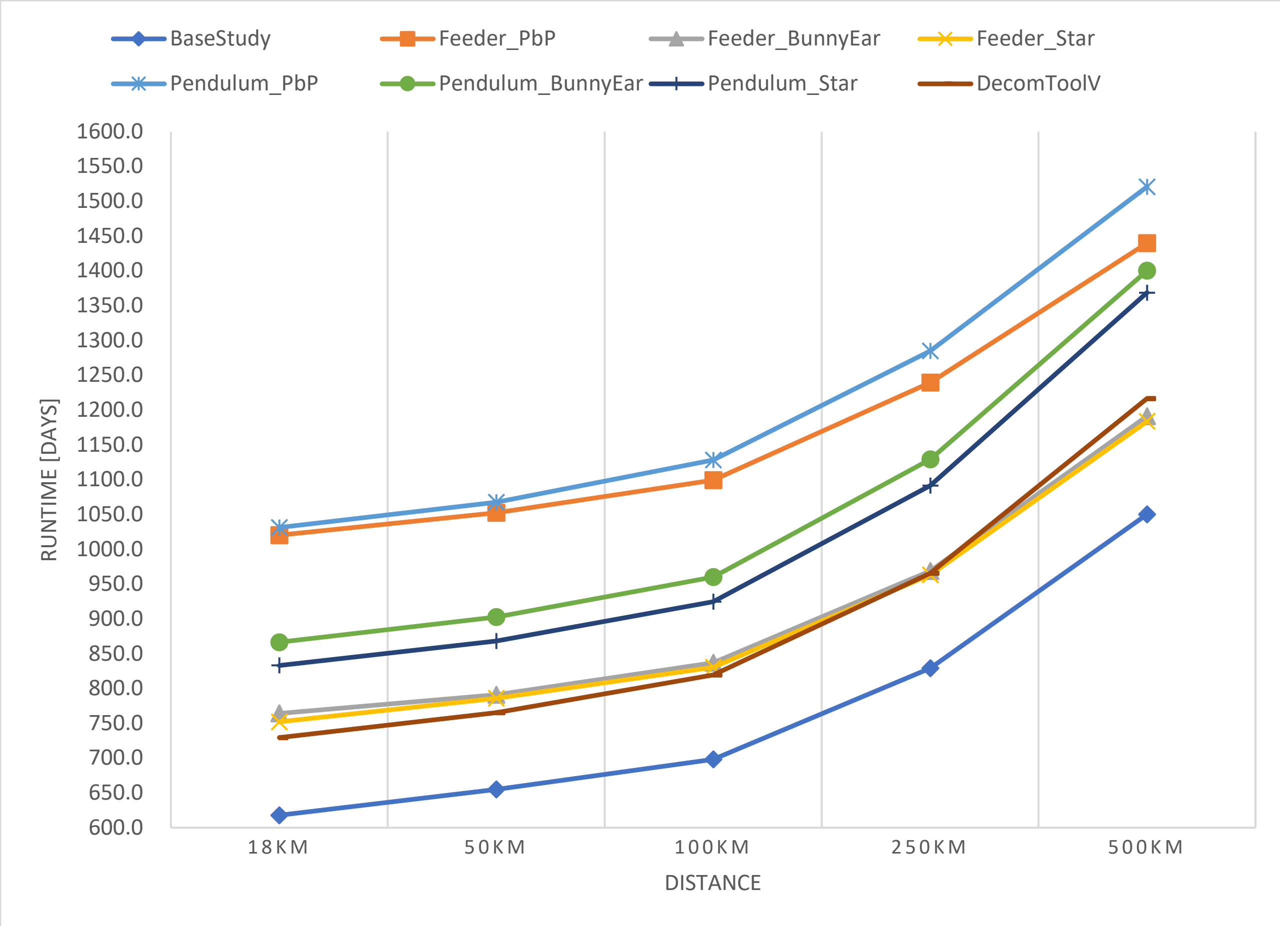
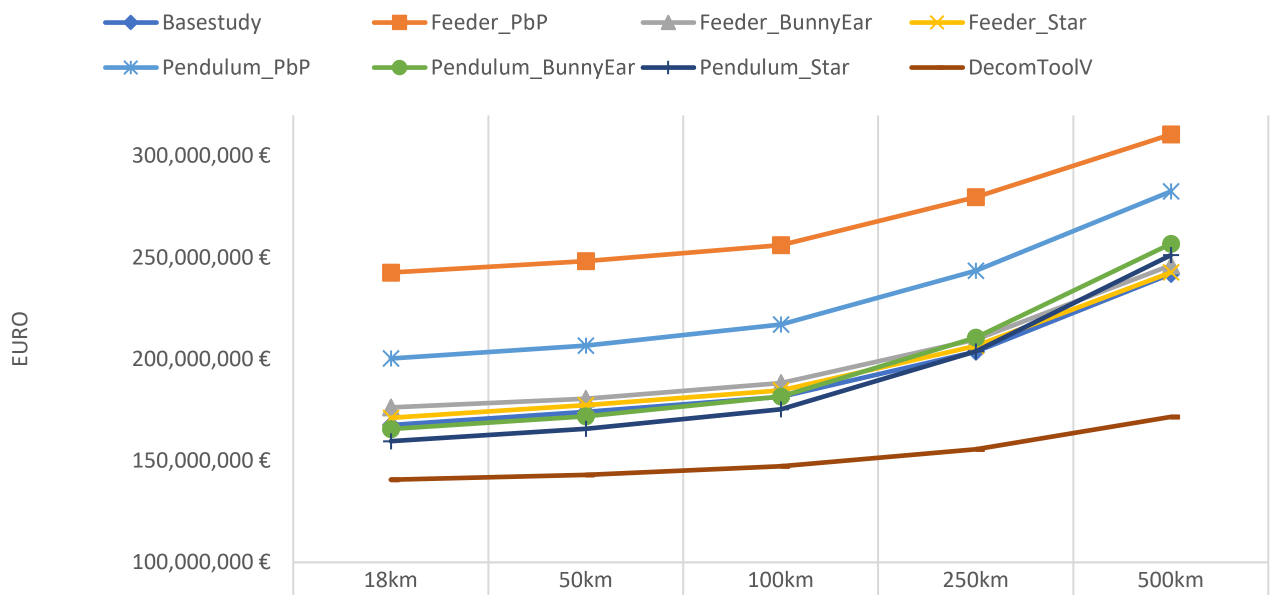


Figure 7: Parameter with increasing distances for Complete Supply Chain – Average Runtime in days

5.1.2 Costs

Figure 8 shows the average costs of different configurations as a function of increasing distances. The configurations feeder Bunny Ear, feeder Star, pendulum Bunny Ear, pendulum Star and base study all move in a very similar curve progression. From this group, Pendulum Star is the cheapest variant, which intersects with the other curves at 250 kilometres and then runs more expensive than the base study. The feeder part-by-part configuration is also significantly more costly than the other logistics systems for longer distances. Above a distance of 100 km, the Feeder Bunny Ear and Feeder Star systems generate costs roughly similar to those of the base study. The pendulum part-by-part configuration is in average about 30 Mio. € higher than the base study. The DecomToolsV turns out to be the cheapest configuration with a margin of 20,000,000 € from the grouping.



	18km	50km	100km	250km	500km
Basestudy	167589713.903 €	174138109.688 €	181465639.208 €	203668112.569 €	241929536.293 €
Feeder_PbP	242648496.726 €	248251874.484 €	256163682.484 €	279698202.625 €	310584843.180 €
Feeder_BunnyEar	176263250.776 €	180594402.831 €	188256602.40 €	209716742.481 €	246191181.335 €
Feeder_Star	171149363.874 €	177426219.303 €	184697608.360 €	206589644.274 €	242686390.072 €
Pendulum_PbP	200342438.319 €	206633046.376 €	217108011.251 €	243580322.471 €	282560904.082 €
Pendulum_BunnyEar	165638388.709 €	171864078.769 €	181629124.115 €	210628464.052 €	256766511.703 €
Pendulum_Star	159646689.085 €	165666853.115 €	175277892.825 €	203838066.134 €	251187511.624 €
DecomToolV	140684107.150 €	143126067.244 €	147271032.611 €	155706600.176 €	171601182.804 €

DISTANCE

Figure 8: Parameter with increasing distances for Complete Supply Chain – Average Costs in €

5.1.3 CO_2-Emissions

Figure 9 shows the average CO_2-Emissions of different configurations as a function of increasing distances.

The lowest CO_2 emissions are emitted by the pendulum Star, pendulum Bunny Ear and DecomToolV configurations. The curves of these pendulum configurations initially run lower than DecomToolV, intersect it at 100 km. The curve of the DecomToolV runs relatively constant, but rises slightly more after 250 km. Pendulum Part-by-Part and the base study have a similar curve progression. They intersect at 100 km after which the pendulum configuration emits more CO_2 than the base study. Feeder Bunny Ear and feeder Star have a higher CO_2 emission than the before mentioned configurations. Feeder Part-by-Part has the highest CO_2 emissions ranging from 40,000 to over 50,000 tons.

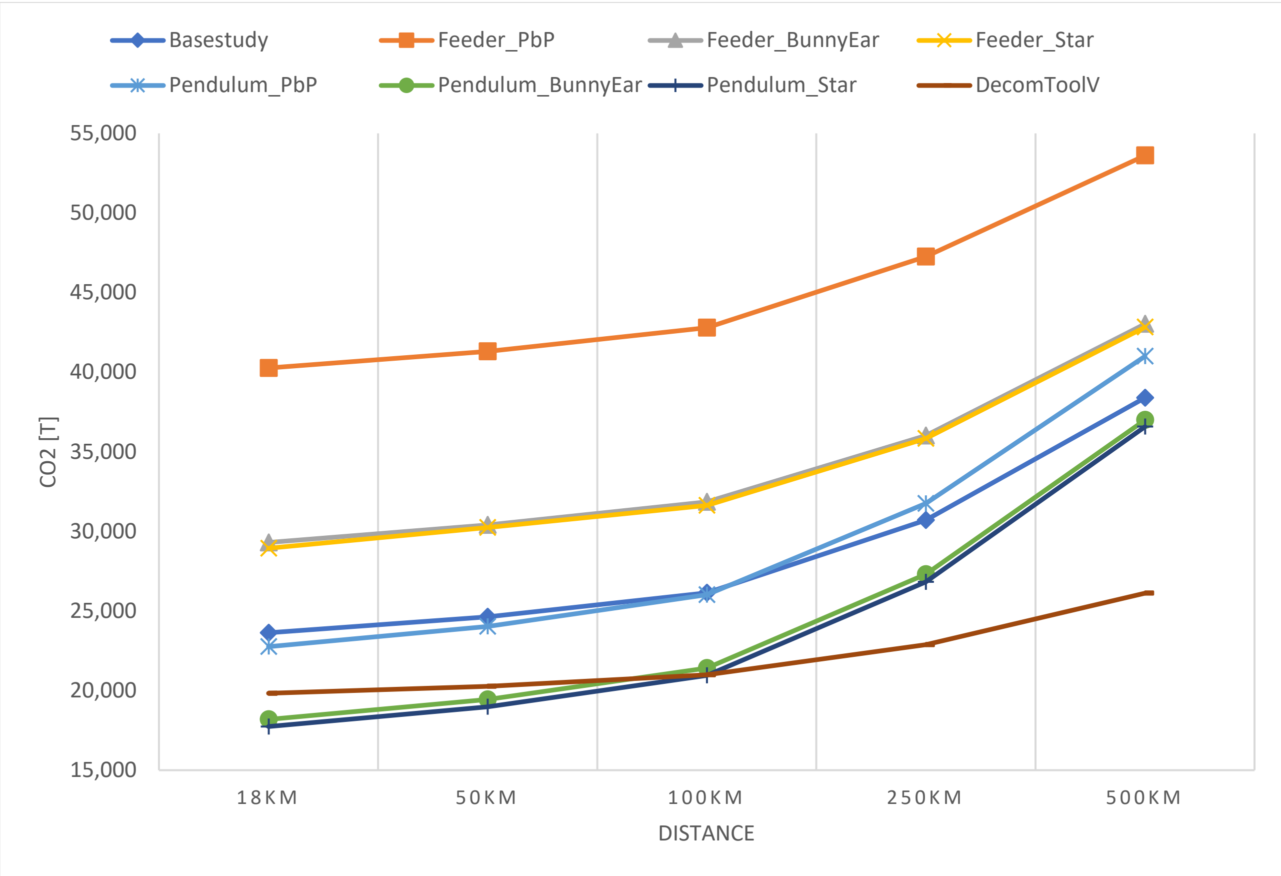


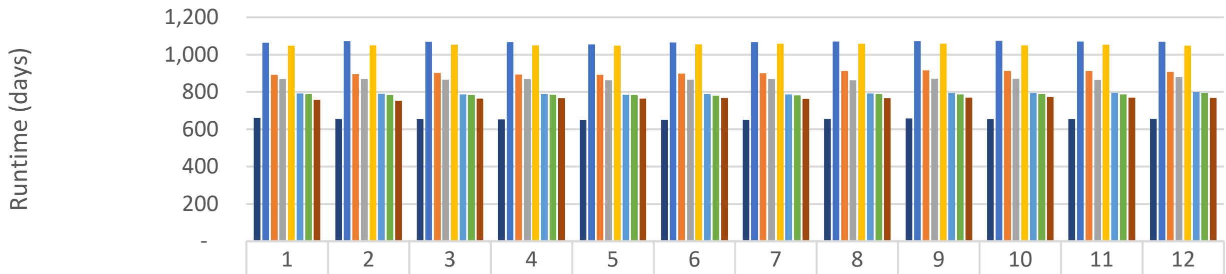
Figure 9: Parameter with increasing distances for Complete Supply Chain – Average CO_2-Emissions in tons

5.1.4 Annual Changes

In the course of the simulation, more than 1.000 simulation runs were performed per scenario and configuration. The start time of these was randomly selected and subsequently clustered by months. In the following, the running time, costs and CO2 emissions are shown over the period of a year. The graphs are shown and explained for a distance of 50 km. Since the graphs for the other distances (100 km, 250 km and 500 km) look very similar, they are not included in the main text in order to maintain a structured overview. The graphics can be found in appendix 1.

Figure 10 shows the progression of the average runtime of different configurations at a distance of 50 km from the coast over a period of one year.

Over the course of the year, the runtime for the base study remains quite even, with a fluctuation of less than two percent. This is similar for the other configurations. With the exception of the pendulum Bunny Ear configuration, where the fluctuation is slightly below three percent, and DecomToolV with a fluctuation of 2.5%. Both configurations have the highest durations in September and October and the lowest at the beginning of the year (January and February, respectively). However, there is no discernible pattern here, the values seem to increase towards the end of the year and decrease towards the summer, although this is not consistent.



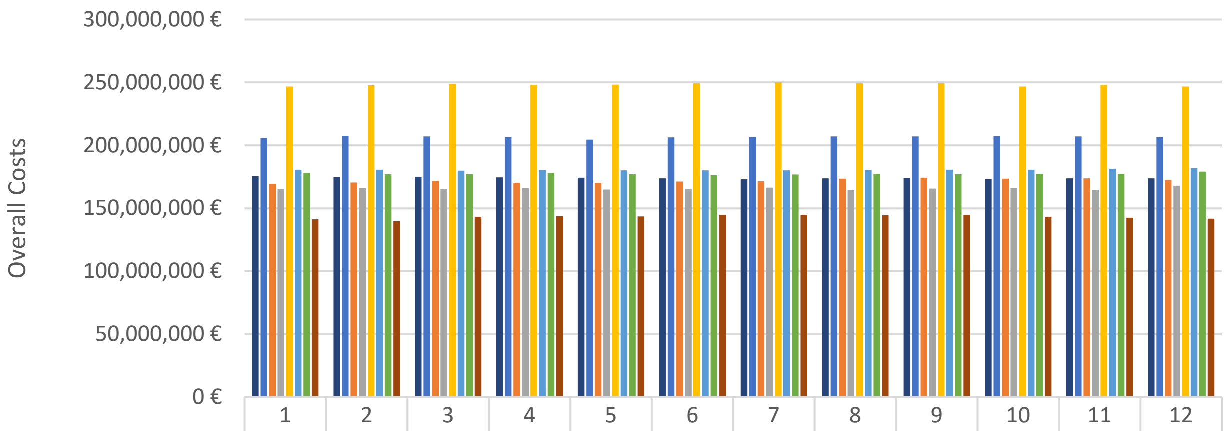
	1	2	3	4	5	6	7	8	9	10	11	12
BaseStudy	661	656	654	653	649	652	651	656	658	656	655	656
Pendulum PbP	1,064	1,072	1,069	1,066	1,056	1,065	1,066	1,070	1,072	1,073	1,071	1,068
Pendulum BunnyEar	892	895	902	894	892	899	900	912	917	913	913	907
Pendulum Star	869	870	866	869	862	866	870	862	871	871	864	880
Feeder PbP	1,048	1,050	1,053	1,050	1,048	1,055	1,058	1,058	1,059	1,049	1,052	1,048
Feeder Bunny Ear	793	790	787	788	785	789	788	792	794	794	795	798
Feeder Star	789	784	783	785	783	781	781	788	787	788	787	794
DecomToolV	758	753	765	767	764	768	764	766	770	773	769	767

Starting Month

Figure 10: Average runtime of different configurations at a distance of 50 km over a period of one year – complete supply chain (1-12 equals the months from January to December)

Figure 11 shows the progression of the average costs of different configurations at a distance of 50 km from the coast over a period of one year.

As with the runtime, the costs over the time span of one year are in a very similar range with a fluctuation of under two percent. Here, too, the pendulum Bunny Ear configuration has a slightly higher fluctuation of under three percent. DecomToolV has a fluctuation of 3.5%. The highest value is in July and September (pendulum Bunny Ear) and the lowest value is in February and January (pendulum Bunny Ear).



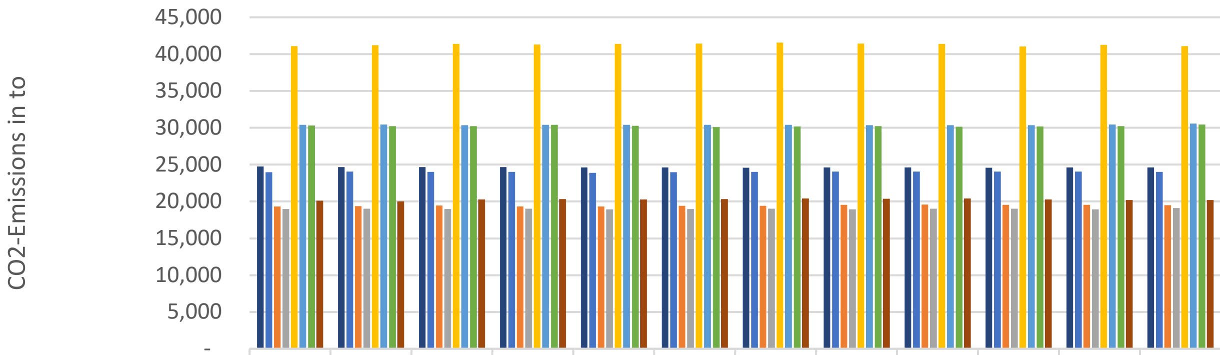
	1	2	3	4	5	6	7	8	9	10	11	12
BaseStudy	175.5M	174.8M	175.0M	174.5M	174.2M	173.8M	173.1M	173.9M	174.0M	173.2M	173.8M	173.8M
Pendulum PbP	205.8M	207.6M	207.0M	206.5M	204.6M	206.3M	206.6M	207.0M	207.1M	207.4M	207.2M	206.5M
Pendulum BunnyEar	169.5M	170.4M	171.8M	170.1M	170.2M	171.2M	171.5M	173.6M	174.3M	173.7M	173.7M	172.4M
Pendulum Star	165.4M	166.0M	165.4M	166.0M	164.9M	165.4M	166.3M	164.3M	165.8M	165.9M	164.6M	167.8M
Feeder PbP	246.8M	247.7M	248.7M	248.0M	248.2M	249.3M	250.0M	249.4M	249.4M	246.7M	248.1M	246.7M
Feeder BunnyEar	180.7M	180.6M	179.8M	180.4M	180.0M	180.3M	180.2M	180.5M	180.6M	180.8M	181.3M	182.0M
Feeder Star	178.1M	177.2M	177.0M	178.1M	177.2M	176.3M	176.9M	177.3M	177.1M	177.4M	177.5M	179.2M
DecomToolV	141.1M	139.8M	143.2M	143.7M	143.5M	144.7M	144.9M	144.6M	144.7M	143.2M	142.5M	141.6M

Starting Month

Figure 11: Average costs of different configurations at a distance of 50 km over a period of one year – complete supply chain (1-12 equals the months January-December; M stands for Million €)

Figure 12 shows the progression CO2 emissions in tons of different configurations at a distance of 50 km from the coast over a period of one year.

All configurations show fluctuations of less than 1%. It is not evident that the CO_2 emissions are dependent on the seasons.



	1	2	3	4	5	6	7	8	9	10	11	12
BaseStudy	24,757	24,664	24,671	24,646	24,619	24,602	24,584	24,642	24,640	24,595	24,630	24,637
Pendulum PbP	23,975	24,073	24,031	23,998	23,884	23,984	24,012	24,050	24,061	24,078	24,052	24,025
Pendulum Bunny Ear	19,315	19,359	19,435	19,333	19,331	19,401	19,417	19,561	19,585	19,553	19,539	19,493
Pendulum Star	18,985	19,009	18,968	18,997	18,927	18,972	19,023	18,917	19,006	19,002	18,921	19,101
Feeder PbP	41,088	41,215	41,380	41,320	41,379	41,445	41,548	41,422	41,393	41,047	41,245	41,077
Feeder BunnyEar	30,396	30,441	30,366	30,418	30,410	30,398	30,381	30,376	30,344	30,374	30,444	30,554
Feeder Star	30,303	30,235	30,222	30,386	30,275	30,106	30,186	30,206	30,140	30,180	30,207	30,441
DecomToolV	20,103	20,027	20,266	20,302	20,280	20,334	20,389	20,363	20,389	20,279	20,212	20,173

Starting Month

Figure 12: Average CO2-Emissions of different configurations at a distance of 50 km over a period of one year – complete supply chain (1-12 equals the months January-December)

As already mentioned, the graphs for the evaluation aspects considered at 100 km, 250 km and 500 km are very similar to those at 50 km. Again, the deviations range from <2-3 %.

5.2 Parameter with increasing distances offshore

In the following, the impacts of parametric changes (here: distance to coast) for the offshore processes are presented and the different configurations described above are compared. Since the offshore processes are assumingly the ones with the biggest impact on runtime, costs and co2-emissions a more detailed look gives further information.

5.2.1 Runtime

Figure 13 shows the average runtimes of different configurations as a function of increasing distances.

The runtimes of the base study are the lowest of all configurations over the distance range of 18 to 500 kilometers. The feeder Star, feeder Bunny Ear and DecomToolV configurations come closest to the runtime of the base study. The two feeder configurations run very similarly. The DecomToolV variant initially runs slightly below the other two, but at 250 kilometers the curves intersect and after that the DecomToolV has a higher runtime. Pendulum Bunny Ear and pendulum Star have parallel curves, with Star having a shorter runtime over the course of the curves. Pendulum Part-by-Part and feeder Part-by-Part have the longest running time, although the two curves initially have a similar course, the course of the pendulum Part-by-Part configuration increases more rapidly after 100 kilometers.

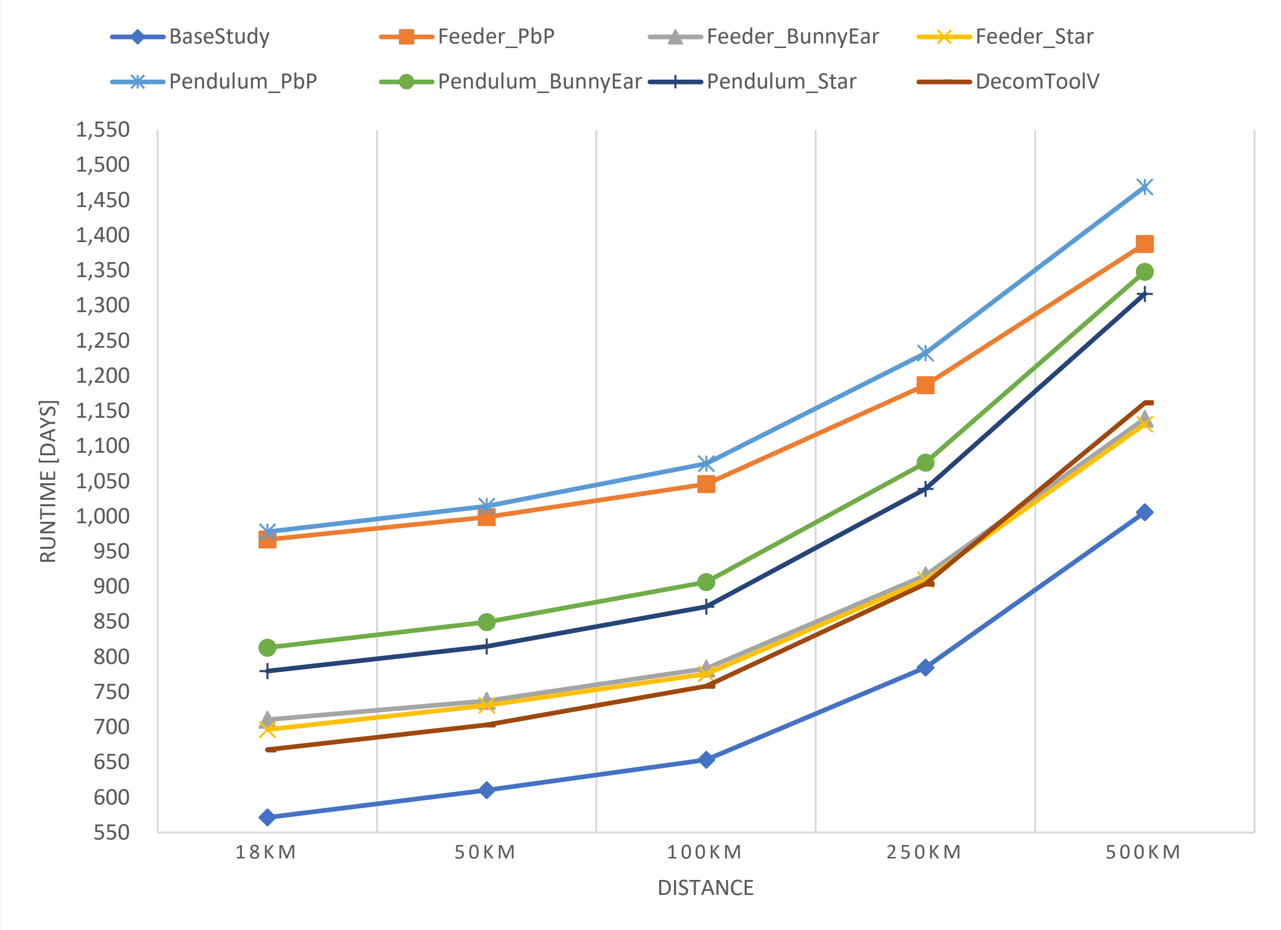


Figure 13: Parameter with increasing distances Offshore – Average Runtime in days

5.2.2 Costs

Figure 14 shows the average costs of different configurations as a function of increasing distances.

As with the complete chain, the DecomToolV configuration has the lowest average cost. After a gap of about 20,000,000 €, some configurations settle in a similar range. Thereby feeder Star and Bunny Ear have a very similar course at the upper end of this cluster. The base study and pendulum Bunny Ear run identically at the beginning, but from 100 kilometers pendulum Bunny Ear increases significantly and is the most expensive configuration from this grouping. Pendulum Star is the least expensive configuration up to 250 kilometers (after DecomToolV), where it intersects the curve of the base study and is more expensive thereafter. Pendulum Part by Part runs with a distance of

30,000,000 € to the clustering. Parallel to it runs the most expensive configuration feeder Part by Part.

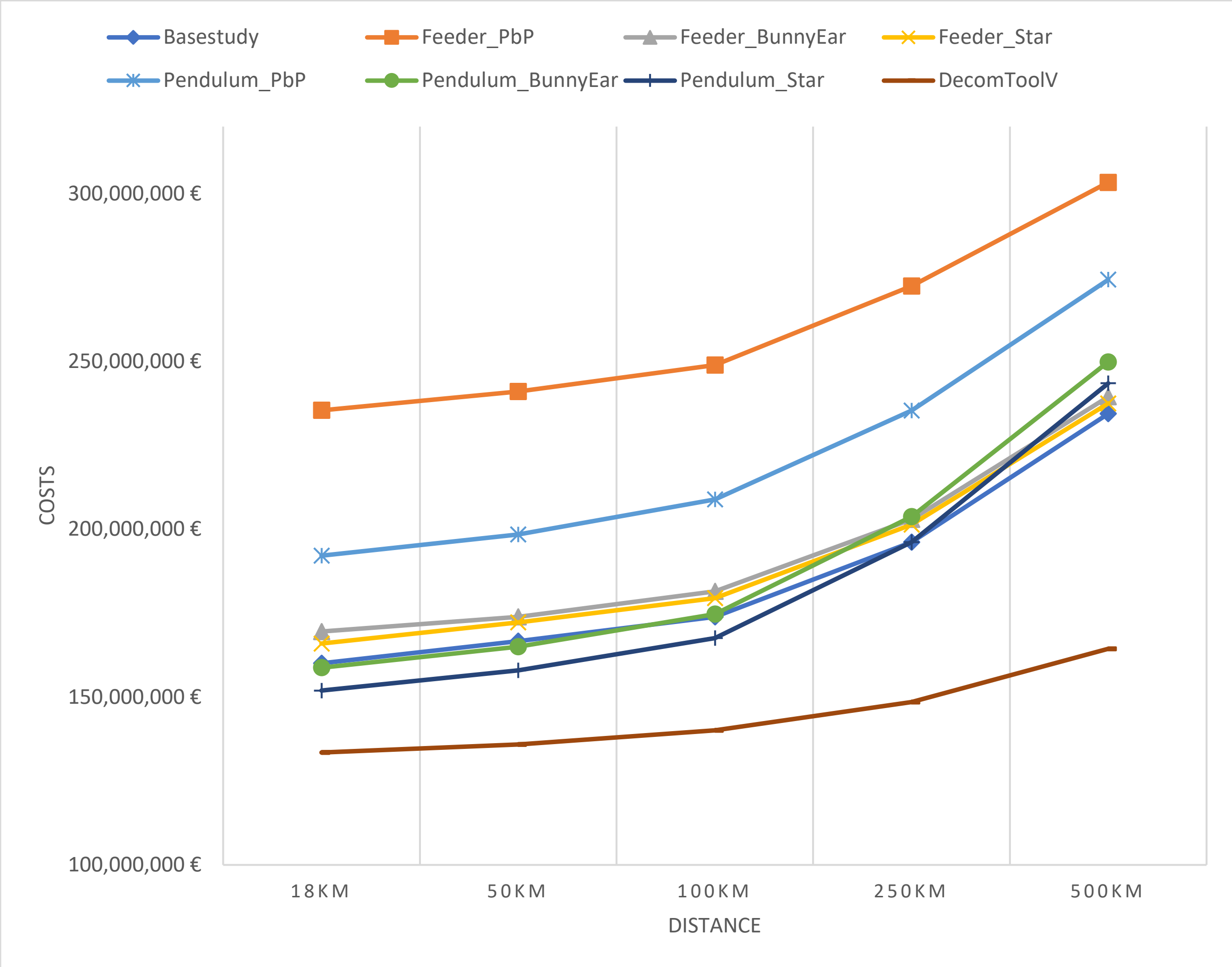


Figure 14: Parameter with increasing distances Offshore – Average Costs in €

5.2.3 CO_2-Emissions

Figure 15 shows the average CO_2-Emissions of different configurations as a function of increasing distances.

The configuration that emits the least CO_2 over the range of 18 to 500 kilometers is with the DecomToolV. Pendulum Star, pendulum Bunny Ear, pendulum Part by Part also have lower CO_2 emissions than the base study. At 18 kilometers, the pendulum Bunny Ear and Star configurations are in the same range as DecomToolV. However, these curves then rise almost identically and have significantly higher CO_2 emissions. The base study and pendulum Part by Part initially run parallel, from 250 km the distance becomes smaller and at 500 km they cross. Feeder Star and Bunny Ear run identically, with a distance of 5,000 tons from the base study. The configuration with the highest CO_2 emissions is feeder Part-by-Part with a distance of 14,000 tons to the base study.

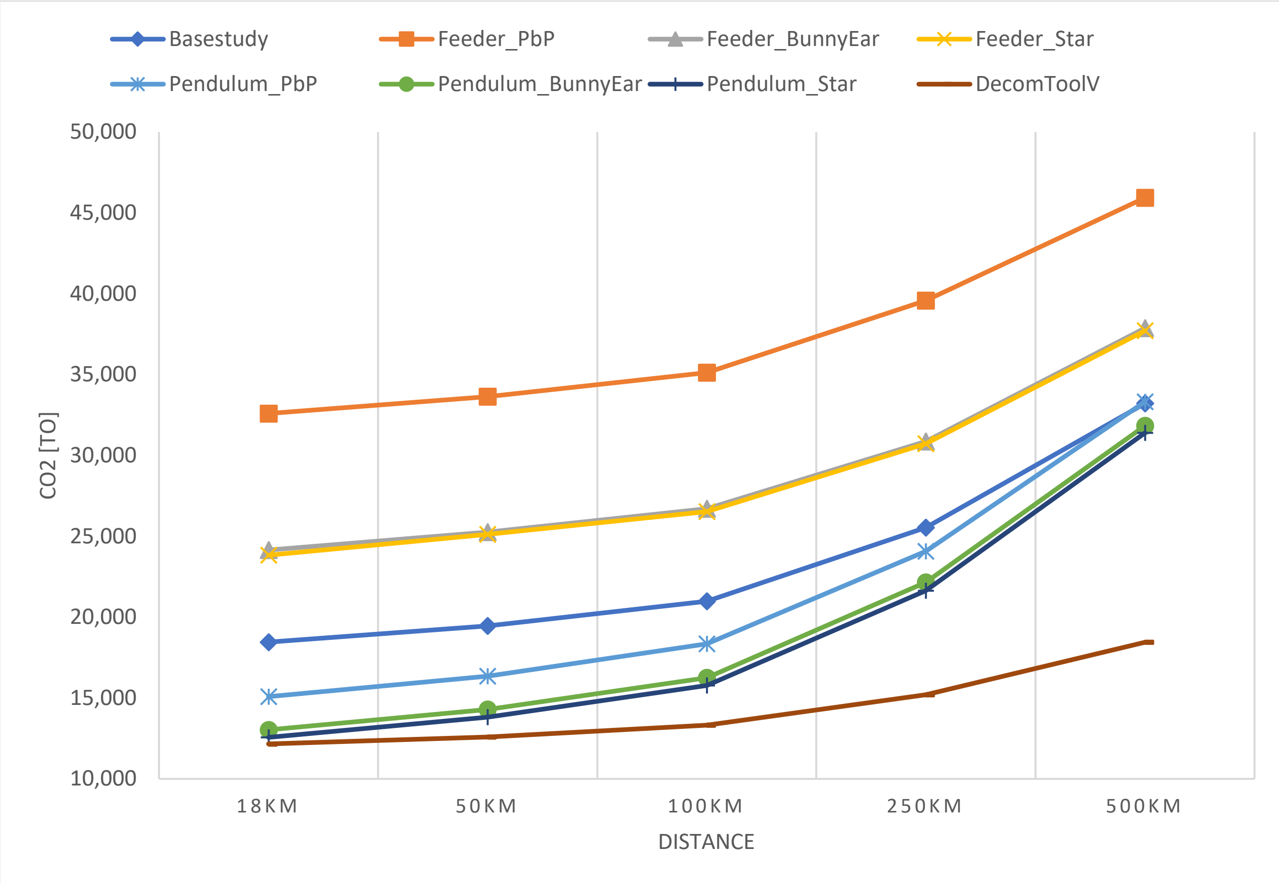


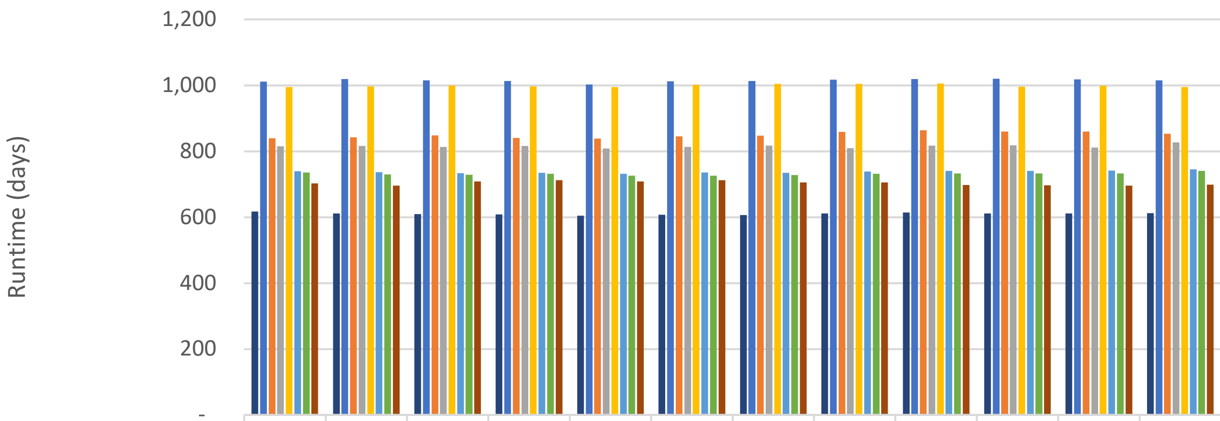
Figure 15: Parameter with increasing distances Offshore – Average CO_2-Emissions in tons

5.2.4 Annual Changes

In the following, the running time, costs and CO2 emissions are shown over the period of a year. The graphs are shown and explained for a distance of 50 km. Since the graphs for the other distances (100 km, 250 km and 500 km) look very similar, they are not included in the main text in order to maintain a structured overview. The graphics can be found in appendix 2.

Figure 16 shows the progression of the average runtime of different configurations at a distance of 50 km from the coast over a period of one year.

The course of the average runtime follows the same pattern as described in chapter 5.1.4. The values are slightly lower, which is due to the fact that only offshore processes are considered. The deviations vary between 2-3% over the year as well.

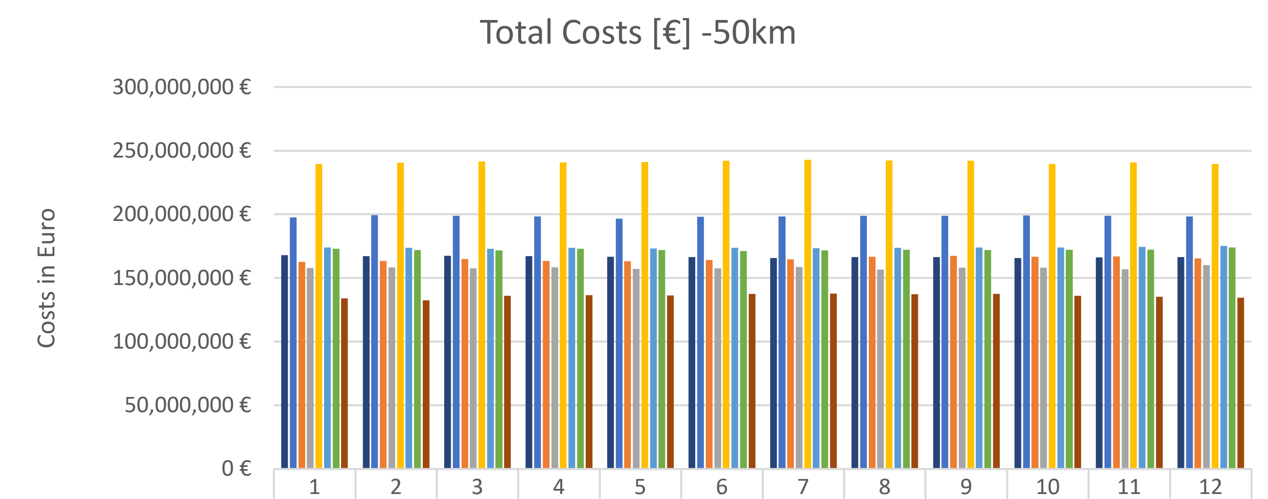


	1	2	3	4	5	6	7	8	9	10	11	12
BaseStudy	617	612	609	608	605	607	606	611	614	611	611	612
Pendulum PbP	1,011	1,019	1,015	1,013	1,002	1,012	1,013	1,017	1,019	1,020	1,018	1,015
Pendulum BunnyEar	839	842	849	840	839	845	847	858	863	860	859	853
Pendulum Star	815	816	813	816	809	813	817	809	817	818	811	827
Feeder PbP	995	996	999	996	995	1,002	1,004	1,005	1,006	995	999	995
Feeder Bunny Ear	739	736	733	735	731	735	734	738	740	740	741	745
Feeder Star	735	730	728	732	726	726	727	732	733	733	733	740
DecomToolV	703	696	708	712	708	712	705	705	698	696	696	698

Starting Month

Figure 16: Average runtime of different configurations at a distance of 50 km over a period of one year – offshore (1-12 equals the months from January to December)

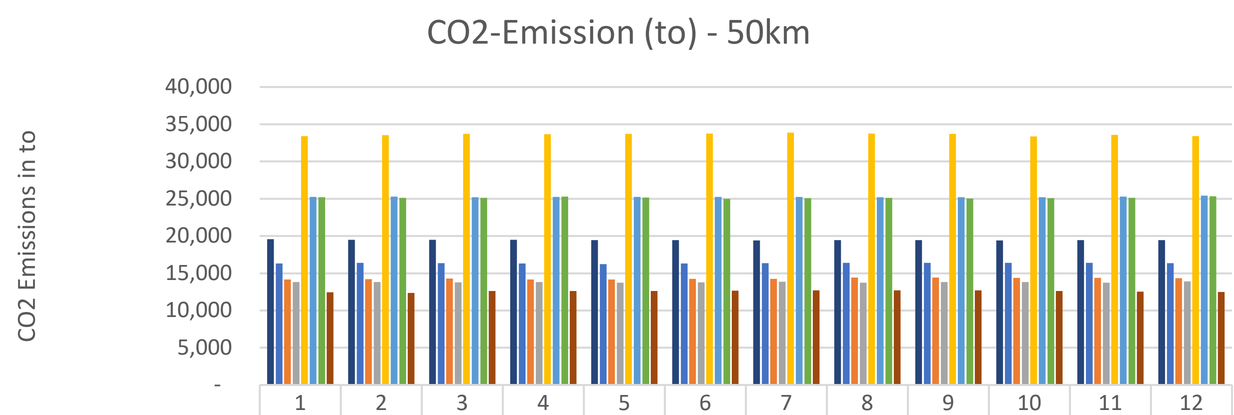
Figure 17 shows the progression of the average costs of different configurations at a distance of 50 km from the coast over a period of one year. The course of the average runtime follows the same pattern as described in chapter 5.1.4. Here, too, the values are lower, as described in the previous graph. The deviations vary between 2-3% over the year as well.



	1	2	3	4	5	6	7	8	9	10	11	12
BaseStudy	168.1M	167.2M	167.4M	167.1M	166.7M	166.3M	165.7M	166.3M	166.5M	165.7M	166.3M	166.3M
Pendulum PbP	197.6M	199.4M	198.7M	198.3M	196.5M	198.0M	198.3M	198.8M	198.9M	199.2M	198.9M	198.2M
Pendulum BunnyEar	162.6M	163.5M	164.9M	163.3M	163.3M	164.3M	164.6M	166.7M	167.4M	166.8M	166.8M	165.5M
Pendulum Star	157.8M	158.4M	157.7M	158.3M	157.2M	157.7M	158.6M	156.7M	158.1M	158.2M	157.0M	160.1M
Feeder PbP	239.6M	240.6M	241.5M	240.8M	241.0M	242.0M	242.8M	242.2M	242.1M	239.6M	240.8M	239.5M
Feeder BunnyEar	174.0M	173.8M	173.1M	173.7M	173.3M	173.6M	173.4M	173.8M	173.9M	174.0M	174.6M	175.3M
Feeder Star	172.8M	172.1M	171.8M	172.9M	171.9M	171.1M	171.6M	172.2M	172.0M	172.2M	172.3M	174.1M
DecomToolV	133.9M	132.6M	136.0M	136.5M	136.4M	137.5M	137.8M	137.3M	137.5M	135.9M	135.2M	134.5M

Figure 17: average costs of different configurations at a distance of 50 km over a period of one year – offshore (1-12 equals the months January-December; M stands for Million €)

Figure 18 shows the progression of the average runtime of different configurations at a distance of 50 km from the coast over a period of one year. The course of the average runtime follows the same pattern as described in chapter 5.1.4. Here, too, the values are lower, as described in the previous two graphs. The deviations vary between 2-3% over the year as well.



	1	2	3	4	5	6	7	8	9	10	11	12
BaseStudy	19,583	19,489	19,493	19,474	19,444	19,426	19,413	19,466	19,465	19,420	19,456	19,462
Pendulum PbP	16,301	16,399	16,355	16,325	16,213	16,308	16,335	16,377	16,387	16,404	16,377	16,349
Pendulum Bunny Ear	14,157	14,201	14,277	14,176	14,172	14,243	14,260	14,402	14,428	14,394	14,380	14,334
Pendulum Star	13,812	13,836	13,792	13,822	13,751	13,794	13,847	13,743	13,830	13,827	13,747	13,926
Feeder PbP	33,418	33,548	33,712	33,651	33,709	33,774	33,878	33,752	33,720	33,379	33,572	33,406
Feeder BunnyEar	25,242	25,286	25,214	25,267	25,255	25,248	25,226	25,224	25,191	25,221	25,289	25,401
Feeder Star	25,191	25,126	25,114	25,277	25,162	24,996	25,075	25,098	25,033	25,069	25,099	25,333
DecomToolV	12,433	12,357	12,596	12,631	12,613	12,663	12,722	12,691	12,719	12,607	12,540	12,504

Starting Month

Figure 18: average CO_2-Emissions of different configurations at a distance of 50 km over a period of one year – offshore (1-12 equals the months from January to December)

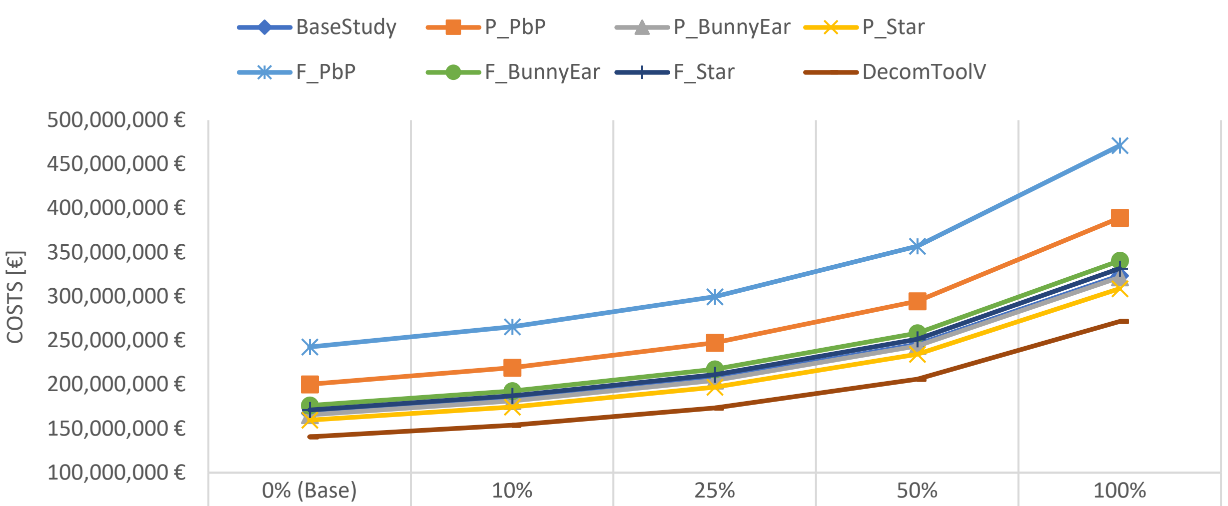
As with the annual graphs of the complete supply chain, there is no correlation of run time, cost, or CO_2 emissions with the seasons.

5.3 Cost development with increasing vessel day rates

5.3.1 Complete Supply Chain

Figure 19 shows the cost developments of the different scenarios with increasing vessel day rates of the complete supply chain.

Simulations were performed at 10%, 25%, 50% and 100% increased day rates starting from the base (0%). As day rates increase, costs also increase in a nearly linear way, with no change in the positions of the different scenarios. The DecomTools vessel remains the least expensive scenario and Feeder Part-by-Part the most expensive scenario.



	0% (Base)	10%	25%	50%	100%
BaseStudy	167,589,714 €	183,172,996 €	206,581,404 €	245,595,419 €	323,623,449 €
P_PbP	200,342,438 €	219,230,182 €	247,560,461 €	294,777,592 €	389,211,854 €
P_BunnyEar	165,638,389 €	181,279,626 €	204,677,888 €	243,674,990 €	321,669,195 €
P_Star	159,646,689 €	174,588,905 €	196,976,821 €	234,290,014 €	308,916,401 €
F_PbP	242,648,497 €	265,571,159 €	299,840,946 €	356,957,256 €	471,189,877 €
F_BunnyEar	176,263,251 €	192,670,903 €	217,315,038 €	258,388,595 €	340,535,709 €
F_Star	171,149,364 €	187,104,479 €	211,209,747 €	251,385,194 €	331,736,088 €
DecomToolV	140,684,107 €	153,826,440 €	173,459,689 €	206,181,771 €	271,625,936 €

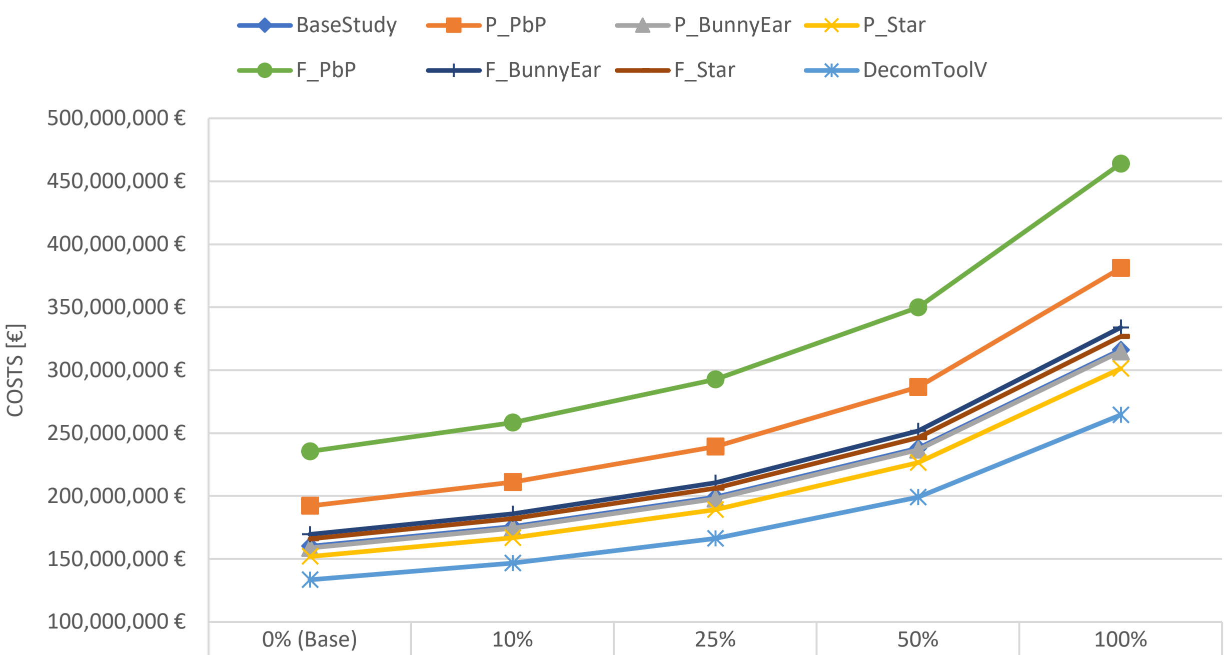
DAY RATE INCREASE

Figure 19: Cost development with increasing vessel day rates – complete supply chain

5.3.3 Offshore

Figure 20 shows the cost developments of the different scenarios with increasing vessel day rates of the offshore processes.

As with the cost development of the offshore process, the total costs increase with increasing day rates. The positions of the scenarios remain the same over the increase in cost. The least expensive scenario is DecomTool Vessel and the most expensive scenario is Feeder Part-by-Part.



	0% (Base)	10%	25%	50%	100%
BaseStudy	160,082,814 €	175,660,512 €	199,068,921 €	238,082,936 €	316,110,965 €
P_PbP	192,144,288 €	211,023,732 €	239,354,010 €	286,571,141 €	381,005,403 €
P_BunnyEar	158,760,863 €	174,411,502 €	197,809,763 €	236,806,866 €	314,801,071 €
P_Star	151,959,232 €	166,901,299 €	189,289,215 €	226,602,408 €	301,228,795 €
F_PbP	235,442,947 €	258,376,625 €	292,646,412 €	349,762,722 €	463,995,344 €
F_BunnyEar	169,550,526 €	185,955,787 €	210,599,922 €	251,673,479 €	333,820,593 €
F_Star	165,963,384 €	182,008,822 €	206,124,196 €	246,316,486 €	326,701,067 €
DecomToolV	133,494,760 €	146,612,773 €	166,246,022 €	198,968,104 €	264,412,269 €

DAY RATE INCREASE

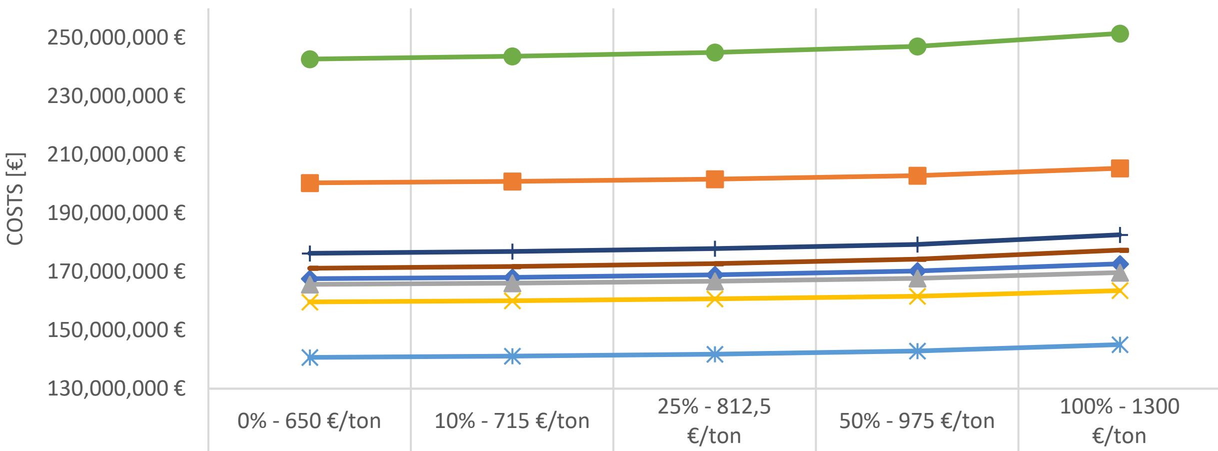
Figure 20: Cost development with increasing day rates – offshore

5.4 Cost development with increasing fuel costs

5.4.1 Complete Supply Chain

Simulations were performed at 10%, 25%, 50% and 100% increased fuel costs starting from the base (0%).

Figure 21 shows the progression of costs with increased ship fuel costs. Increasing fuel costs results in only a minimal increase in costs over the course of the curve. With a 100% increase, total costs are only about 3% higher than the initial condition. The increase in fuel costs therefore has minimal to no impact on total costs when the wind farm is at an 18 km distance from the coast.



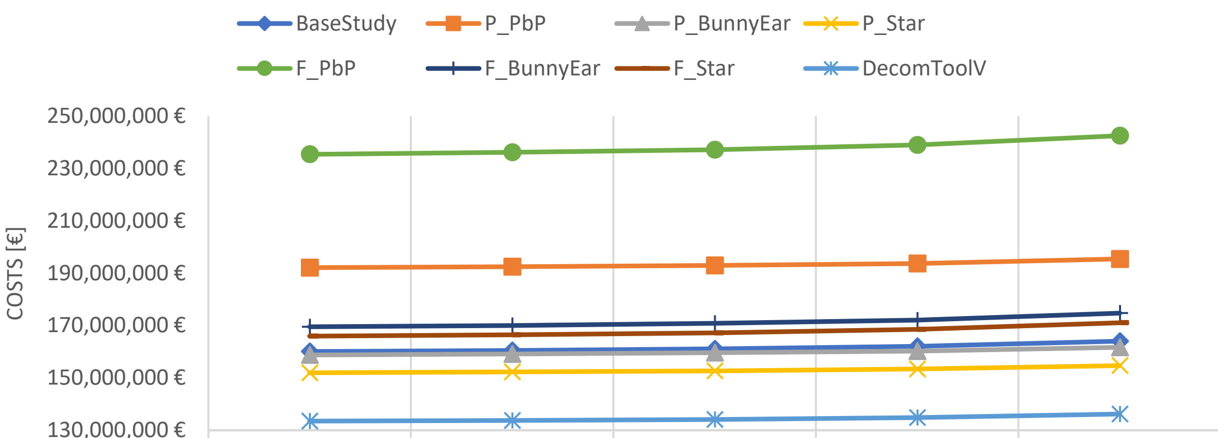
	0% - 650 €/ton	10% - 715 €/ton	25% - 812,5 €/ton	50% - 975 €/ton	100% - 1300 €/ton
BaseStudy	167,589,714 €	168,078,144 €	168,867,048 €	170,187,032 €	172,673,559 €
P_PbP	200,342,438 €	200,852,666 €	201,613,623 €	202,824,632 €	205,331,753 €
P_BunnyEar	165,638,389 €	166,082,014 €	166,737,507 €	167,733,880 €	169,686,217 €
P_Star	159,646,689 €	160,053,195 €	160,656,769 €	161,623,255 €	163,503,555 €
F_PbP	242,648,497 €	243,625,475 €	244,873,626 €	247,012,473 €	251,423,781 €
F_BunnyEar	176,263,251 €	176,855,494 €	177,832,018 €	179,348,266 €	182,597,292 €
F_Star	171,149,364 €	171,738,259 €	172,724,696 €	174,223,027 €	177,355,375 €
DecomToolV	140,684,107 €	141,165,819 €	141,758,121 €	142,861,129 €	145,057,844 €

FUEL COSTS INCREASE

Figure 21: Cost development with increasing fuel costs per ton – Complete supply chain

5.4.3 Offshore

Figure 22 shows the progression of costs with increased ship fuel costs. Increasing fuel costs results in only a minimal increase in costs over the course of the curve. With a 100% increase, total costs are only about 3% higher than the initial condition. The increase in fuel costs therefore has minimal to no impact on total costs when the wind farm is at an 18 km distance from the coast.



	0% - 650 €/ton	10% - 715 €/ton	25% - 812,5 €/ton	50% - 975 €/ton	100% - 1300 €/ton
BaseStudy	160,082,814 €	160,449,996 €	161,064,432 €	162,105,113 €	164,049,440 €
P_PbP	192,144,288 €	192,478,776 €	192,988,336 €	193,770,124 €	195,473,527 €
P_BunnyEar	158,760,863 €	159,109,436 €	159,581,069 €	160,298,616 €	161,688,950 €
P_Star	151,959,232 €	152,249,083 €	152,690,734 €	153,370,198 €	154,694,733 €
F_PbP	235,442,947 €	236,259,596 €	237,249,103 €	238,980,956 €	242,566,149 €
F_BunnyEar	169,550,526 €	170,023,382 €	170,833,770 €	172,057,007 €	174,753,446 €
F_Star	165,963,384 €	166,445,283 €	167,266,508 €	168,497,418 €	171,072,692 €
DecomToolV	133,494,760 €	133,794,681 €	134,154,917 €	134,825,334 €	136,192,916 €

FUEL COSTS INCREASE

Figure 22: Cost development with increasing fuel costs per ton - Offshore

6 Conclusion

Table 10 shows the differences of the examined parameters runtime, costs and CO_2-Emissions compared to the base study in percent at a distance of 18 km to the coastline.

All configurations have a longer runtime than the baseline study. The pendulum Part-by-Part scenario has the largest discrepancy from the baseline study at 66.90%. DecomToolV has the lowest deviation with 18.05 %. DecomToolV also has the lowest cost with a difference of -16.05% from the baseline study. The pendulum bunny ear and pendulum star configuration costs are below those of the baseline study. The feeder part-by-part configuration is the most expensive one with 44.79% higher costs than the baseline study.

Pendulum Star has the largest negative divergence at -24.92%, and thus the lowest CO_2 emissions. The scenario pendulum BunnyEar has a similar deviation with -23.03%. The DecomToolV and pendulum Part-by-Part also have negative offsets, i.e. lower CO_2 emissions than the baseline study. The other scenarios have significantly higher CO_2 emissions compared to the base study.

All in all, neither of the scenarios reviewed has better values than the baseline study in all aspects. The scenarios P_BunnyEar, P_Star and DecomToolV come closest, as they all three have two aspects each that have better values than the base study. Of these, DecomToolV has the best values. In terms of runtime, this scenario comes closest to the baseline study, and in terms of cost, it has the lowest cost of all configurations. CO2 emissions are also significantly lower than in the baseline study, at around -16%.

Table 9: difference of average runtime, cost and CO_2-Emissions compared to base study

Scenario	Ø Runtime in %	Ø Cost in %	Ø CO_2-Emissions in %
P_PbP	66.90	19.54	-3.69
P_BunnyEar	40.24	-1.16	-23.03
P_Star	34.82	-4.74	-24.92
F_PbP	65.12	44.79	70.38
F_BunnyEar	23.66	5.18	24.00
F_Star	21.72	2.12	22.47
DecomToolV	18.05	-16.05	-16.08

Table 10 shows the differences of the examined parameters runtime, costs and CO_2-Emissions compared to the base study in percent at a distance of 18 km to the coastline. With regard to the distances of the complete supply chain, the scenarios F_Star, F_BunnyEar and DecomToolV come closest to the baseline study in terms of average runtime over the course of 18 to 500 km.

In terms of costs, DecomToolV has the best values, which fall below the values of the baseline study. Up to a distance of 100 km, the P_Star, P_BunnyEar and DecomToolV scenarios are the best, with values below those of the baseline study. After that, the values for P_Star and P_BunnyEar increase and DecomToolV has the best values for CO_2 emissions.

When looking at the offshore processes, it is the same as for the complete supply chain with the exception of CO_2 emissions. There DecomToolV has the lowest values over the entire course of the distances. The difference in offshore and the complete supply chain in this case affects the course of the curves. For the other scenarios, the curves are very similar, but have lower values for offshore. This is not the case for CO_2 emissions. Here the values for P_Star and P_BunnyEar are minimally higher than DecomToolV at the beginning. For the complete supply chain, the values are lower than DecomToolV, and are only higher after 100 km, as already described. Whether the differences affect DecomToolV and the values are therefore lower or the other scenarios and they are therefore higher cannot be deduced from the results.

Increased ship day rates lead to an increase in the total cost of all simulated scenarios for both the complete supply chain and offshore, this has no effect on the ranking of the scenarios. DecomTools vessel remains the least expensive scenario and Feeder Part-by-Part the most expensive.

Increasing fuel costs does not significantly increase total costs offshore or in the complete supply chain (18 km offshore). This can be attributed to the fact that the share of fuel costs in the total costs is very low at this distance.

Looking to the future, this generic tool can be used to conduct interesting studies using a wide range of parameters from different stakeholders. The aims here can be of a cost-saving nature, as well as with regard to the reduction of CO2 emissions. This parameter therefore has a significant impact on costs. The use of alternative, cleaner fuels would have a positive impact on CO2 emissions, but would also lead to an increase in costs. However, a higher "CO2 price", would further equal this costs increase and create a fundamental incentive for climate-friendly and alternative fuels, which will have an overall significant positive effect on technology development.

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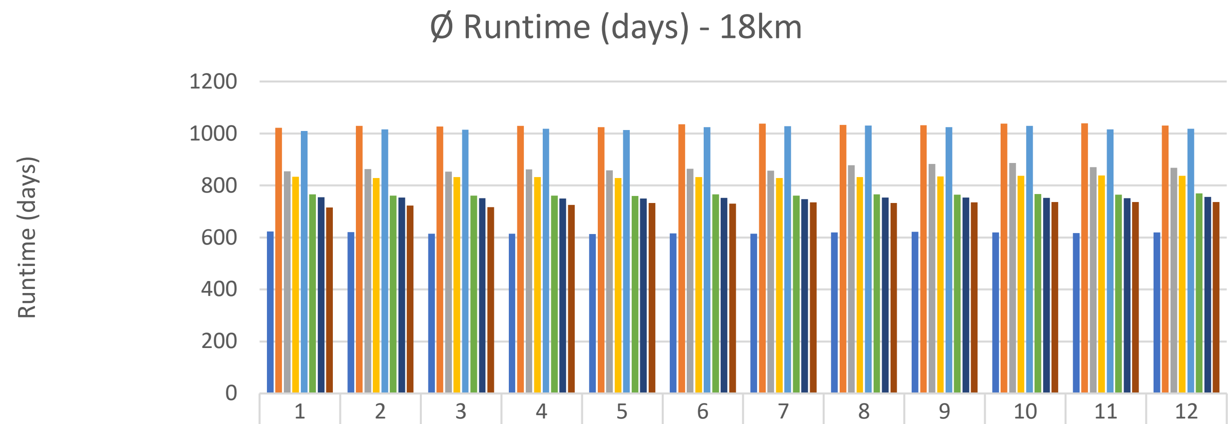
Appendix

List of Figures

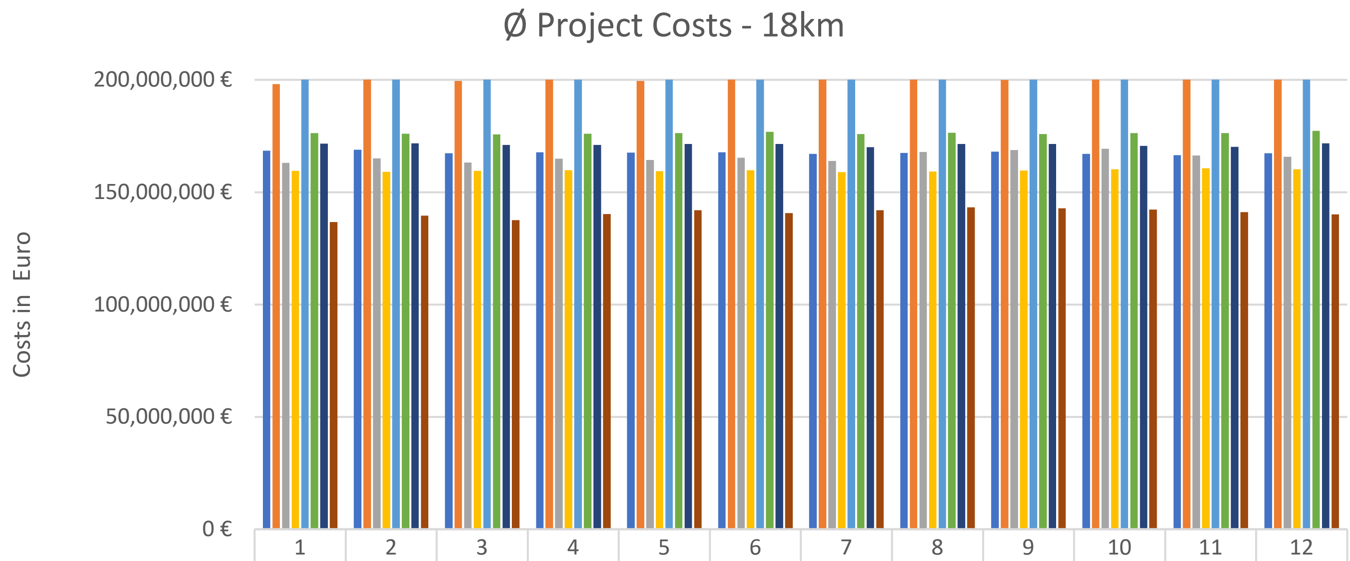
Appendix 1: Complete Supply Chain



	1	2	3	4	5	6	7	8	9	10	11	12
BaseStudy	623	621	615	615	613	616	615	619	622	620	617	620
Pendulum PbP	1,022	1,029	1,027	1,029	1,024	1,035	1,037	1,033	1,031	1,038	1,039	1,031
Pendulum Bunny Ear	854	863	853	862	858	864	857	878	883	886	870	868
Pendulum Star	834	829	832	833	829	833	829	832	835	837	838	837
Feeder PbP	1,010	1,016	1,015	1,018	1,013	1,025	1,028	1,031	1,025	1,029	1,016	1,018
Feeder BunnyEar	766	762	761	761	760	766	761	766	765	767	765	770
Feeder Star	755	754	751	750	750	753	747	753	754	753	751	756
DecomToolV	715	723	716	725	733	730	735	733	735	736	736	736

Starting Month

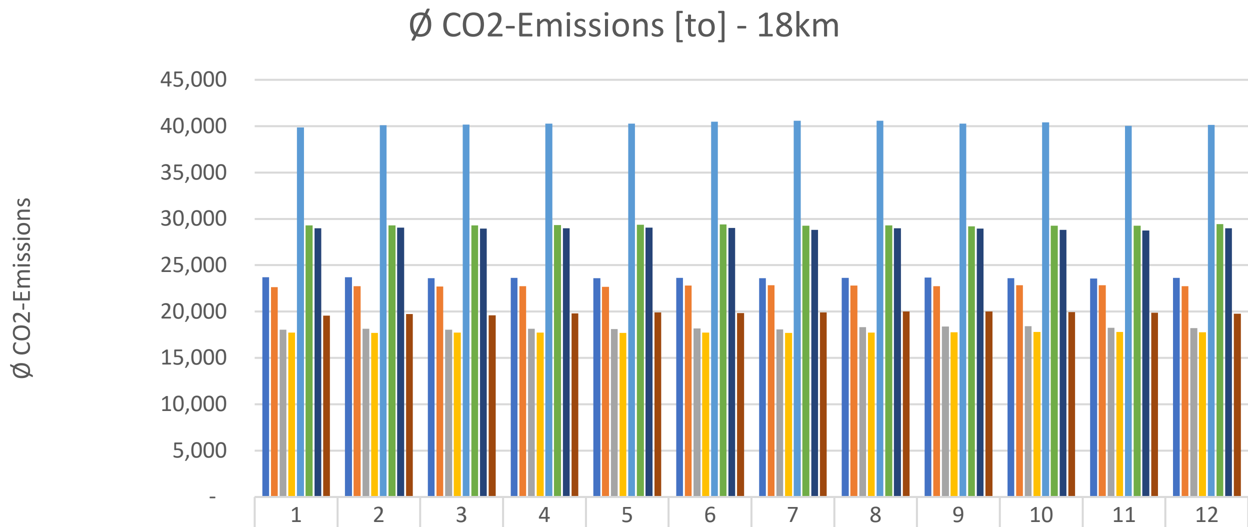
Figure 1: average runtime of different configurations at a distance of 18 km over a period of one year - complete supply chain (1-12 equals the months from January to December)



	1	2	3	4	5	6	7	8	9	10	11	12
BaseStudy	168.4M	168.8M	167.3M	167.7M	167.7M	167.7M	167.0M	167.4M	168.0M	167.1M	166.5M	167.4M
Pendulum PbP	198.1M	200.1M	199.5M	200.1M	199.4M	201.2M	201.8M	200.7M	200.0M	201.4M	201.8M	200.0M
Pendulum Bunny Ear	163.0M	165.1M	163.2M	164.9M	164.4M	165.3M	163.9M	167.9M	168.8M	169.2M	166.3M	165.8M
Pendulum Star	159.5M	159.0M	159.5M	159.8M	159.3M	159.8M	159.0M	159.2M	159.7M	160.1M	160.6M	160.1M
Feeder PbP	239.6M	241.8M	241.7M	242.4M	241.9M	244.1M	244.9M	245.1M	243.1M	244.4M	241.1M	241.6M
Feeder BunnyEar	176.3M	176.0M	175.7M	175.9M	176.3M	176.8M	175.8M	176.5M	175.9M	176.3M	176.3M	177.3M
Feeder Star	171.6M	171.8M	171.0M	171.0M	171.5M	171.5M	170.0M	171.5M	171.4M	170.6M	170.2M	171.7M
DecomToolV	136.7M	139.5M	137.5M	140.3M	142.0M	140.7M	141.9M	143.3M	142.8M	142.2M	141.2M	140.1M

Starting Month

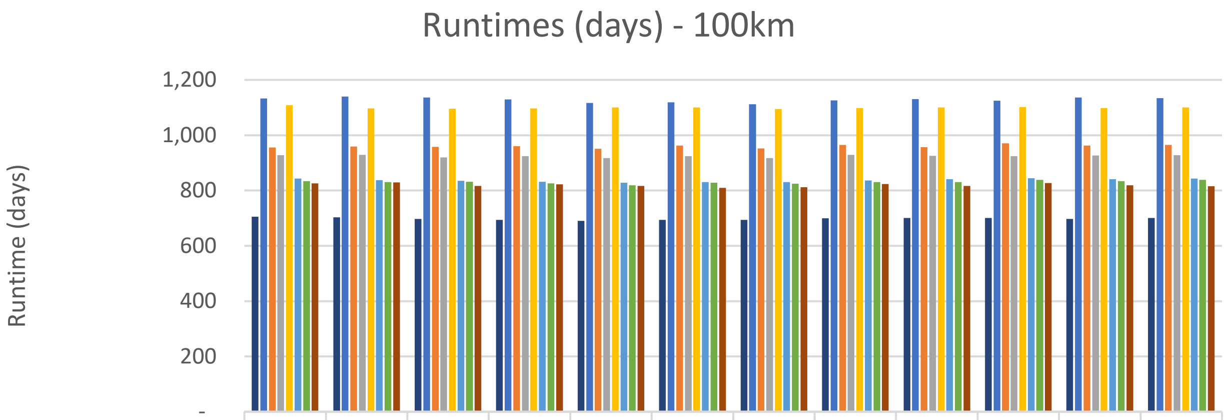
Figure 2: average costs of different configurations at a distance of 18 km over a period of one year – complete supply chain (1-12 equals the months from January to December)



	1	2	3	4	5	6	7	8	9	10	11	12
BaseStudy	23,719	23,693	23,598	23,621	23,613	23,626	23,594	23,635	23,657	23,618	23,573	23,639
Pendulum PbP	22,636	22,738	22,702	22,730	22,686	22,809	22,845	22,792	22,744	22,834	22,850	22,741
Pendulum Bunny Ear	18,037	18,149	18,033	18,130	18,097	18,166	18,084	18,330	18,384	18,417	18,237	18,211
Pendulum Star	17,743	17,697	17,730	17,741	17,705	17,748	17,701	17,728	17,751	17,789	17,803	17,782
Feeder PbP	39,844	40,100	40,164	40,265	40,273	40,490	40,581	40,583	40,289	40,428	40,040	40,122
Feeder BunnyEar	29,306	29,304	29,287	29,326	29,363	29,385	29,260	29,299	29,199	29,247	29,251	29,419
Feeder Star	28,987	29,064	28,956	28,978	29,051	29,011	28,816	28,969	28,935	28,816	28,745	28,976
DecomToolV	19,551	19,742	19,595	19,786	19,915	19,843	19,917	20,025	20,006	19,940	19,880	19,774

Starting Month

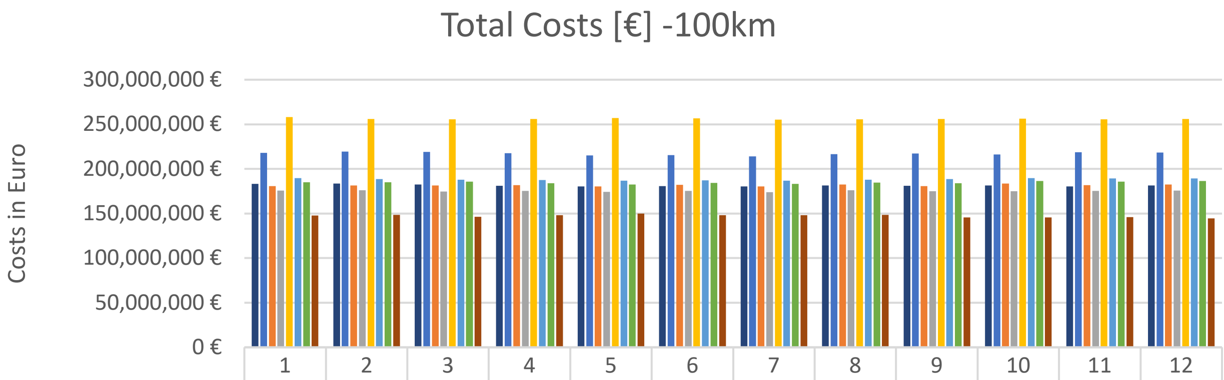
Figure 3: average CO_2-Emissions of different configurations at a distance of 18 km over a period of one year – complete supply chain (1-12 equals the months from January to December)



	1	2	3	4	5	6	7	8	9	10	11	12
BaseStudy	705	703	698	694	690	694	694	700	700	701	697	700
Pendulum PbP	1,133	1,140	1,137	1,129	1,117	1,119	1,112	1,126	1,131	1,125	1,137	1,135
Pendulum BunnyEar	956	959	958	960	951	962	952	965	957	970	962	965
Pendulum Star	928	929	920	925	918	924	918	929	925	925	926	928
Feeder PbP	1,109	1,098	1,096	1,097	1,100	1,101	1,094	1,098	1,100	1,101	1,099	1,101
Feeder Bunny Ear	843	837	835	832	828	831	831	837	841	845	841	843
Feeder Star	833	830	831	826	819	828	824	830	831	839	834	839
DecomToolV	826	829	817	822	816	809	812	824	817	827	819	815

Starting Month

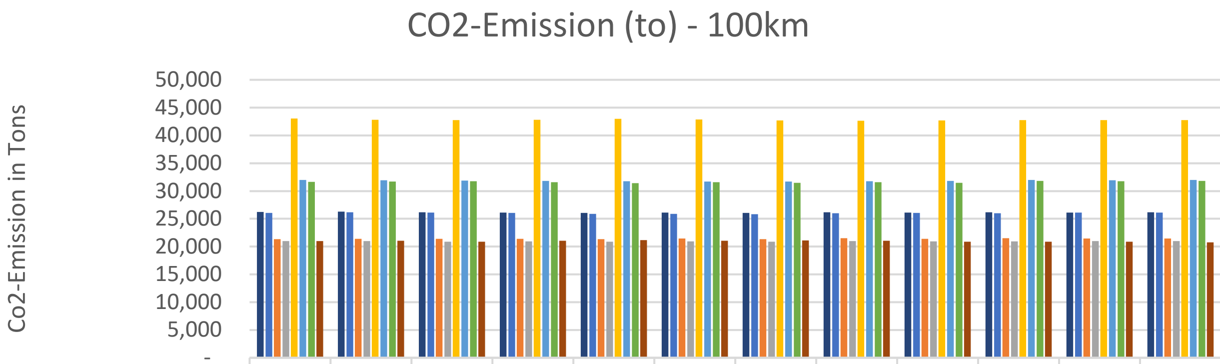
Figure 4: average runtime of different configurations at a distance of 100 km over a period of one year – complete supply chain (1-12 equals the months from January to December)



	1	2	3	4	5	6	7	8	9	10	11	12
BaseStudy	183.3M	183.7M	182.4M	181.0M	180.4M	180.8M	180.3M	181.3M	181.1M	181.3M	180.4M	181.4M
Pendulum PbP	217.9M	219.5M	218.9M	217.6M	215.3M	215.3M	214.1M	216.5M	217.3M	216.1M	218.6M	218.2M
Pendulum BunnyEar	180.6M	181.5M	181.4M	181.9M	180.5M	182.1M	180.3M	182.7M	180.8M	183.5M	181.8M	182.4M
Pendulum Star	175.8M	176.2M	174.5M	175.4M	174.4M	175.4M	174.1M	176.2M	175.1M	175.0M	175.5M	175.7M
Feeder PbP	258.1M	255.9M	255.8M	256.1M	257.2M	256.7M	255.1M	255.5M	255.8M	256.2M	255.6M	256.1M
Feeder BunnyEar	189.5M	188.5M	188.0M	187.5M	186.8M	187.0M	186.9M	188.0M	188.5M	189.8M	189.2M	189.3M
Feeder Star	185.0M	184.9M	185.6M	183.9M	182.6M	184.2M	183.2M	184.6M	183.9M	186.4M	185.8M	186.3M
DecomToolV	147.9M	148.6M	146.2M	148.0M	150.0M	148.2M	148.2M	148.5M	145.6M	145.6M	146.0M	144.4M

Starting Month

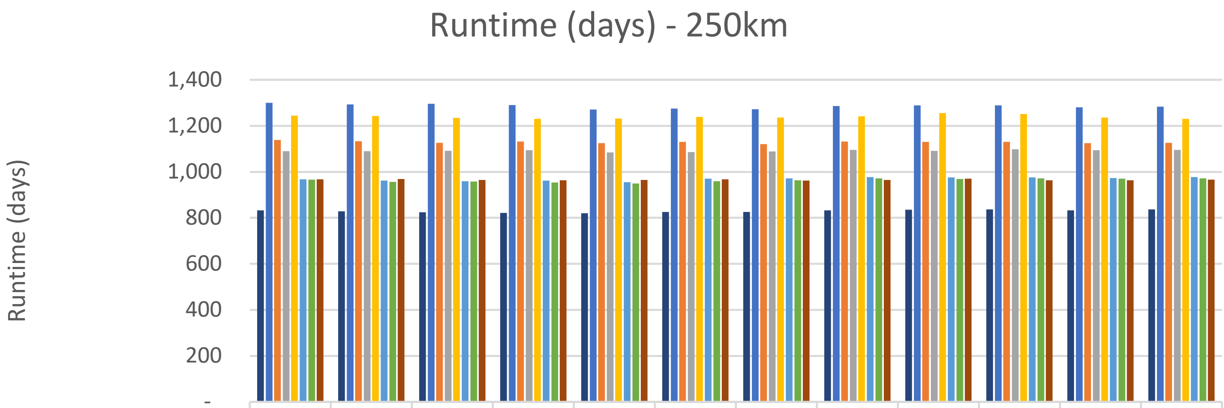
Figure 5: average costs of different configurations at a distance of 100 km over a period of one year – complete supply chain (1-12 equals the months from January to December)



	1	2	3	4	5	6	7	8	9	10	11	12
BaseStudy	26,257	26,284	26,194	26,109	26,060	26,107	26,085	26,158	26,139	26,150	26,095	26,153
Pendulum PbP	26,079	26,165	26,125	26,036	25,901	25,914	25,847	26,002	26,053	25,979	26,122	26,098
Pendulum Bunny Ear	21,361	21,409	21,389	21,403	21,329	21,443	21,334	21,488	21,371	21,536	21,439	21,480
Pendulum Star	20,987	21,003	20,892	20,948	20,866	20,938	20,878	21,016	20,937	20,938	20,968	20,991
Feeder PbP	43,023	42,796	42,758	42,821	43,008	42,882	42,674	42,651	42,670	42,731	42,724	42,757
Feeder BunnyEar	32,014	31,940	31,857	31,806	31,746	31,719	31,712	31,779	31,807	31,992	31,937	31,962
Feeder Star	31,658	31,696	31,747	31,585	31,420	31,587	31,454	31,560	31,484	31,814	31,743	31,824
DecomToolV	21,005	21,049	20,880	21,042	21,173	21,053	21,093	21,069	20,881	20,865	20,901	20,774

Starting Month

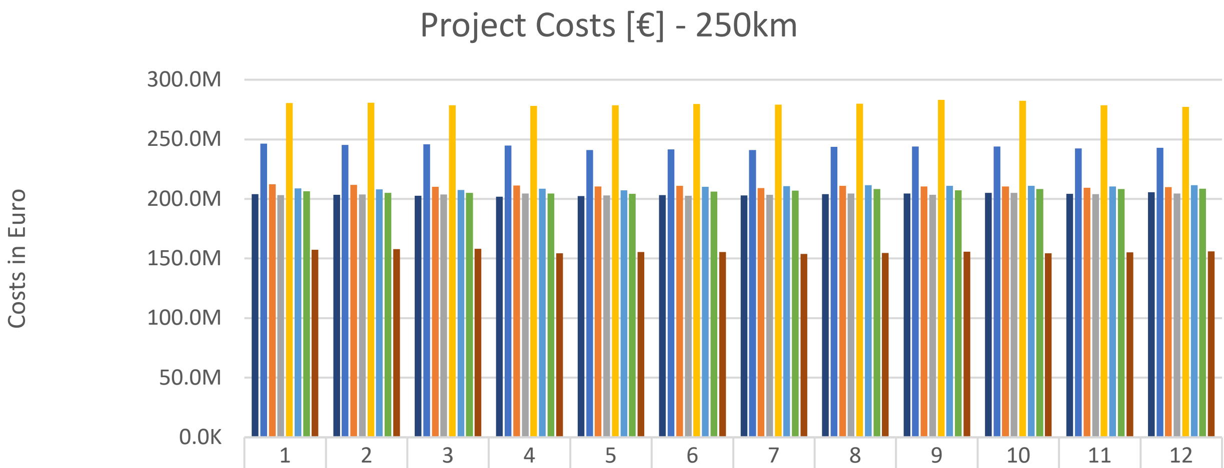
Figure 6: average CO_2-Emissions of different configurations at a distance of 100 km over a period of one year – complete supply chain (1-12 equals the months from January to December)



	1	2	3	4	5	6	7	8	9	10	11	12
BaseStudy	832	828	824	822	820	825	826	832	835	836	833	837
Pendulum PbP	1,300	1,293	1,295	1,290	1,271	1,275	1,272	1,287	1,288	1,288	1,280	1,283
Pendulum Bunny Ear	1,139	1,134	1,127	1,132	1,125	1,131	1,120	1,131	1,130	1,131	1,124	1,126
Pendulum Star	1,089	1,090	1,091	1,095	1,084	1,086	1,089	1,096	1,092	1,099	1,094	1,095
Feeder PbP	1,244	1,242	1,234	1,230	1,232	1,239	1,236	1,242	1,256	1,252	1,236	1,231
Feeder BunnyEar	967	962	960	962	955	970	971	977	976	976	973	978
Feeder Star	966	957	957	953	949	960	964	972	969	972	971	972
DecomToolV	967	969	965	963	965	968	962	965	970	963	964	965

Starting Month

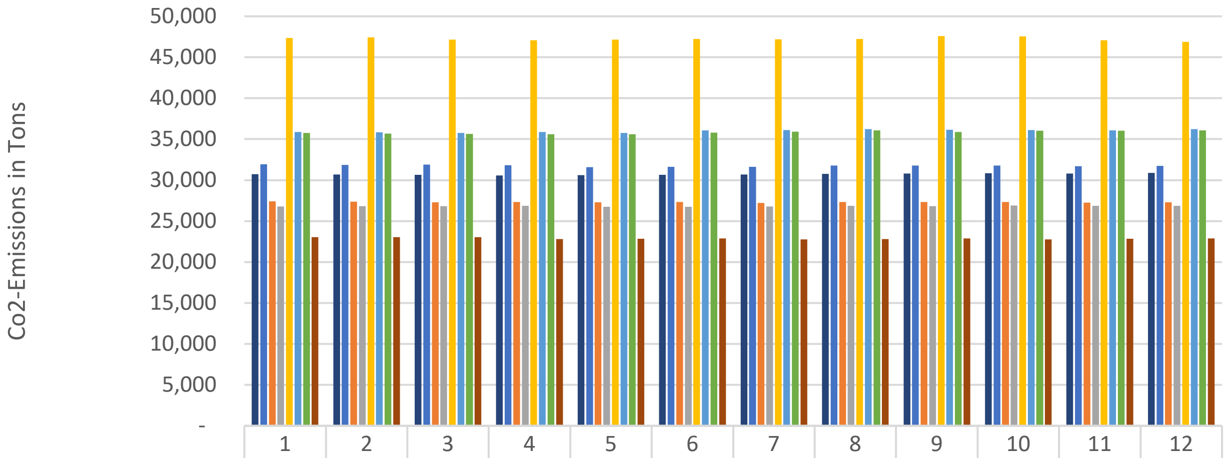
Figure 7: average runtime of different configurations at a distance of 250 km over a period of one year – complete supply chain (1-12 equals the months from January to December)



	1	2	3	4	5	6	7	8	9	10	11	12
BaseStudy	203.9M	203.4M	202.7M	201.9M	202.4M	203.1M	202.9M	204.0M	204.6M	205.1M	204.4M	205.5M
Pendulum PbP	246.3M	245.3M	245.8M	244.7M	241.1M	241.6M	241.1M	243.8M	244.0M	244.0M	242.4M	243.0M
Pendulum BunnyEar	212.4M	211.7M	210.2M	211.3M	210.4M	211.0M	209.0M	211.0M	210.5M	210.5M	209.5M	209.8M
Pendulum Star	203.1M	203.7M	203.8M	204.6M	202.8M	202.8M	203.5M	204.6M	203.5M	205.0M	204.1M	204.4M
Feeder PbP	280.6M	280.8M	278.7M	277.9M	278.6M	279.7M	279.0M	280.0M	283.1M	282.4M	278.6M	277.1M
Feeder BunnyEar	208.9M	208.2M	207.6M	208.5M	207.2M	210.1M	210.7M	211.5M	211.1M	211.0M	210.4M	211.6M
Feeder Star	206.4M	205.1M	205.0M	204.5M	204.2M	206.1M	207.0M	208.4M	207.3M	208.4M	208.2M	208.5M
DecomToolV	157.4M	158.0M	158.0M	154.4M	155.4M	155.4M	153.8M	154.8M	155.8M	154.3M	155.2M	155.9M

Figure 8: average costs of different configurations at a distance of 250 km over a period of one year – complete supply chain (1-12 equals the months from January to December)

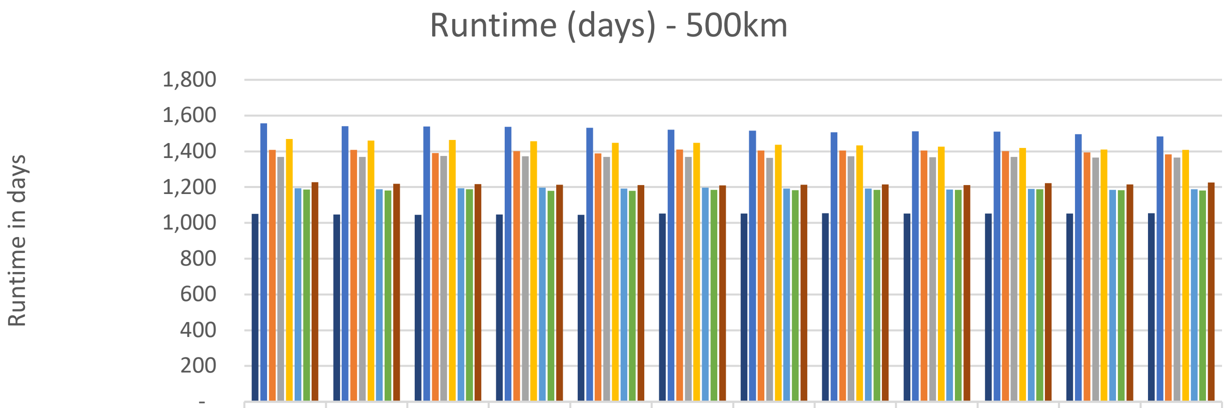
CO2-Emissions (to) - 250km



	1	2	3	4	5	6	7	8	9	10	11	12
BaseStudy	30,720	30,681	30,648	30,579	30,611	30,658	30,666	30,744	30,784	30,837	30,787	30,868
Pendulum PbP	31,921	31,853	31,878	31,804	31,578	31,633	31,607	31,779	31,790	31,789	31,690	31,731
Pendulum BunnyEar	27,420	27,366	27,273	27,333	27,278	27,326	27,212	27,342	27,311	27,316	27,249	27,273
Pendulum Star	26,780	26,804	26,804	26,843	26,740	26,747	26,789	26,867	26,811	26,893	26,841	26,862
Feeder PbP	47,367	47,412	47,160	47,057	47,173	47,249	47,196	47,247	47,594	47,551	47,080	46,880
Feeder BunnyEar	35,889	35,845	35,741	35,867	35,740	36,082	36,120	36,245	36,135	36,124	36,081	36,235
Feeder Star	35,764	35,677	35,642	35,586	35,595	35,785	35,906	36,053	35,893	36,030	36,041	36,051
DecomToolV	23,027	23,043	23,052	22,809	22,839	22,860	22,764	22,793	22,878	22,746	22,845	22,864

Starting Month

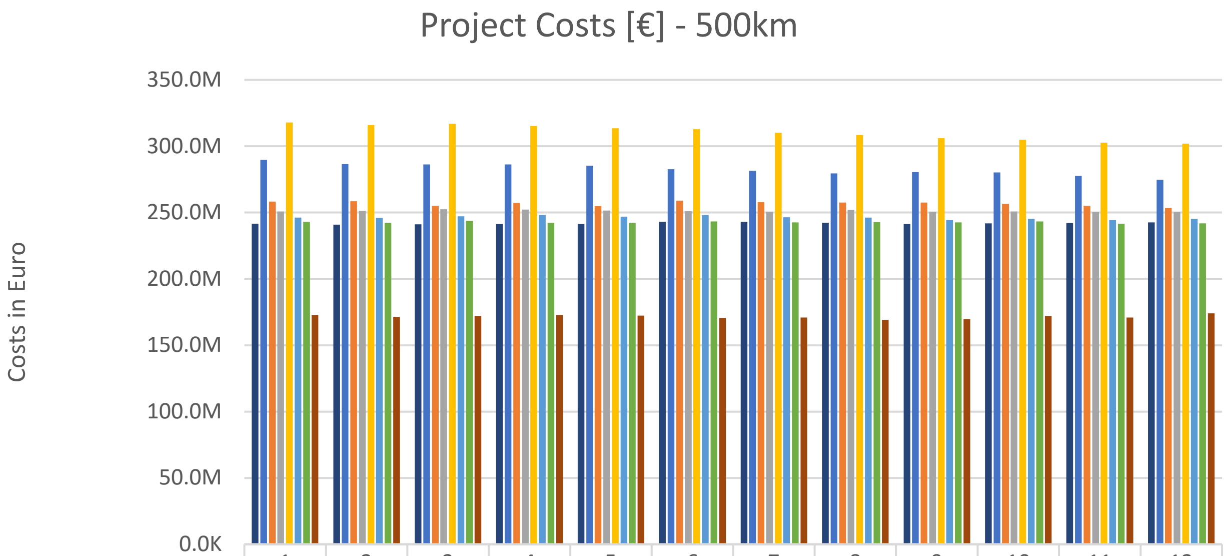
Figure 9: average CO_2-Emissions of different configurations at a distance of 250 km over a period of one year – complete supply chain (1-12 equals the months from January to December)



	1	2	3	4	5	6	7	8	9	10	11	12
BaseStudy	1,051	1,047	1,046	1,046	1,044	1,052	1,052	1,054	1,052	1,053	1,052	1,054
Pendulum PbP	1,557	1,540	1,540	1,538	1,532	1,521	1,515	1,507	1,512	1,510	1,497	1,483
Pendulum BunnyEar	1,409	1,408	1,391	1,402	1,389	1,411	1,405	1,405	1,406	1,401	1,393	1,384
Pendulum Star	1,368	1,369	1,375	1,373	1,368	1,368	1,364	1,373	1,367	1,368	1,365	1,365
Feeder PbP	1,469	1,460	1,464	1,456	1,448	1,447	1,437	1,433	1,425	1,420	1,411	1,408
Feeder BunnyEar	1,193	1,189	1,194	1,197	1,191	1,197	1,192	1,192	1,187	1,190	1,185	1,189
Feeder Star	1,186	1,181	1,188	1,180	1,179	1,185	1,183	1,185	1,185	1,189	1,182	1,182
DecomToolV	1,227	1,218	1,217	1,213	1,212	1,210	1,213	1,215	1,211	1,222	1,216	1,226

Starting Month

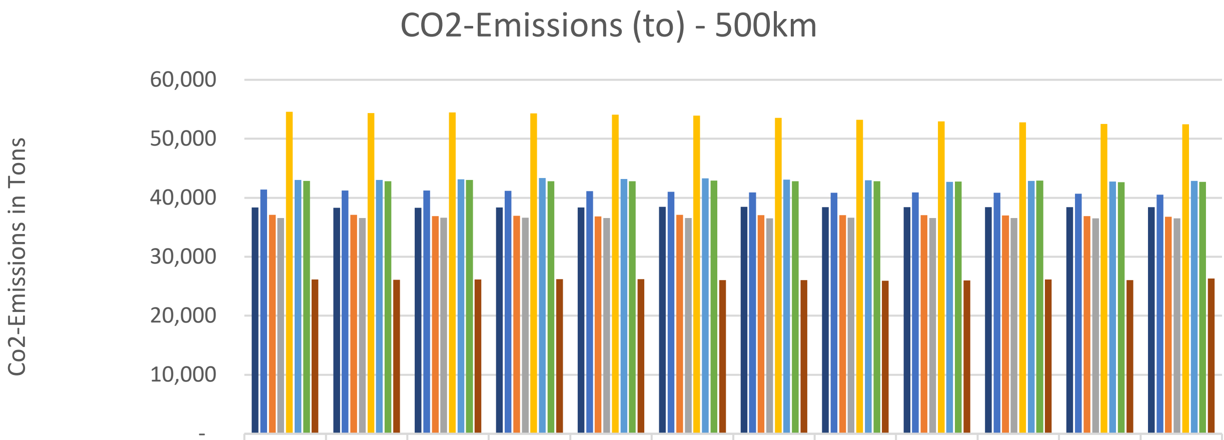
Figure 10: average runtime of different configurations at a distance of 500 km over a period of one year – complete supply chain (1-12 equals the months from January to December)



	1	2	3	4	5	6	7	8	9	10	11	12
BaseStudy	241.7M	241.0M	241.1M	241.4M	241.3M	243.2M	243.0M	242.4M	241.4M	242.0M	242.2M	242.5M
Pendulum PbP	289.7M	286.6M	286.4M	286.2M	285.3M	282.6M	281.6M	279.6M	280.5M	280.2M	277.5M	274.7M
Pendulum BunnyEar	258.3M	258.6M	255.0M	257.3M	254.9M	258.9M	257.9M	257.7M	257.5M	256.6M	255.2M	253.4M
Pendulum Star	250.9M	251.3M	252.6M	252.2M	251.6M	251.1M	250.5M	252.0M	250.6M	250.9M	250.2M	250.4M
Feeder PbP	317.9M	316.0M	317.0M	315.3M	313.6M	312.8M	310.1M	308.4M	306.2M	304.8M	302.7M	302.1M
Feeder BunnyEar	246.3M	245.9M	247.1M	248.2M	247.0M	248.1M	246.5M	246.1M	244.4M	245.3M	244.3M	245.2M
Feeder Star	243.1M	242.4M	243.9M	242.3M	242.3M	243.4M	242.6M	242.8M	242.6M	243.4M	241.6M	241.8M
DecomToolV	172.8M	171.4M	172.2M	172.8M	172.3M	170.7M	170.9M	169.3M	169.7M	172.1M	170.9M	174.1M

Starting Month

Figure 11: average costs of different configurations at a distance of 500 km over a period of one year – complete supply chain (1-12 equals the months from January to December)

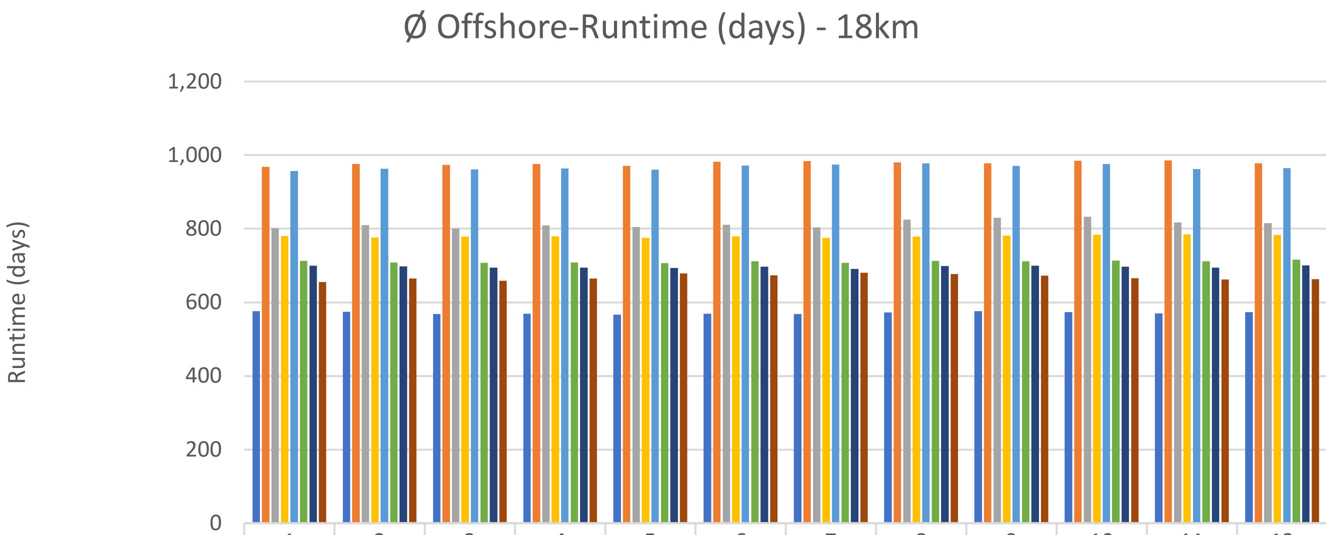


	1	2	3	4	5	6	7	8	9	10	11	12
BaseStudy	38,360	38,318	38,318	38,352	38,368	38,459	38,476	38,433	38,391	38,397	38,394	38,413
Pendulum PbP	41,421	41,227	41,217	41,193	41,138	40,994	40,936	40,835	40,886	40,865	40,702	40,539
Pendulum BunnyEar	37,087	37,088	36,884	36,975	36,869	37,116	37,061	37,062	37,049	36,992	36,908	36,802
Pendulum Star	36,559	36,571	36,647	36,615	36,569	36,565	36,531	36,634	36,549	36,564	36,524	36,533
Feeder PbP	54,558	54,348	54,480	54,293	54,105	53,940	53,567	53,250	52,962	52,773	52,517	52,444
Feeder BunnyEar	43,021	43,010	43,158	43,344	43,203	43,294	43,098	42,988	42,722	42,863	42,731	42,881
Feeder Star	42,863	42,816	43,026	42,815	42,814	42,914	42,821	42,803	42,773	42,891	42,660	42,676
DecomToolV	26,167	26,119	26,154	26,213	26,186	26,064	26,071	25,955	25,982	26,138	26,059	26,303

Starting Month

Figure 12: average CO_2-Emissions of different configurations at a distance of 500 km over a period of one year – complete supply chain (1-12 equals the months from January to December)

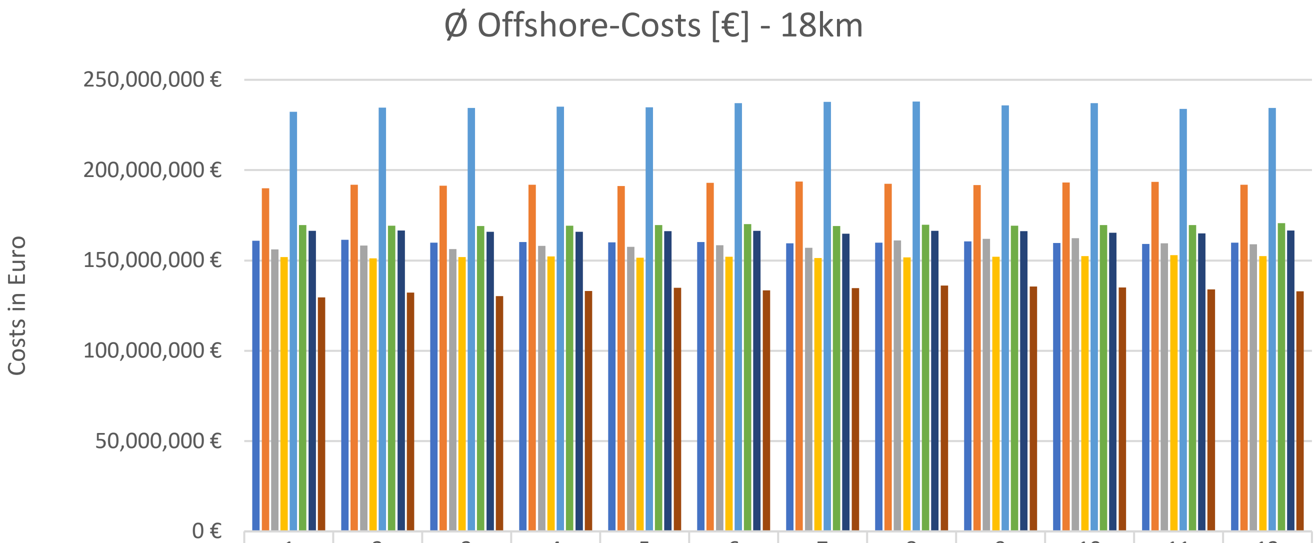
Appendix 2: Offshore



	1	2	3	4	5	6	7	8	9	10	11	12
BaseStudy	576	574	568	569	566	570	568	573	576	574	570	573
Pendulum PbP	968	976	973	976	971	982	984	980	978	984	986	978
Pendulum BunnyEar	801	810	800	809	805	811	804	825	830	832	817	815
Pendulum Star	781	776	779	780	775	780	775	779	782	784	785	783
Feeder PbP	957	963	962	964	960	972	974	977	971	976	962	964
Feeder BunnyEar	713	708	707	708	707	712	708	713	712	713	712	716
Feeder Star	700	698	695	695	694	697	691	699	700	697	694	700
DecomToolV	656	664	659	665	679	674	680	677	672	665	662	663

Starting Month

Figure 13: average runtime of different configurations at a distance of 18 km over a period of one year – offshore (1-12 equals the months from January to December)



	1	2	3	4	5	6	7	8	9	10	11	12
BaseStudy	161.0M	161.3M	159.8M	160.2M	160.1M	160.3M	159.5M	159.9M	160.5M	159.6M	159.1M	159.9M
Pendulum PbP	189.9M	191.9M	191.4M	191.9M	191.2M	193.1M	193.6M	192.5M	191.8M	193.2M	193.6M	191.8M
Pendulum BunnyEar	156.1M	158.2M	156.2M	158.0M	157.5M	158.4M	157.0M	161.0M	161.9M	162.4M	159.4M	158.9M
Pendulum Star	151.9M	151.2M	151.9M	152.1M	151.6M	152.1M	151.3M	151.6M	152.0M	152.5M	152.9M	152.4M
Feeder PbP	232.4M	234.7M	234.5M	235.2M	234.7M	237.0M	237.7M	237.9M	235.9M	237.1M	233.9M	234.4M
Feeder BunnyEar	169.7M	169.2M	169.0M	169.3M	169.6M	170.1M	169.1M	169.8M	169.2M	169.6M	169.5M	170.6M
Feeder Star	166.4M	166.6M	165.8M	165.8M	166.2M	166.3M	164.8M	166.3M	166.2M	165.4M	165.0M	166.6M
DecomToolV	129.6M	132.3M	130.3M	133.0M	134.9M	133.5M	134.7M	136.1M	135.6M	135.0M	134.0M	132.9M

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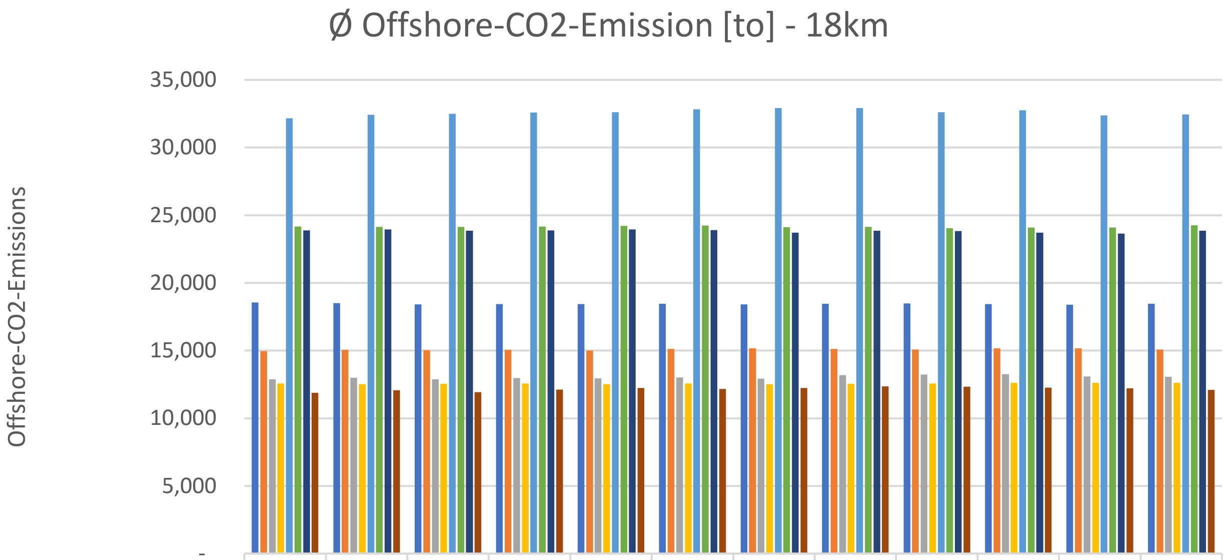
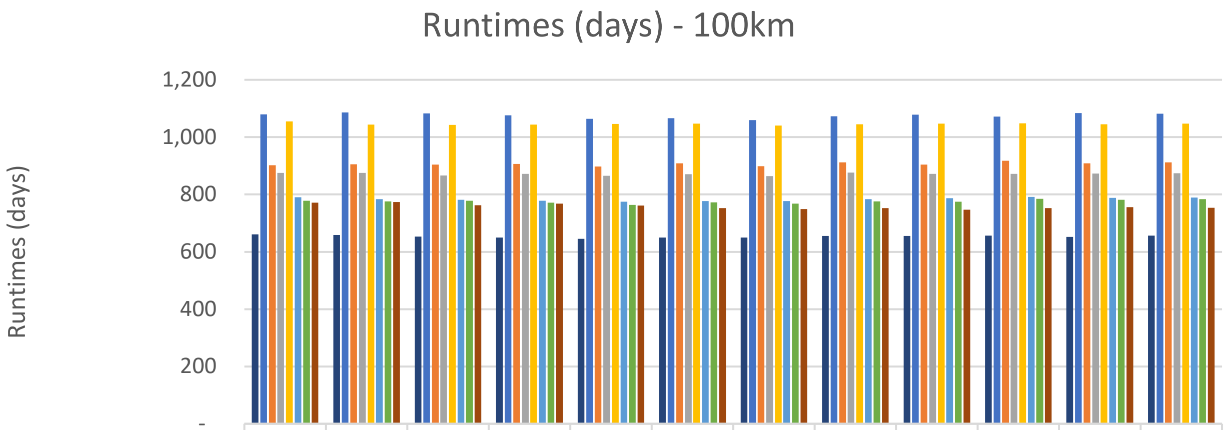
Figure 14: average costs of different configurations at a distance of 18 km over a period of one year – offshore (1-12 equals the months from January to December)



	1	2	3	4	5	6	7	8	9	10	11	12
BaseStudy	18,544	18,519	18,422	18,446	18,435	18,452	18,418	18,460	18,482	18,443	18,400	18,463
Pendulum PbP	14,963	15,064	15,029	15,057	15,011	15,135	15,171	15,118	15,070	15,160	15,175	15,068
Pendulum BunnyEar	12,878	12,991	12,873	12,973	12,941	13,008	12,926	13,173	13,226	13,259	13,078	13,054
Pendulum Star	12,569	12,519	12,556	12,566	12,530	12,572	12,524	12,555	12,576	12,614	12,627	12,607
Feeder PbP	32,172	32,432	32,491	32,597	32,602	32,822	32,912	32,912	32,618	32,757	32,371	32,452
Feeder BunnyEar	24,155	24,150	24,135	24,174	24,210	24,231	24,106	24,147	24,045	24,096	24,098	24,267
Feeder Star	23,876	23,955	23,846	23,869	23,940	23,902	23,705	23,858	23,824	23,706	23,635	23,867
DecomToolV	11,884	12,071	11,926	12,115	12,247	12,176	12,246	12,357	12,337	12,270	12,211	12,104

Starting Month

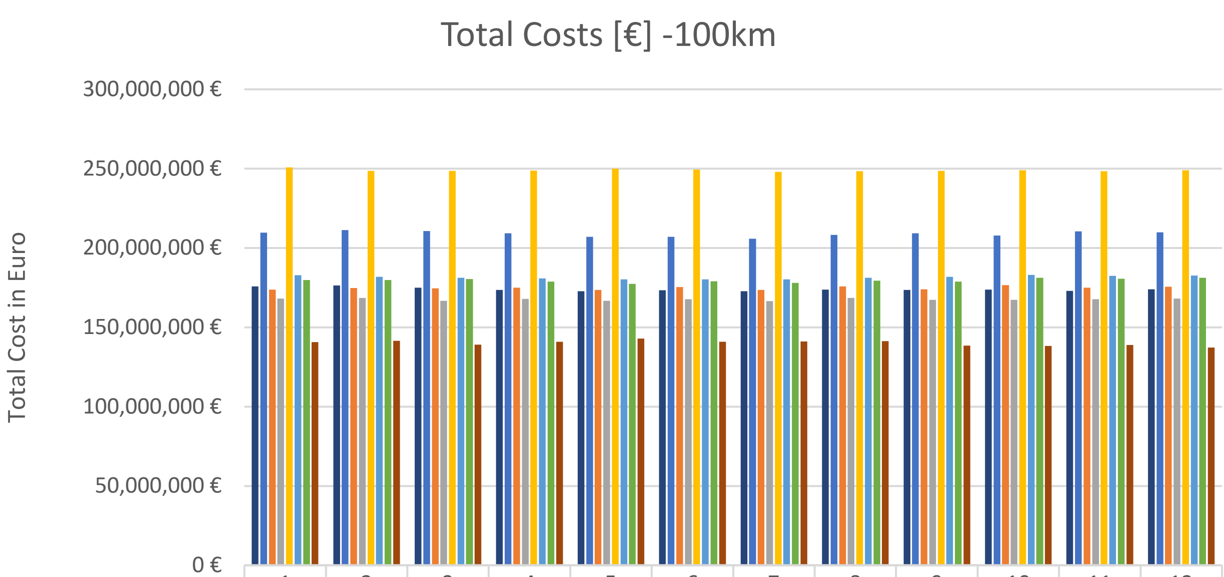
Figure 15: average CO_2-Emissions of different configurations at a distance of 18 km over a period of one year – offshore (1-12 equals the months from January to December)



Starting Month	1	2	3	4	5	6	7	8	9	10	11	12
BaseStudy	661	659	653	650	645	650	649	655	656	656	652	656
Pendulum PbP	1,080	1,086	1,083	1,076	1,063	1,066	1,059	1,072	1,078	1,071	1,084	1,081
Pendulum BunnyEar	903	906	905	907	898	909	899	912	904	917	909	912
Pendulum Star	875	875	866	872	865	871	864	876	872	872	873	875
Feeder PbP	1,055	1,044	1,043	1,044	1,047	1,047	1,041	1,045	1,047	1,048	1,045	1,047
Feeder Bunny Ear	790	784	781	779	774	777	777	783	787	791	788	789
Feeder Star	778	776	778	771	764	773	768	776	775	784	781	784
DecomToolV	772	773	762	768	762	753	749	752	747	753	756	753

Starting Month

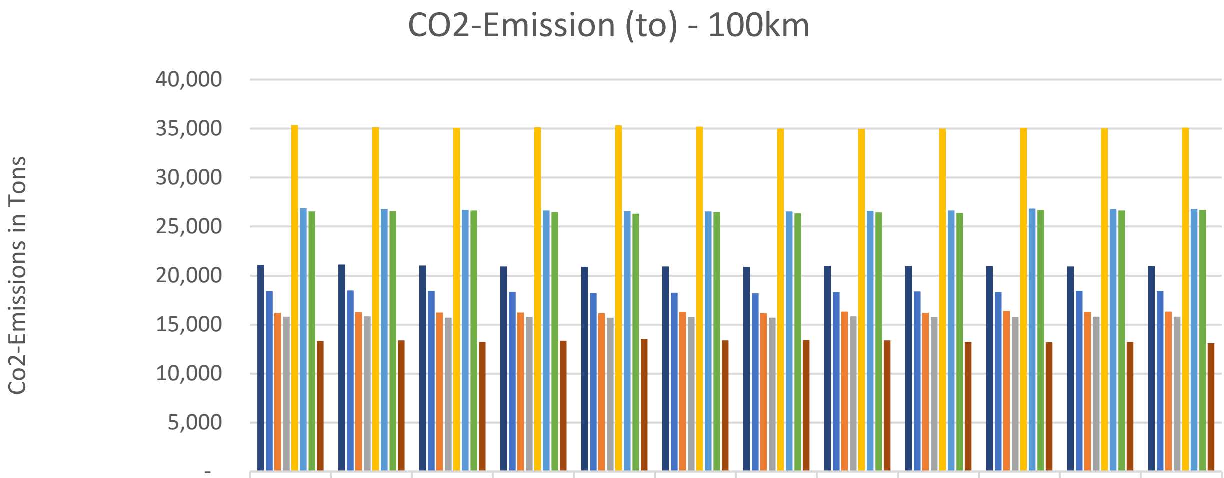
Figure 16: average runtime of different configurations at a distance of 100 km over a period of one year – offshore (1-12 equals the months from January to December)



	1	2	3	4	5	6	7	8	9	10	11	12
BaseStudy	175.8M	176.3M	174.9M	173.5M	172.8M	173.4M	172.7M	173.8M	173.6M	173.8M	173.0M	173.9M
Pendulum PbP	209.6M	211.3M	210.7M	209.3M	207.1M	207.1M	205.9M	208.2M	209.2M	207.9M	210.4M	209.9M
Pendulum BunnyEar	173.7M	174.7M	174.5M	175.0M	173.6M	175.3M	173.5M	175.8M	173.9M	176.6M	175.0M	175.6M
Pendulum Star	168.1M	168.6M	166.7M	167.8M	166.8M	167.6M	166.4M	168.5M	167.4M	167.3M	167.8M	168.1M
Feeder PbP	250.9M	248.7M	248.5M	248.9M	250.1M	249.5M	248.0M	248.3M	248.5M	249.0M	248.4M	248.9M
Feeder BunnyEar	182.8M	181.8M	181.3M	180.8M	180.2M	180.2M	180.2M	181.2M	181.8M	183.0M	182.3M	182.6M
Feeder Star	179.8M	179.8M	180.4M	178.9M	177.4M	179.0M	178.0M	179.3M	178.7M	181.2M	180.6M	181.2M
DecomToolV	140.7M	141.4M	139.0M	140.8M	142.9M	141.0M	141.1M	141.2M	138.5M	138.3M	138.8M	137.2M

Starting Month

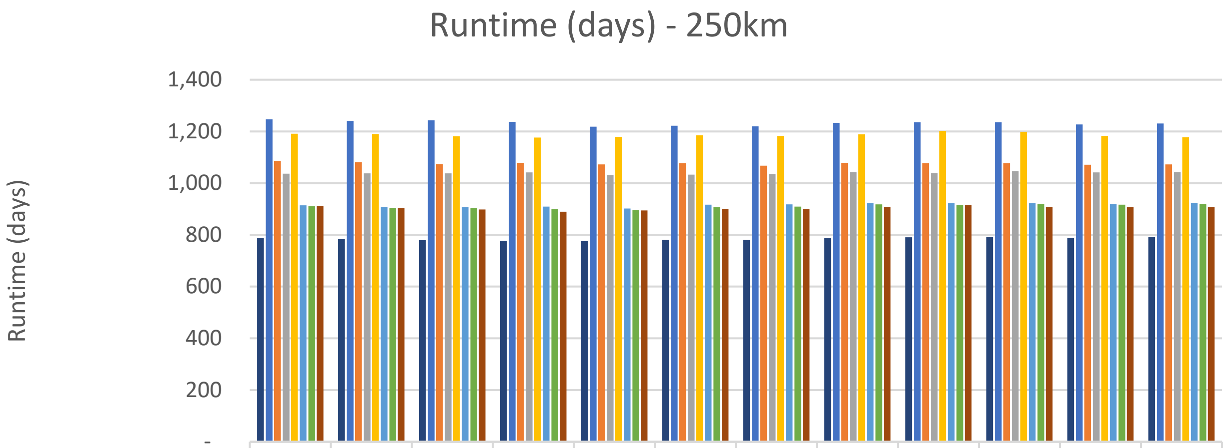
Figure 17: average costs of different configurations at a distance of 100 km over a period of one year – offshore (1-12 equals the months from January to December)



	1	2	3	4	5	6	7	8	9	10	11	12
BaseStudy	21,080	21,112	21,018	20,932	20,882	20,933	20,908	20,982	20,964	20,974	20,922	20,976
Pendulum PbP	18,402	18,490	18,451	18,361	18,228	18,240	18,172	18,327	18,379	18,305	18,449	18,424
Pendulum Bunny Ear	16,204	16,253	16,230	16,245	16,169	16,287	16,177	16,328	16,212	16,376	16,284	16,322
Pendulum Star	15,813	15,829	15,714	15,776	15,692	15,761	15,703	15,840	15,762	15,763	15,793	15,815
Feeder PbP	35,352	35,125	35,087	35,151	35,340	35,210	35,006	34,982	34,996	35,061	35,055	35,089
Feeder BunnyEar	26,860	26,786	26,704	26,652	26,594	26,563	26,561	26,624	26,654	26,838	26,780	26,810
Feeder Star	26,547	26,588	26,635	26,478	26,309	26,479	26,345	26,448	26,375	26,703	26,632	26,714
DecomToolV	13,334	13,380	13,210	13,371	13,506	13,381	13,425	13,398	13,212	13,194	13,231	13,106

Starting Month

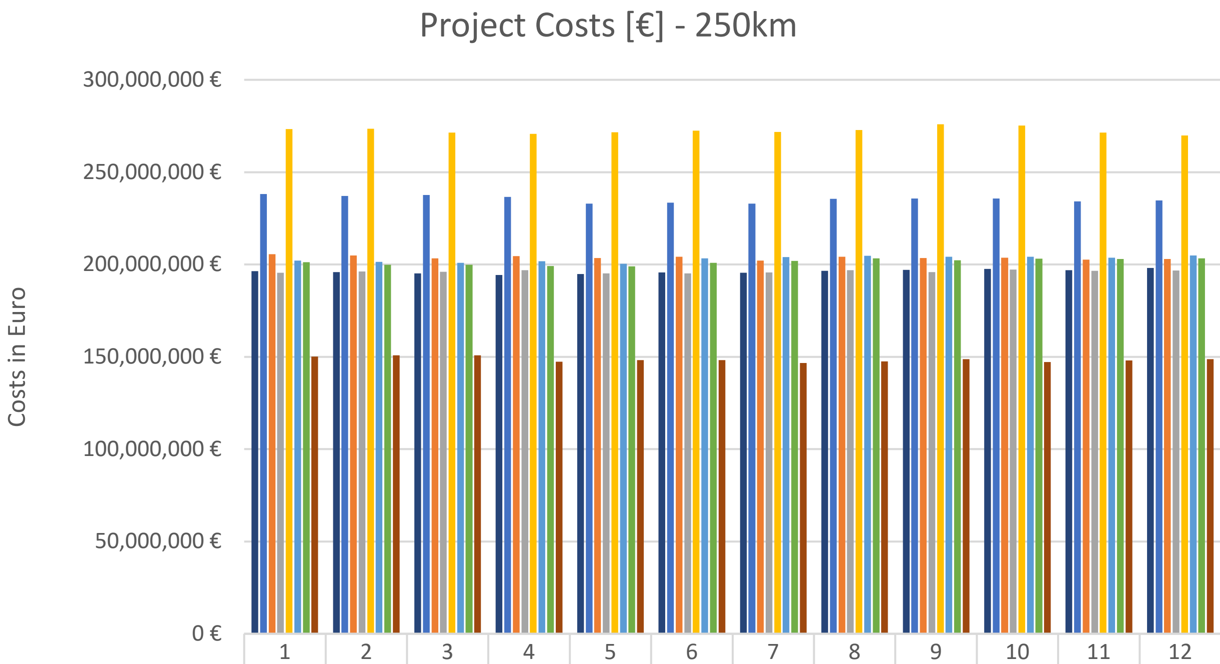
Figure 18: average CO_2-Emissions of different configurations at a distance of 100 km over a period of one year – offshore (1-12 equals the months from January to December)



	1	2	3	4	5	6	7	8	9	10	11	12
BaseStudy	788	783	779	777	776	781	781	788	790	792	789	793
Pendulum PbP	1,247	1,241	1,243	1,237	1,218	1,222	1,219	1,234	1,236	1,235	1,227	1,230
Pendulum Bunny Ear	1,086	1,081	1,074	1,079	1,073	1,078	1,068	1,078	1,077	1,078	1,072	1,073
Pendulum Star	1,036	1,038	1,038	1,042	1,031	1,033	1,036	1,043	1,039	1,046	1,041	1,042
Feeder PbP	1,191	1,189	1,181	1,177	1,179	1,186	1,183	1,189	1,203	1,199	1,183	1,178
Feeder BunnyEar	914	909	907	909	902	917	918	924	923	923	920	925
Feeder Star	911	903	903	899	896	907	910	918	916	919	917	919
DecomToolV	911	903	898	890	895	901	899	908	916	908	907	907

Starting Month

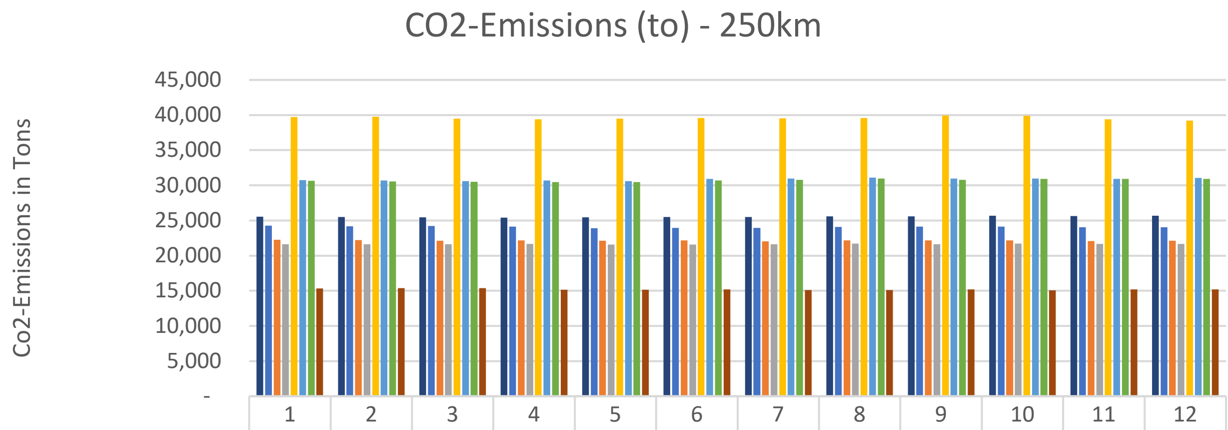
Figure 19: average runtime of different configurations at a distance of 250 km over a period of one year – offshore (1-12 equals the months from January to December)



	1	2	3	4	5	6	7	8	9	10	11	12
BaseStudy	196.4M	195.9M	195.2M	194.4M	194.8M	195.6M	195.4M	196.6M	197.1M	197.6M	197.0M	198.1M
Pendulum PbP	238.1M	237.2M	237.6M	236.5M	233.0M	233.4M	232.9M	235.6M	235.7M	235.7M	234.2M	234.8M
Pendulum BunnyEar	205.5M	204.8M	203.3M	204.5M	203.5M	204.2M	202.2M	204.1M	203.6M	203.7M	202.7M	203.0M
Pendulum Star	195.5M	196.1M	196.1M	196.9M	195.2M	195.1M	195.8M	196.9M	195.8M	197.3M	196.5M	196.7M
Feeder PbP	273.3M	273.6M	271.5M	270.7M	271.5M	272.5M	271.9M	272.8M	275.9M	275.1M	271.3M	269.9M
Feeder BunnyEar	202.2M	201.4M	200.8M	201.8M	200.4M	203.4M	204.0M	204.8M	204.3M	204.3M	203.7M	204.9M
Feeder Star	201.3M	199.9M	199.8M	199.2M	199.0M	200.9M	201.8M	203.2M	202.2M	203.2M	203.0M	203.4M
DecomToolV	150.2M	150.8M	150.8M	147.3M	148.2M	148.1M	146.6M	147.6M	148.7M	147.1M	148.0M	148.8M

Starting Month

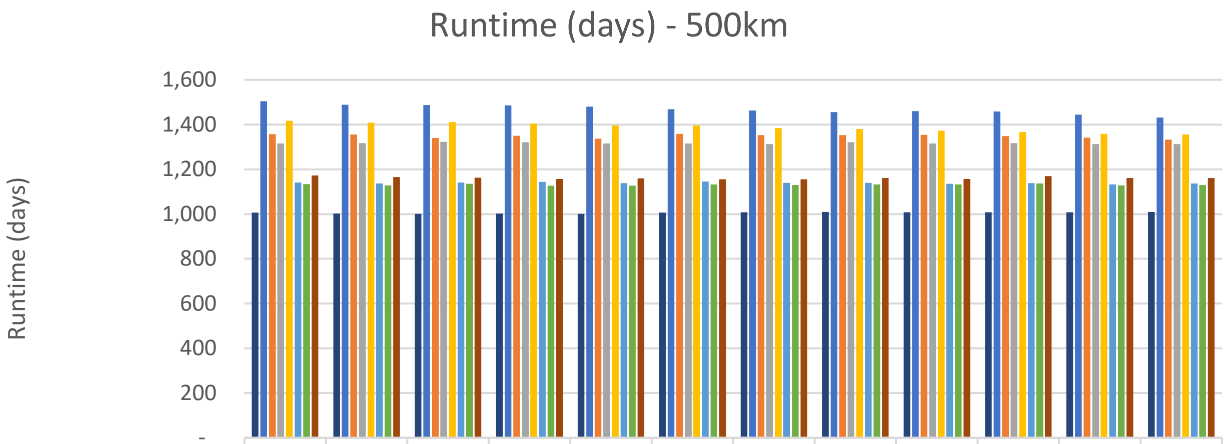
Figure 20: average costs of different configurations at a distance of 250 km over a period of one year – offshore (1-12 equals the months from January to December)



	1	2	3	4	5	6	7	8	9	10	11	12
BaseStudy	25,546	25,506	25,473	25,405	25,434	25,482	25,492	25,570	25,608	25,662	25,615	25,693
Pendulum PbP	24,246	24,182	24,204	24,130	23,905	23,959	23,934	24,106	24,113	24,113	24,018	24,056
Pendulum BunnyEar	22,261	22,207	22,115	22,175	22,119	22,169	22,054	22,185	22,152	22,160	22,092	22,115
Pendulum Star	21,605	21,632	21,626	21,669	21,565	21,573	21,612	21,693	21,635	21,718	21,668	21,684
Feeder PbP	39,697	39,742	39,491	39,385	39,506	39,580	39,528	39,576	39,926	39,880	39,409	39,209
Feeder BunnyEar	30,737	30,691	30,588	30,714	30,586	30,929	30,968	31,091	30,979	30,972	30,927	31,080
Feeder Star	30,656	30,568	30,532	30,475	30,483	30,674	30,796	30,945	30,786	30,919	30,931	30,941
DecomToolV	15,357	15,373	15,379	15,141	15,169	15,187	15,095	15,122	15,211	15,076	15,175	15,195

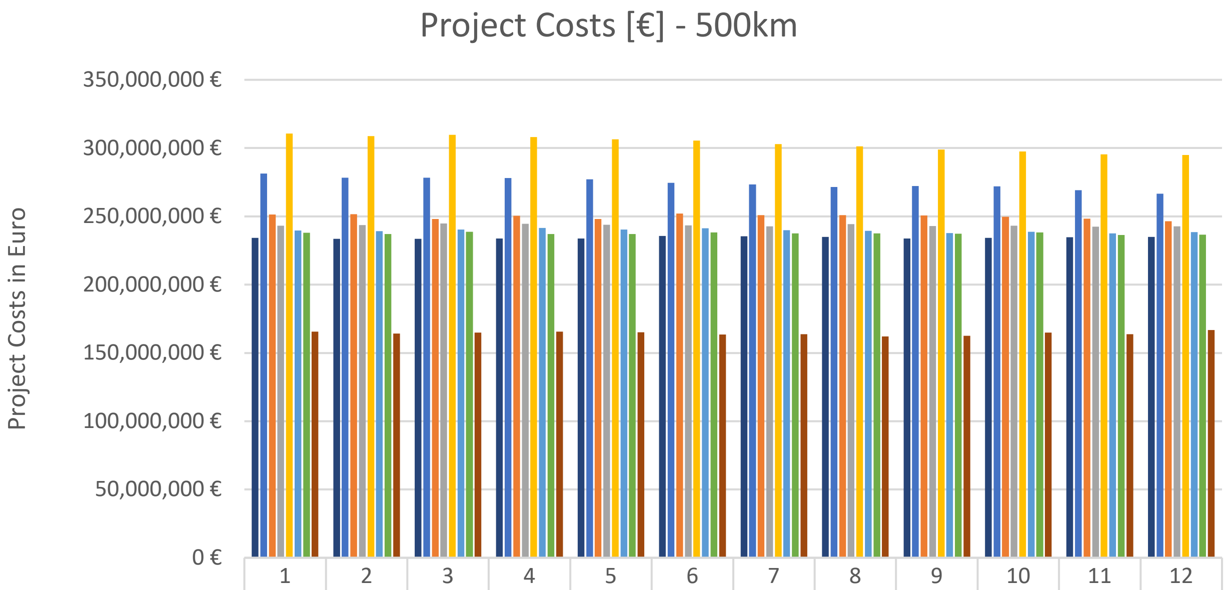
Starting Month

Figure 21: average CO_2-Emissions of different configurations at a distance of 250 km over a period of one year – offshore (1-12 equals the months from January to December)



	1	2	3	4	5	6	7	8	9	10	11	12
BaseStudy	1,007	1,003	1,001	1,002	1,000	1,007	1,007	1,009	1,008	1,009	1,007	1,009
Pendulum PbP	1,505	1,488	1,487	1,486	1,480	1,469	1,463	1,455	1,460	1,458	1,445	1,431
Pendulum BunnyEar	1,356	1,356	1,339	1,350	1,337	1,358	1,353	1,353	1,353	1,349	1,341	1,332
Pendulum Star	1,316	1,317	1,323	1,321	1,316	1,316	1,312	1,321	1,315	1,316	1,313	1,313
Feeder PbP	1,417	1,408	1,411	1,404	1,396	1,395	1,385	1,380	1,373	1,367	1,358	1,356
Feeder BunnyEar	1,141	1,137	1,141	1,144	1,139	1,145	1,140	1,140	1,135	1,138	1,133	1,136
Feeder Star	1,134	1,129	1,135	1,127	1,126	1,133	1,130	1,133	1,133	1,136	1,129	1,129
DecomToolV	1,173	1,165	1,163	1,157	1,159	1,155	1,156	1,161	1,157	1,169	1,160	1,162

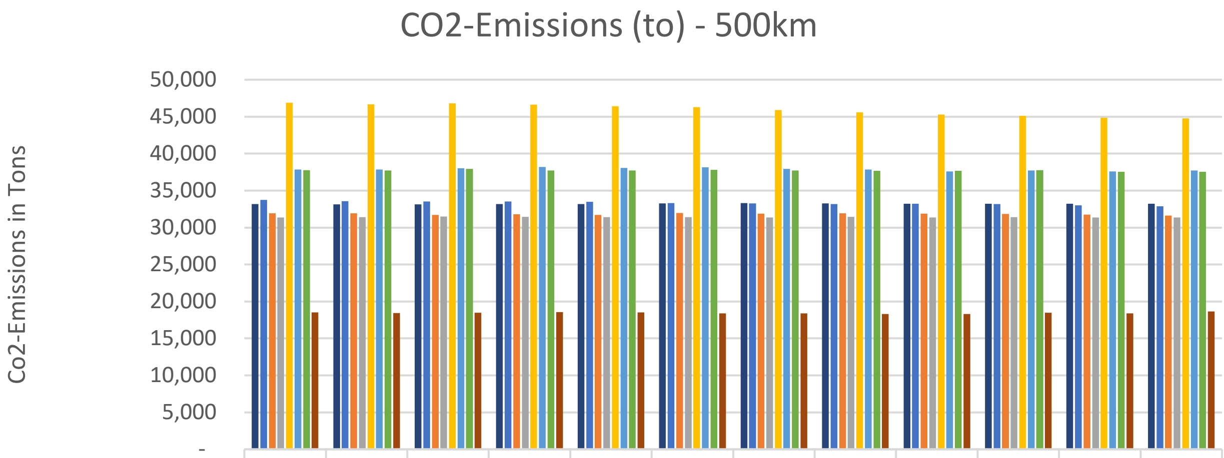
Figure 22: average runtime of different configurations at a distance of 500 km over a period of one year – offshore (1-12 equals the months from January to December)



	1	2	3	4	5	6	7	8	9	10	11	12
BaseStudy	234.2M	233.5M	233.6M	233.9M	233.9M	235.7M	235.5M	235.0M	233.9M	234.3M	234.7M	235.0M
Pendulum PbP	281.5M	278.4M	278.2M	278.1M	277.1M	274.5M	273.3M	271.4M	272.2M	272.0M	269.3M	266.5M
Pendulum BunnyEar	251.4M	251.6M	248.2M	250.4M	248.0M	252.1M	251.0M	250.8M	250.6M	249.8M	248.3M	246.5M
Pendulum Star	243.2M	243.7M	244.9M	244.5M	243.9M	243.5M	242.8M	244.3M	242.9M	243.2M	242.6M	242.6M
Feeder PbP	310.7M	308.9M	309.7M	308.2M	306.4M	305.6M	302.9M	301.2M	299.0M	297.6M	295.5M	294.9M
Feeder BunnyEar	239.6M	239.2M	240.3M	241.5M	240.3M	241.3M	239.9M	239.4M	237.7M	238.6M	237.5M	238.4M
Feeder Star	237.9M	237.2M	238.8M	237.1M	237.1M	238.2M	237.4M	237.6M	237.4M	238.3M	236.5M	236.6M
DecomToolV	165.7M	164.2M	164.9M	165.6M	165.0M	163.5M	163.7M	162.1M	162.5M	164.8M	163.8M	166.8M

Starting Month

Figure 23: average costs of different configurations at a distance of 500 km over a period of one year – offshore (1-12 equals the months from January to December)



	1	2	3	4	5	6	7	8	9	10	11	12
BaseStudy	33,185	33,143	33,144	33,177	33,195	33,286	33,300	33,261	33,214	33,219	33,220	33,238
Pendulum PbP	33,746	33,552	33,544	33,521	33,464	33,322	33,262	33,162	33,211	33,190	33,028	32,865
Pendulum BunnyEar	31,930	31,927	31,727	31,817	31,710	31,959	31,902	31,905	31,890	31,836	31,750	31,643
Pendulum Star	31,385	31,397	31,473	31,441	31,393	31,390	31,354	31,459	31,373	31,387	31,349	31,355
Feeder PbP	46,886	46,679	46,807	46,625	46,435	46,268	45,899	45,579	45,293	45,103	44,847	44,776
Feeder BunnyEar	37,867	37,857	38,003	38,190	38,050	38,140	37,947	37,834	37,570	37,711	37,576	37,728
Feeder Star	37,754	37,704	37,919	37,706	37,703	37,804	37,713	37,693	37,662	37,783	37,552	37,566
DecomToolV	18,500	18,449	18,483	18,543	18,514	18,395	18,401	18,286	18,312	18,467	18,391	18,632

Figure 24: average CO_2-Emissions of different configurations at a distance of 500 km over a period of one year – offshore (1-12 equals the months from January to December)