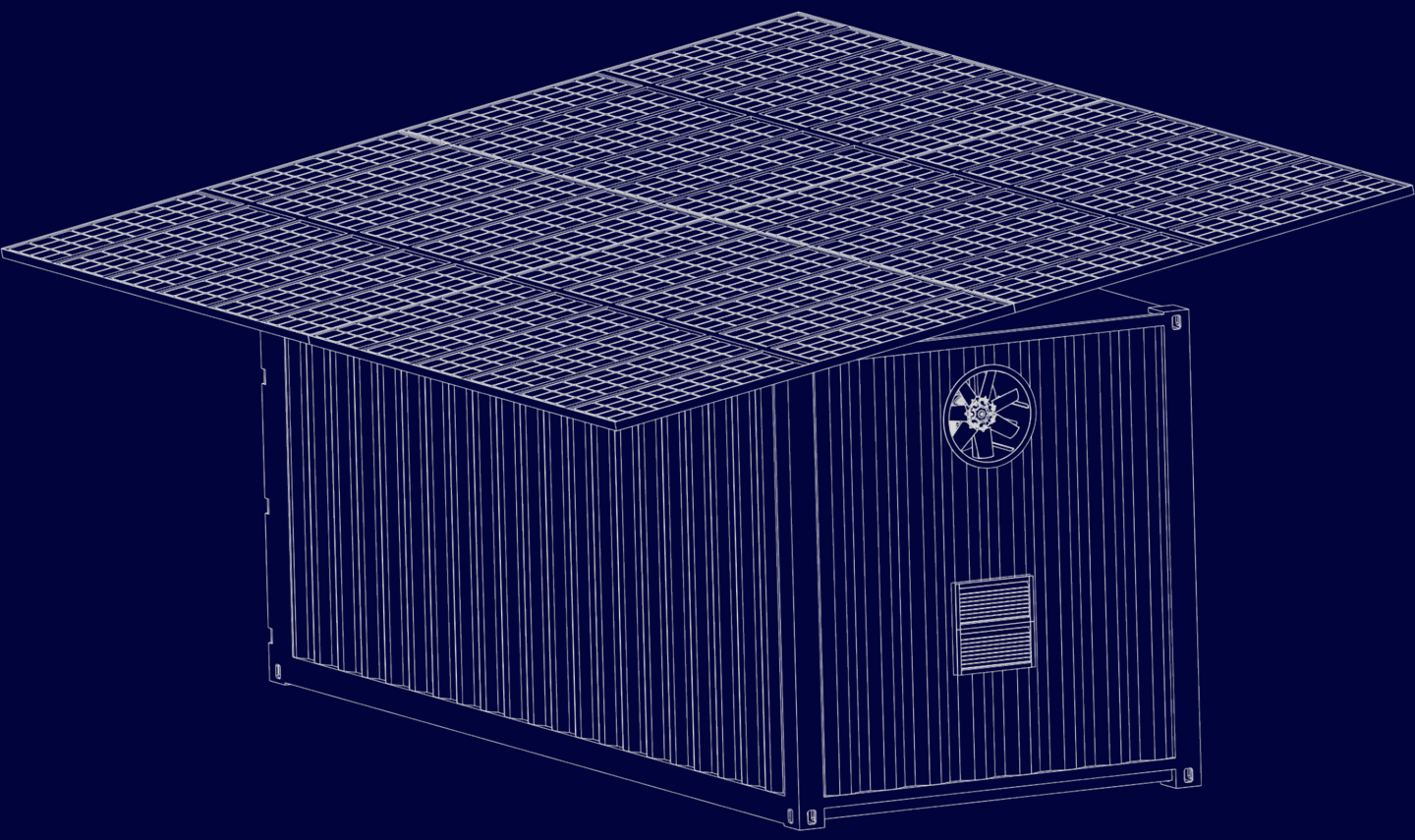
Solar-Powered Dryer for Prolonged Rainy Season



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About the Authors

Dr Marcelo Precoppe is an Associate Professor in Agricultural Engineering at the University of Greenwich, UK. He has been working on participatory technology development for over 20 years, with a focus on designing and testing efficient and affordable drying systems for small-scale farmers and processors. He is also skilled in using multiphysics simulations to optimise the performance and reliability of drying technologies in different environments.

Professor Benedict Iorzer Labe is a professor of industrial technology at the Benue State University, Nigeria. He has a wealth of experience in manufacturing technology and has developed and implemented several innovative solutions for food processing and preservation.

Acknowledgements

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Introduction

This manual is a guide on how to build a solar-powered dryer. This dryer is an innovative solution for drying agricultural products, such as fruits, vegetables, herbs, and spices. It uses photovoltaic panels to generate electricity from the sun, which is then used to heat water using electric water heaters. The heat of the water is transferred to the air using a radiator, and an electric fan creates a forced airflow through the drying chamber. An electric water pump circulates the water between the heaters and the radiator. The novelty of this dryer is that it stores energy in the form of hot water inside the heating tanks, which is much cheaper than storing energy in batteries. This allows the dryer to operate during the night and even during prolonged rainy periods, ensuring a continuous and reliable drying process. Some energy is also stored in batteries to power the fan and the water pump, but the bulk of the energy is stored in the form of hot water.

The dryer is built inside a 6 m (20 ft) shipping container, which provides a sturdy and spacious structure for the drying chamber and the other components. The walls of the container are covered with 100 mm thick thermal insulation, which reduces heat loss and improves the efficiency of the dryer. The material to be dried is loaded on trolleys, which can be easily moved in and out of the container. The dryer can process 200 kg of agricultural material in 24 hours, but its capacity varies according to the type and moisture content of the material.

The dryer was developed using multiphysics simulation, which allowed to optimise the performance and design of each component. However, this guide is not a rigid manual, but a flexible framework that points the direction of travel. It allows for all kinds of adaptations to suit the local availability of materials and components, making it easy to build and maintain.

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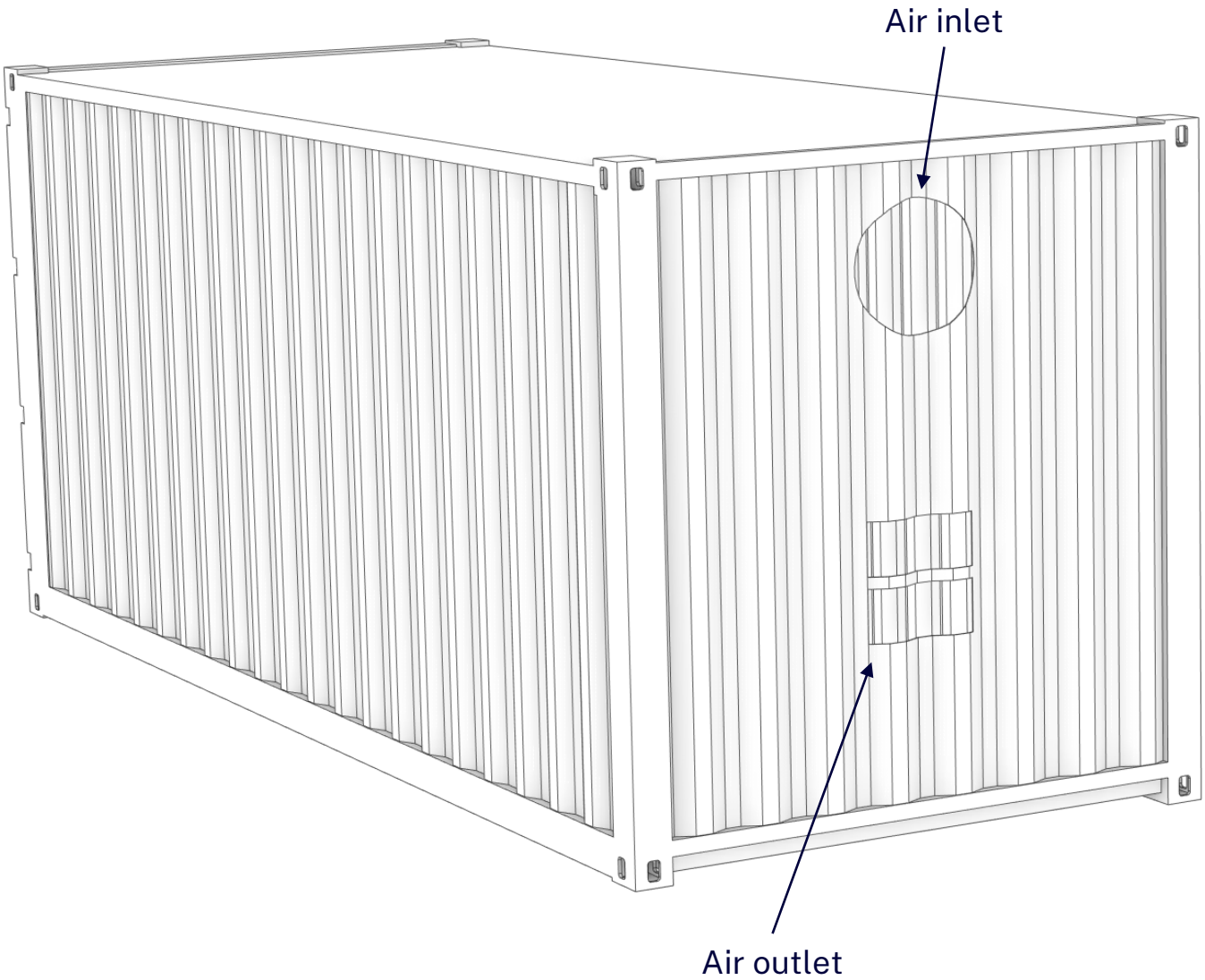
6 m (20 feet) container

A 6m (20ft) container will serve as the primary structure for housing the solar-powered dryer. To ensure proper air circulation, two openings are made at the back of the container: one for air inlet and one for air outlet. The air inlet allows fresh air to enter the drying chamber, while the air outlet allows the moist air to exit the chamber. The openings are fitted with filters to prevent dust and insects from entering the container. The exact dimensions of the openings depend on the commercially available sizes of the fan and the louvre outlet.



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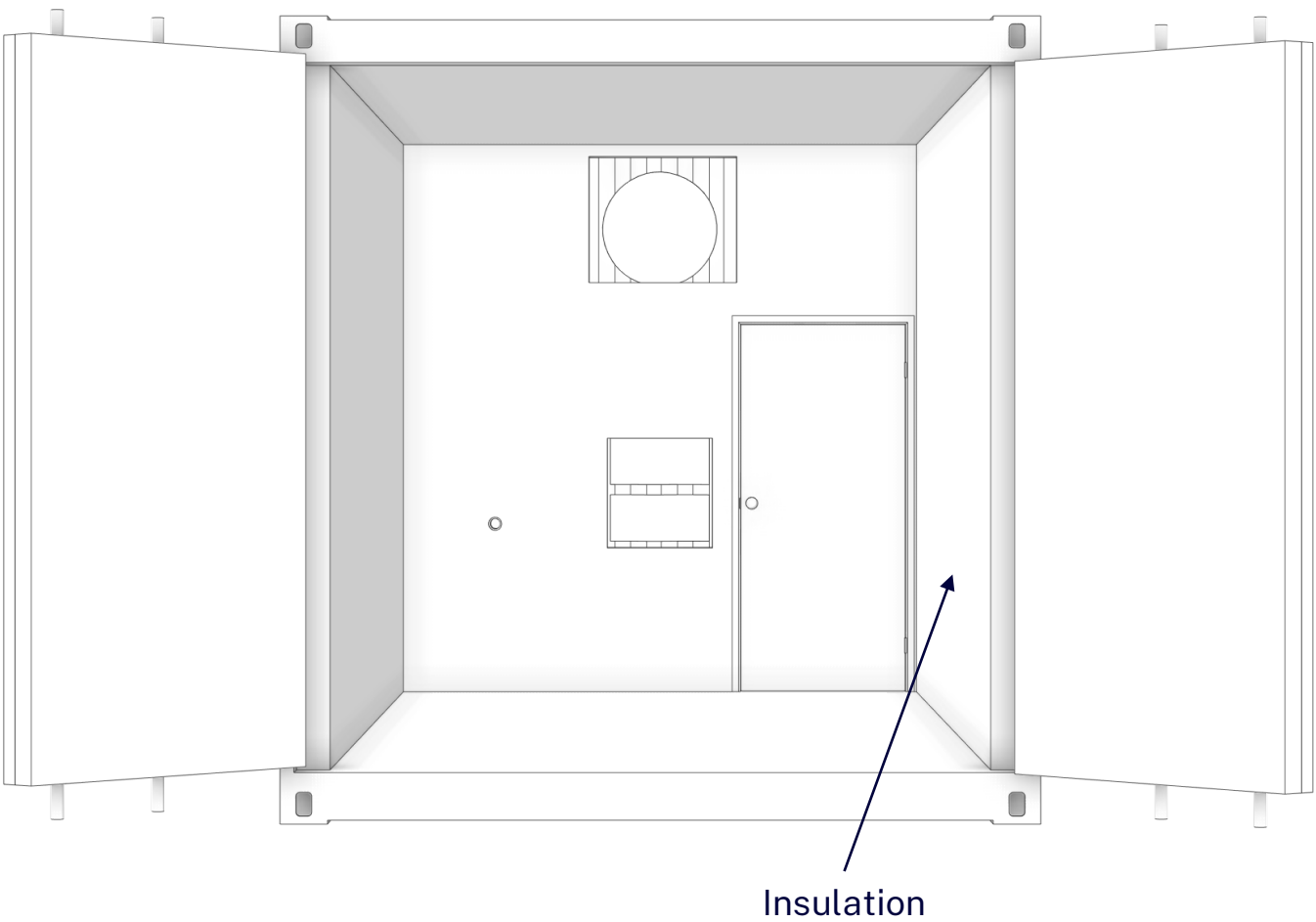
Thermal insulation

The container's walls, doors, and ceiling should be covered with a layer of thermal insulation to ensure optimal thermal performance. This insulation will act as a barrier to heat transfer, reducing heat losses. Many kinds of insulation materials can be used for this purpose, such as fibreglass, cellulose, mineral wool, foam board, and spray foam insulation. The choice of insulation material depends on the local availability and cost. To allow proper air circulation, there are openings at the back of the insulation for the air inlet and the air outlet. These openings should match the size and position of the openings on the container's wall.



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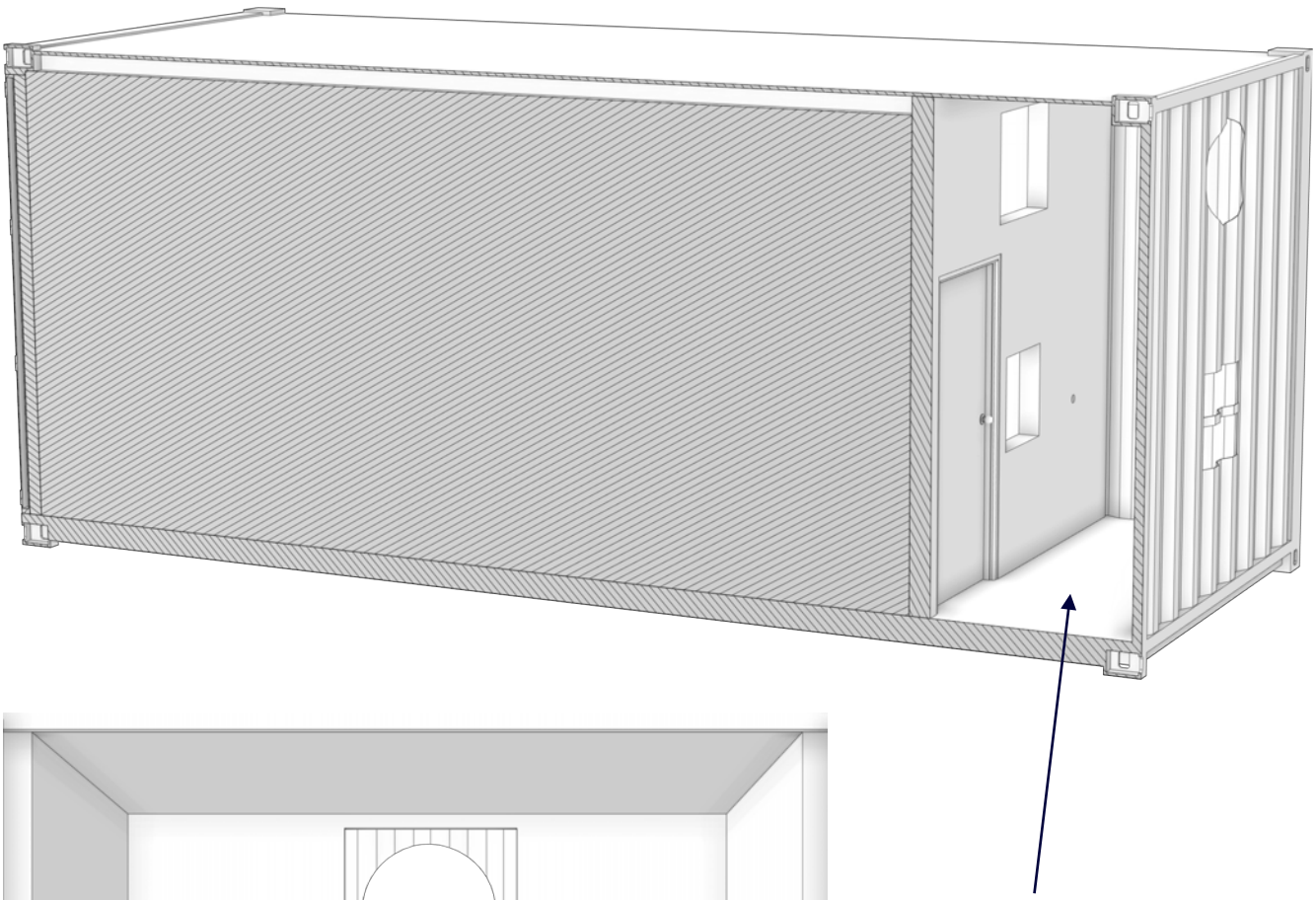
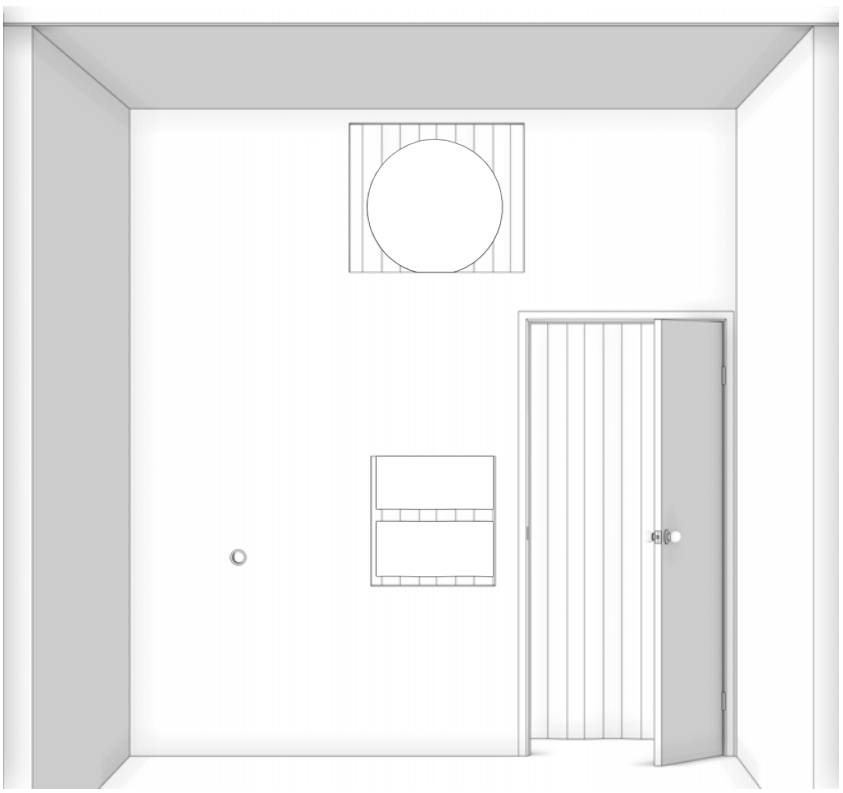
Thermal insulation

The container's insulation does not cover its entire interior but leaves a gap at the back where the water heaters will be placed. To access this area, there is a door in the back insulation. There is no specific size for this area, but it should be large enough to fit the water heaters inside it; therefore, it will depend on the size of the water heater chosen.





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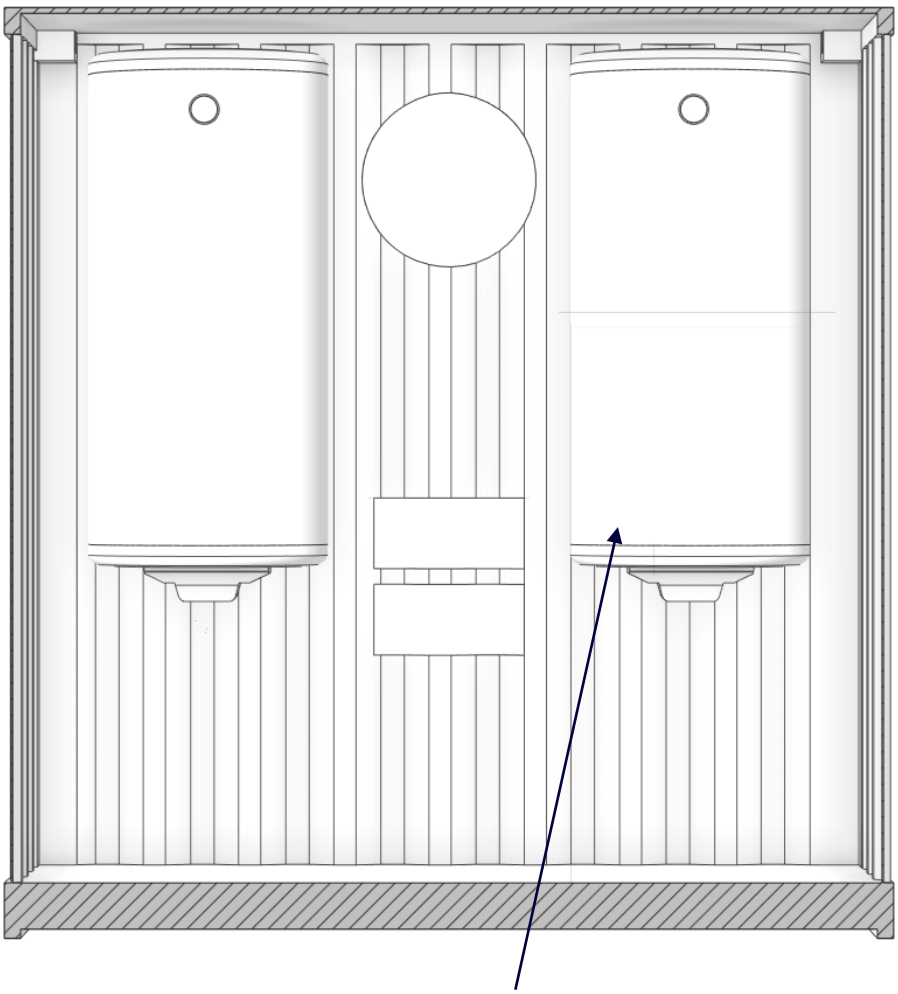
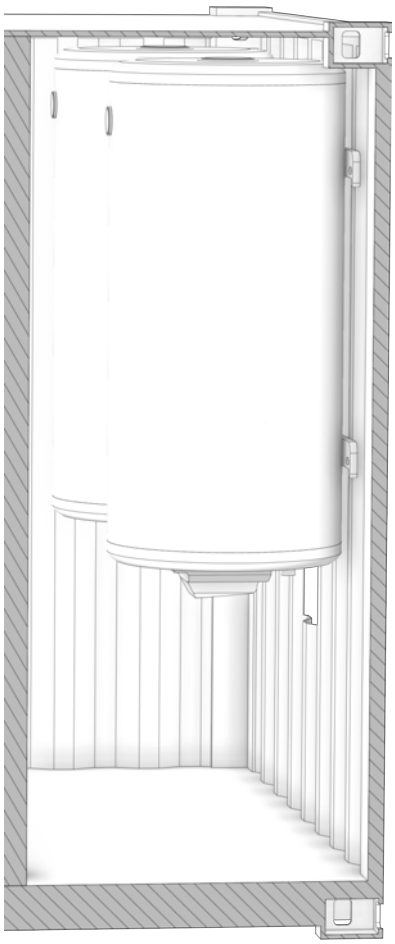
Water heater

The water heater is a key component of the solar-powered dryer, as it converts the solar energy into heat and stores it in the form of hot water. The water heater is a domestic electric water heater cylinder, installed in the back of the container, in a space that is left uninsulated for this purpose. The size and number of water heaters depend on the availability and cost of the heaters, but they should meet the following criteria: the total water volume should be at least 300 litres, and the total power should be at least 6 kW. This ensures that there is sufficient hot water to heat the air in the drying chamber and to keep the drying temperature constant. The ideal setup is to use two water heaters, each with a capacity of 150 litres and a power of 3 kW.





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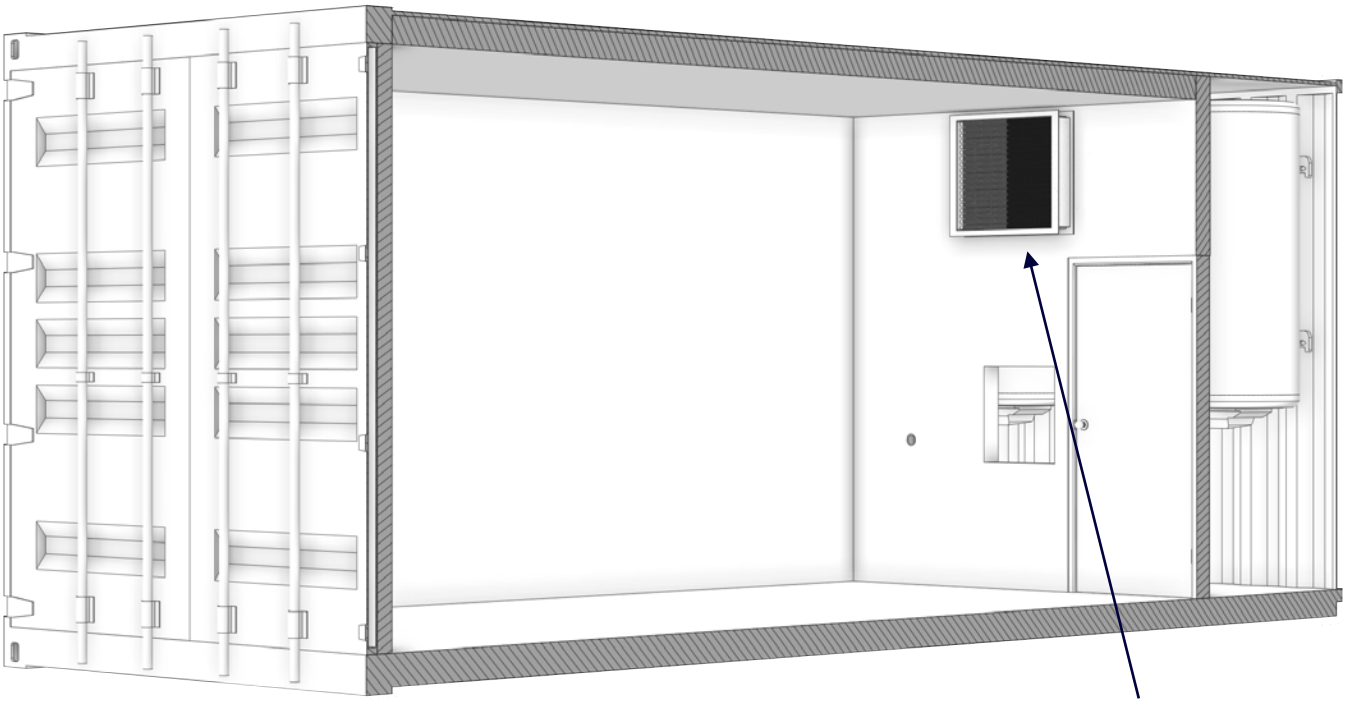
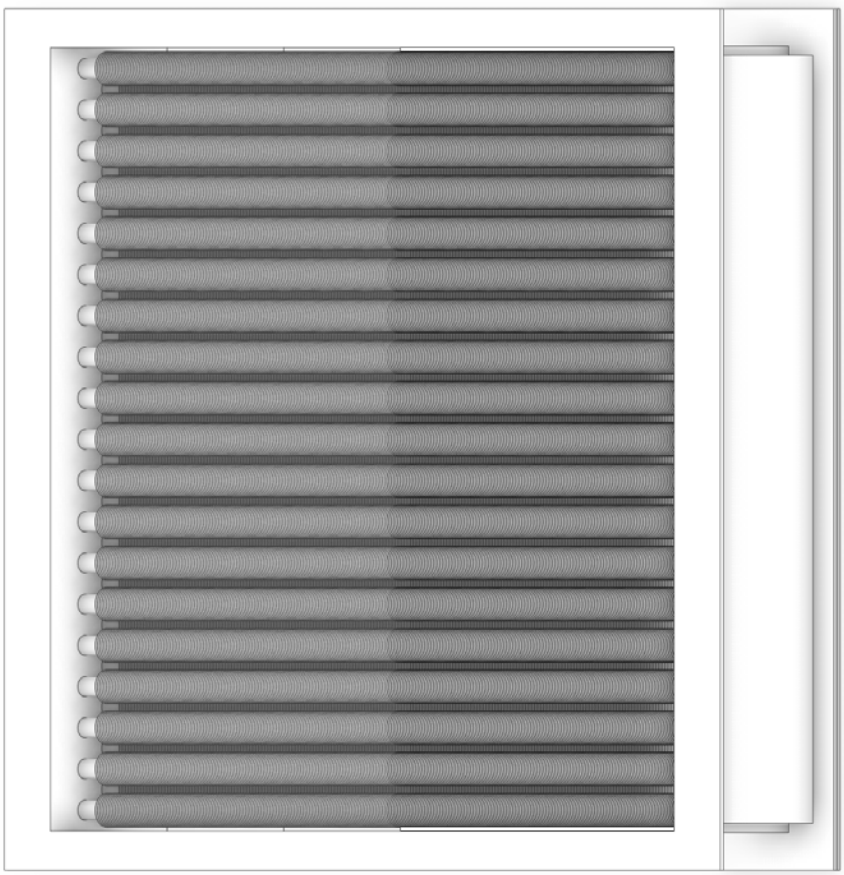
Radiator

The radiator is the device that transfers the heat from water to the drying air. It is installed on the back insulation wall. The radiator can be any off-the-shelf radiator that is designed to operate with water, such as those used in vehicles.



The radiator should be installed at the back insulating wall, positioned on the centre of the wall and as close to the ceiling insulation as possible



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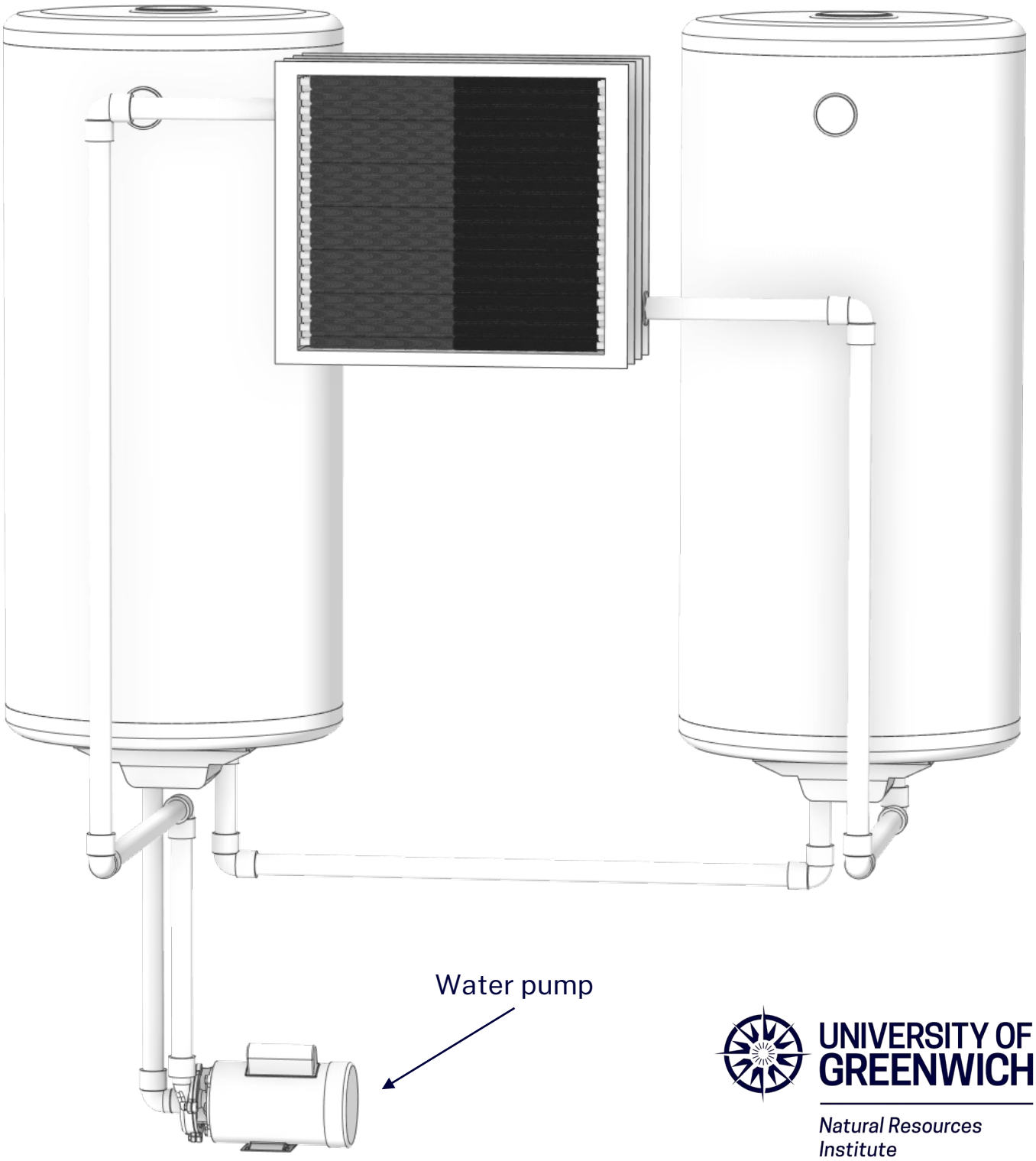
Water pump and pipes

The water pump and pipes circulate the hot water from the water heaters to the radiator. The water pump and pipes are located in the back of the container, along with the water heaters. The water tanks are connected in series, so the water flows through each tank before reaching the radiator. Any type of pump graded for constant operation and able to operate at above 90 °C can be used.



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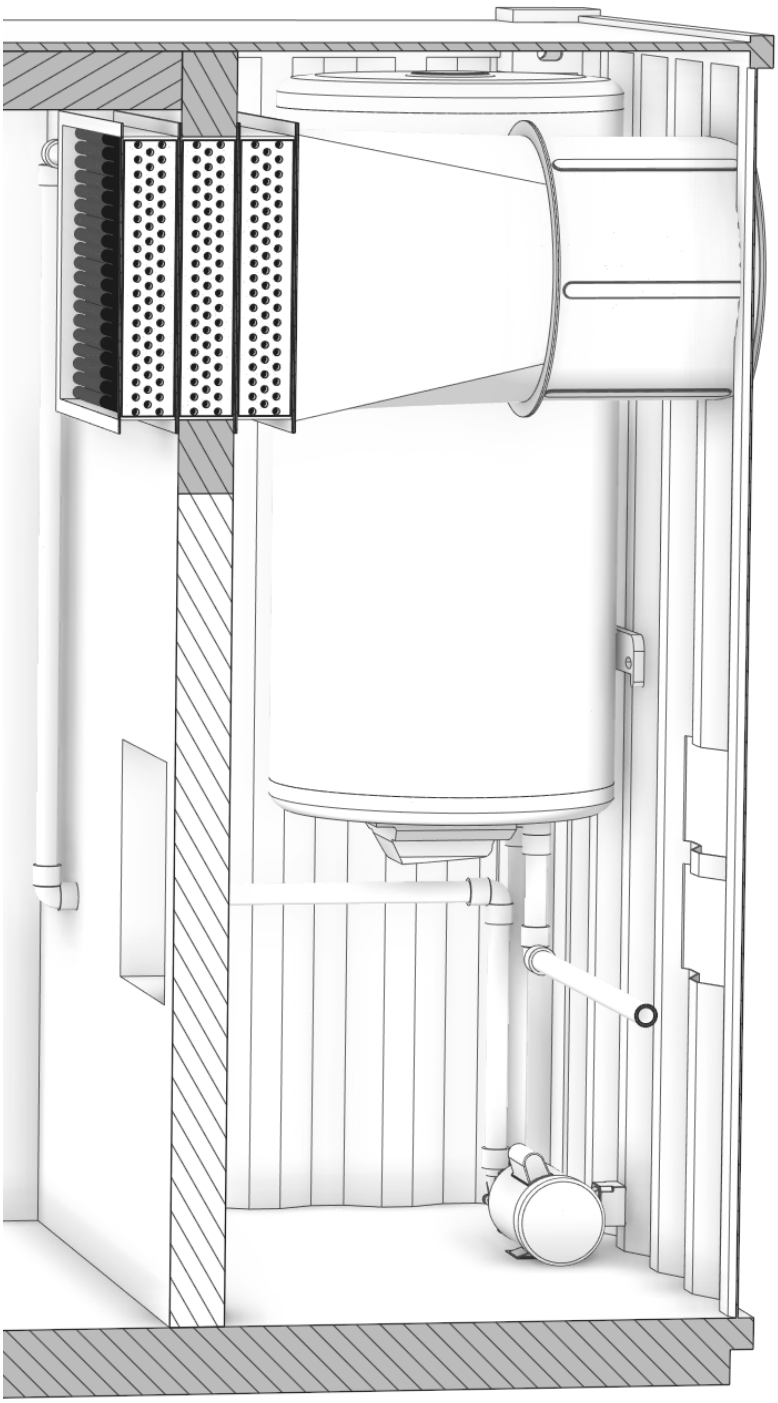
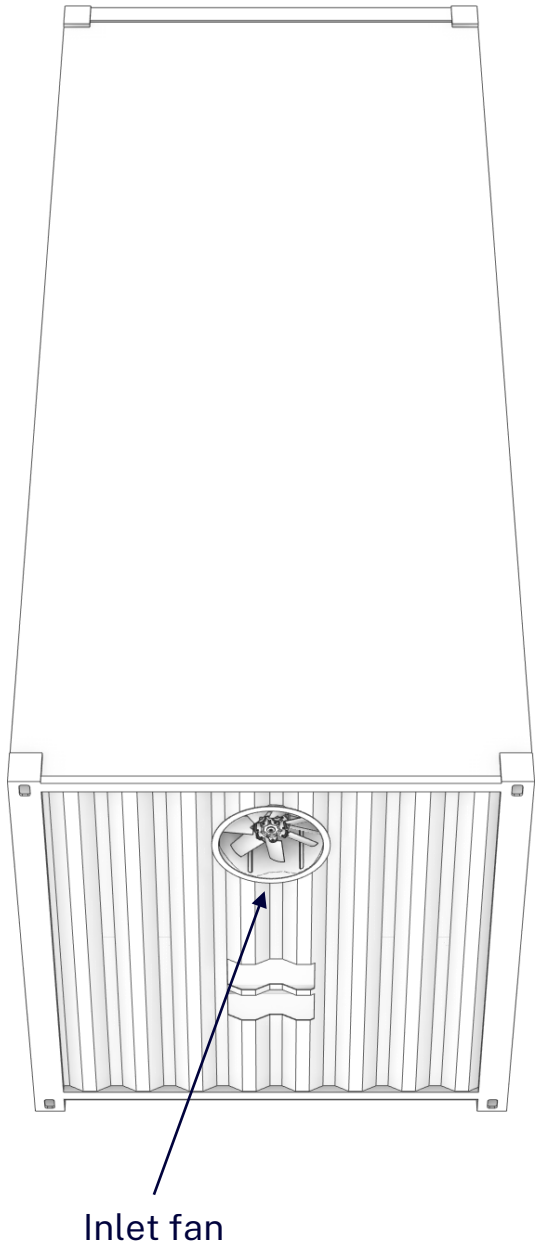
Fan

The fan is the device that creates a forced airflow inside the drying chamber. The fan is placed at the back of the container and is connected to the radiator by a round-to-square duct. Any kind of fan that is graded for constant operation can be used. The choice depends on the availability and cost.





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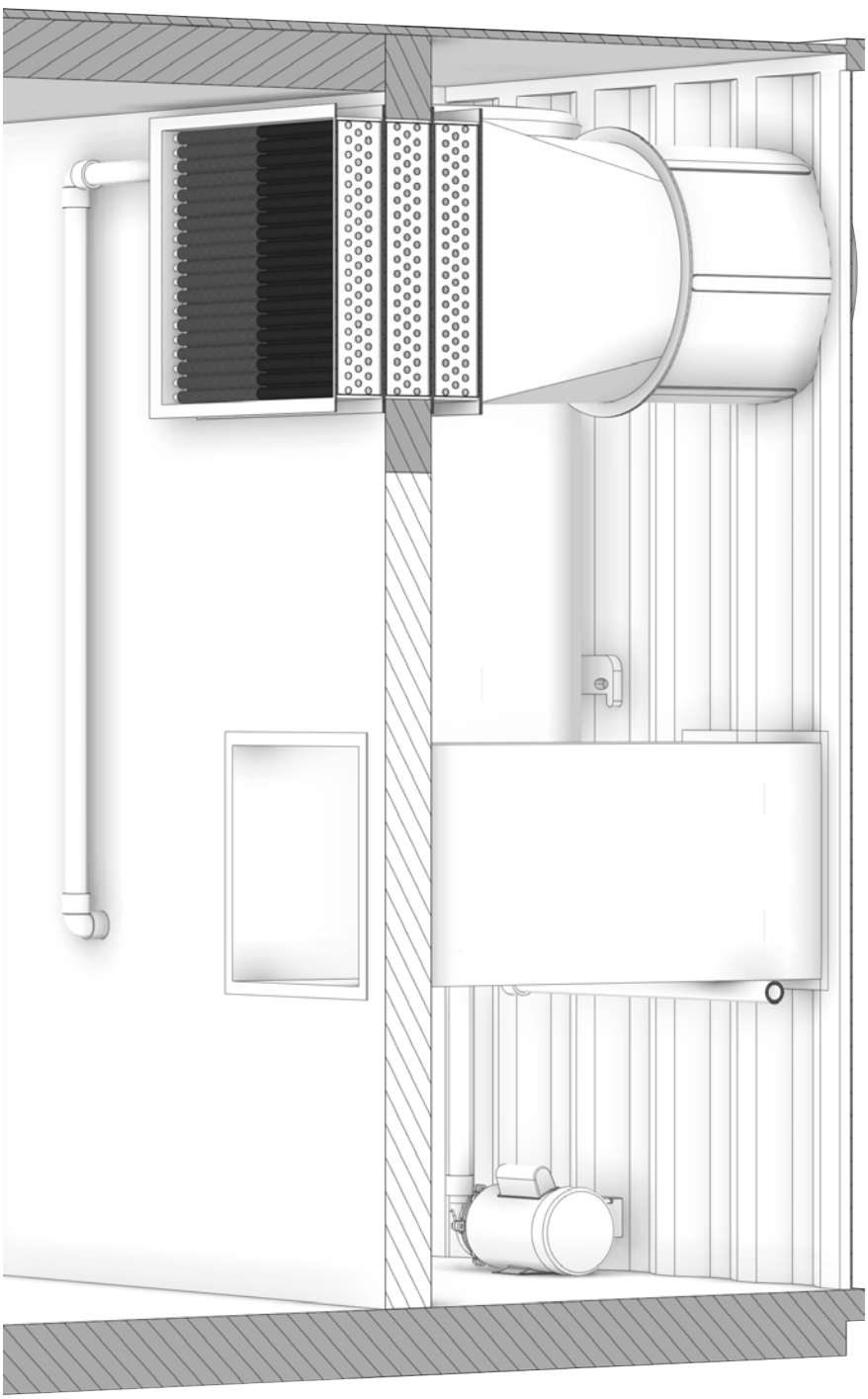
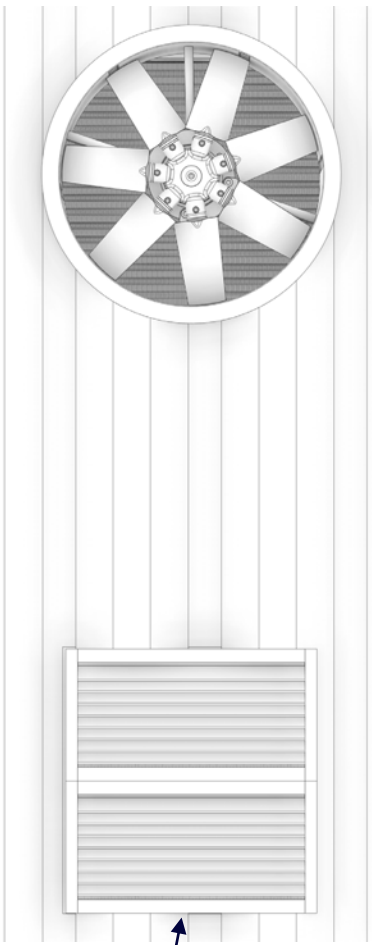
Exhaust louvre

The air outlet allows the moist air to exit the drying chamber, and it is installed at the back of the container. The air outlet consists of an exhaust louvre and a square duct. The exhaust louvre prevents rain and dust from entering the container while allowing air to flow. The square duct connects the exhaust louvre to the back insulated wall of the drying chamber, creating a pathway for the air to exit. Any off-the-shelf exhaust louvre designed to operate with moist air can be used.





Exhaust louvre

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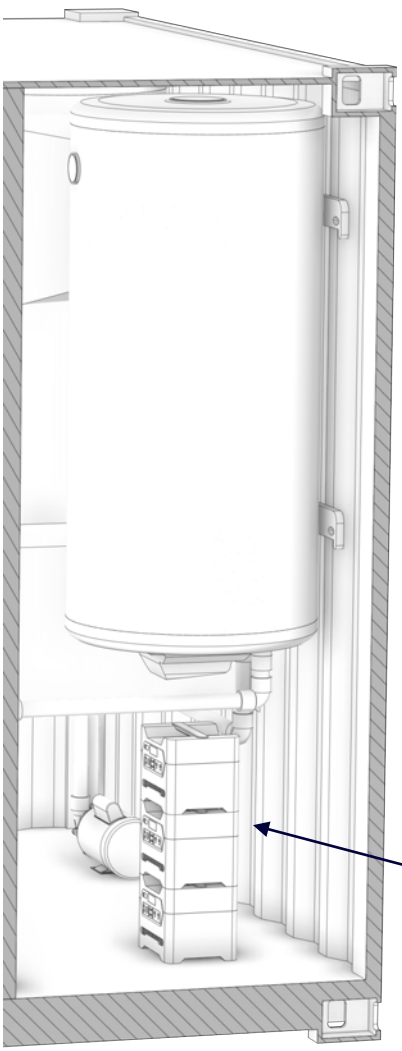
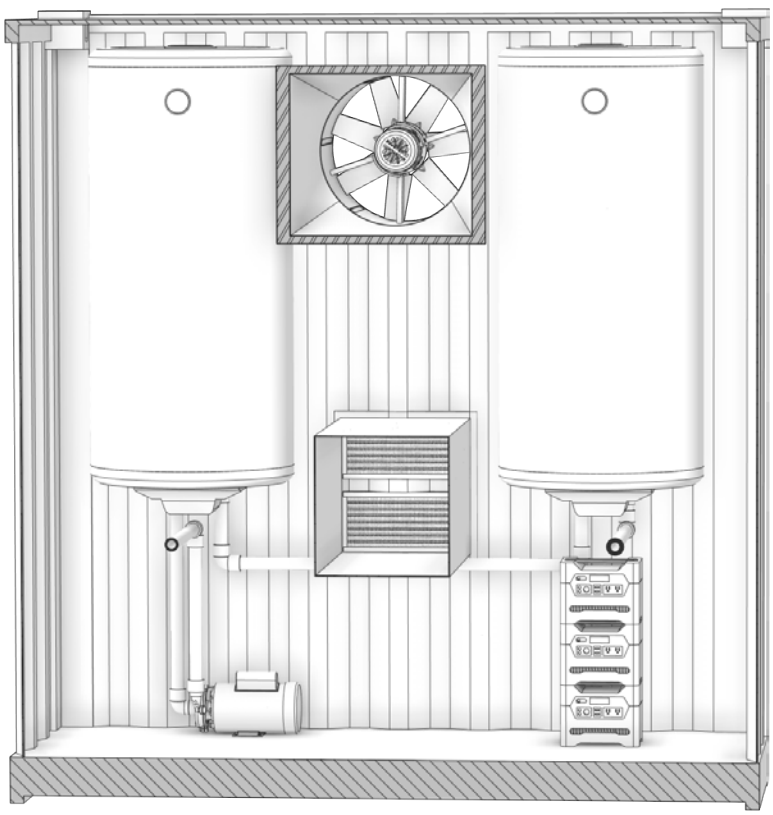
Portable power station

The portable power station is a device that integrates batteries, an inverter, and a charger controller in one unit. Each water heater should be connected to a separate portable power station. The main role of this portable power station is to invert the DC electricity from the solar panels to AC electricity for the water heater. The battery of this portable power station will likely run out of power a few hours after sunset, but this is not an issue as the energy will be stored in the form of heat in the water tanks. The portable power station should have a power output that matches the power input of the water heater. For instance, if the water heater has a power input of 3 kW, the portable power station should have a power output of at least 3 kW. The water pump and the fan should be connected to another portable power station. This portable power station should have sufficient battery capacity and a suitable power output to run the water pump and the fan for at least 24 hours without a charge. The portable power station is installed in the same area where the water heater and pump are located, in the back of the container.





Portable power station

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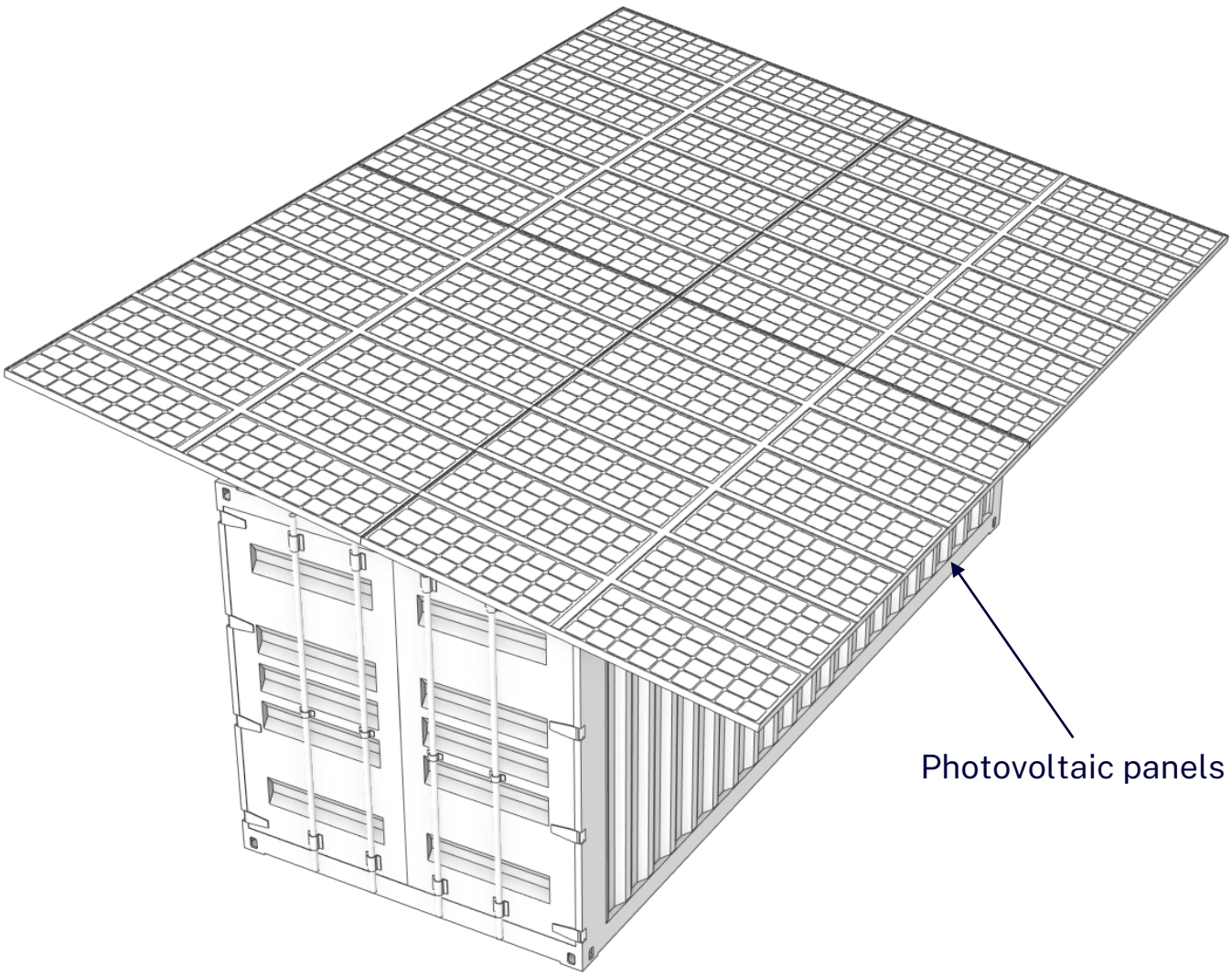
Photovoltaic panels

The photovoltaic panels are devices that capture the sun's energy and convert it into electricity. The photovoltaic panels are installed on the top of the container, ensuring maximum exposure to sunlight. There is no specific number of panels to install, but it is recommended to over-dimension the system, meaning to install as many panels as can be fitted on the top of the container. This is because the electricity storage in batteries has been under-dimensioned, relying more on the heat storage in water tanks. By over-dimensioning the photovoltaic panels, we can ensure that there is enough electricity generated during the day to power the water heaters and charge the batteries.



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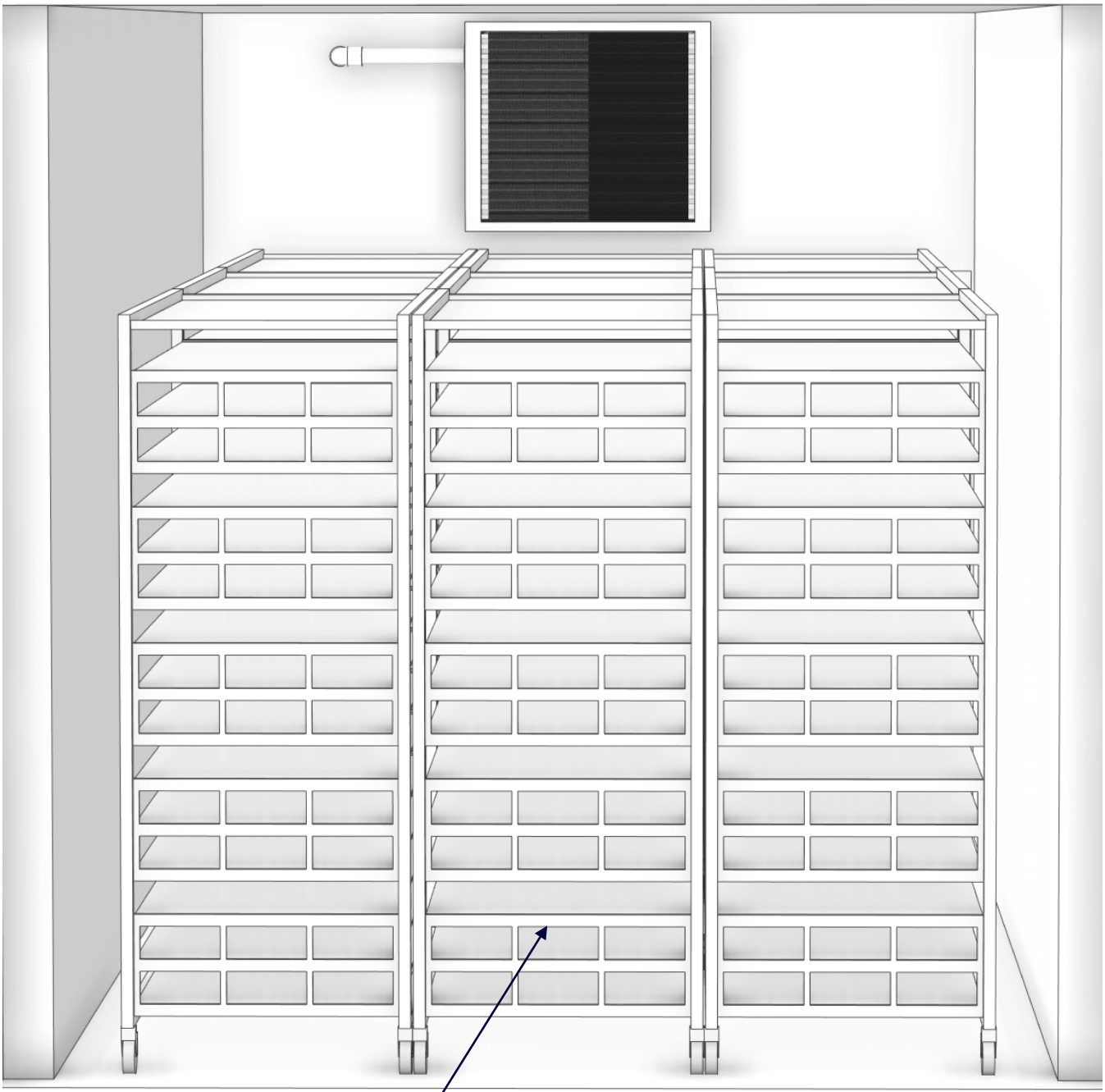
Trolleys

The material to be dried is placed on the trays of the trolleys. The trolleys are carts with wheels that allow easy movement in and out of the container. The trays are flat surfaces that support the material. The trays are made of food-grade stainless steel, while the trolley can be made of any heat-resistant material coated with corrosion-resistant paint.



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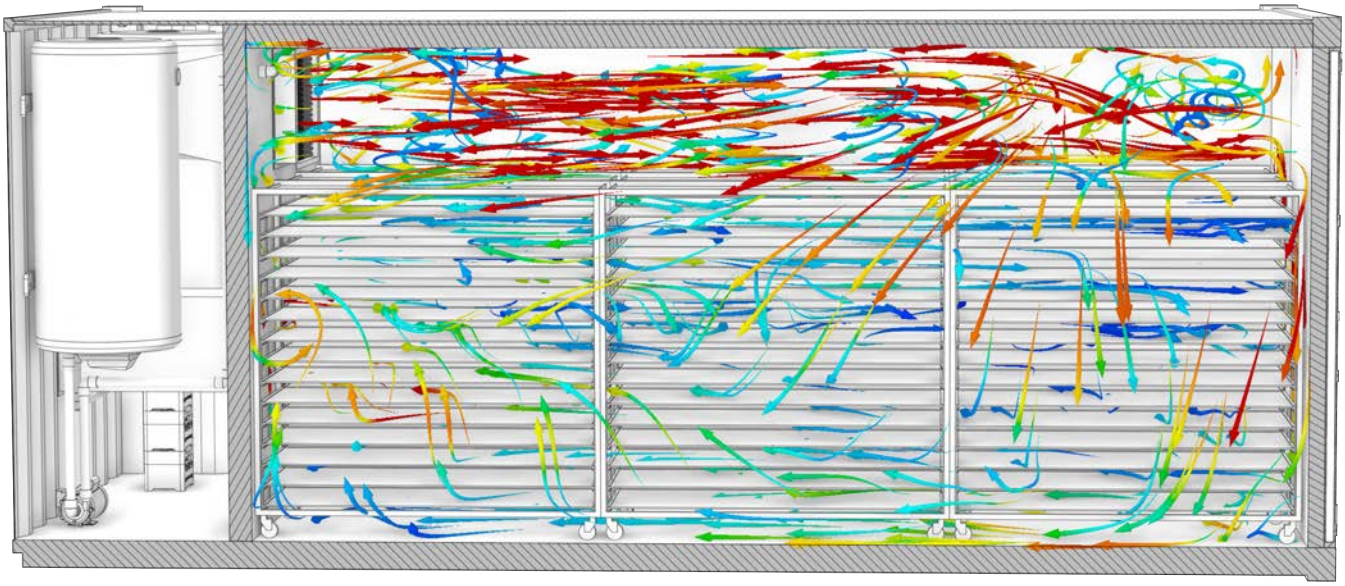
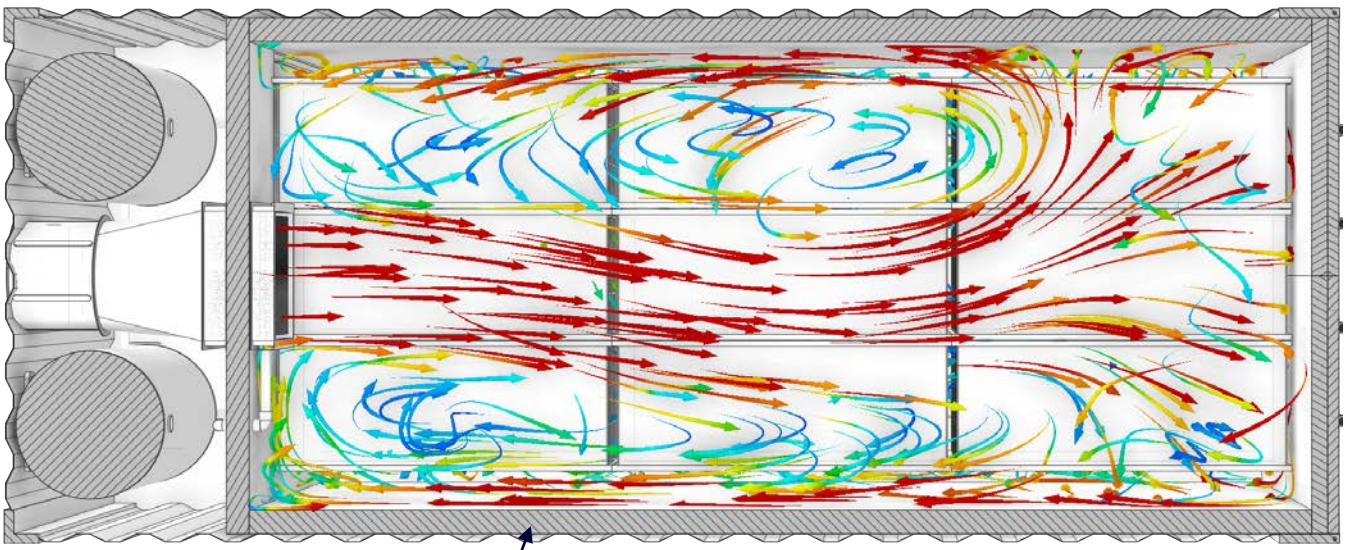
Trolleys

Unlike other parts of the dryer, the trolleys have less flexibility in terms of design and size. This is because the trolleys have a great impact on the airflow and the drying uniformity. Drying uniformity is one of the greatest problems of hot air dryers, as it affects the quality and efficiency of the drying process. To maximize the drying uniformity, extensive work was done using computational fluid dynamics (CFD) coupled with the discrete element method (DEM) to dimension the trolleys in a way that optimizes the airflow and the heat transfer in the drying chamber. Therefore, custom-made trolleys need to be built





Dryer top view

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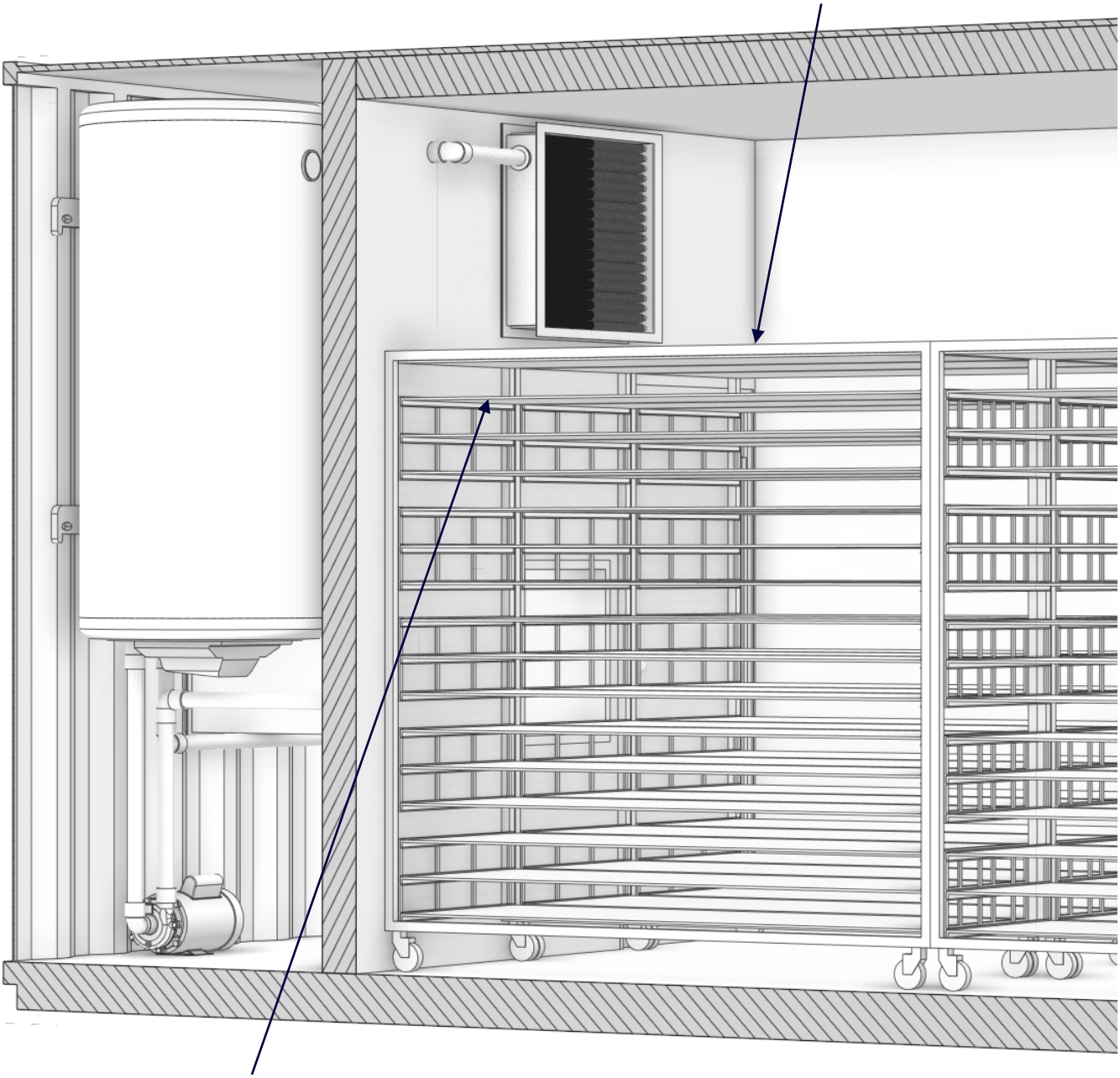
Trolleys

The trolley height is the distance from the floor to the top of the trolley. There is some flexibility regarding the trolley height, as long as the top of the trolley is below the radiator and the top tray is not taller than 1.5 meters high.



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Trolleys

The trolley has a closed top that serves as an air guide. Do not use the trolley cover as a tray or put anything on it.

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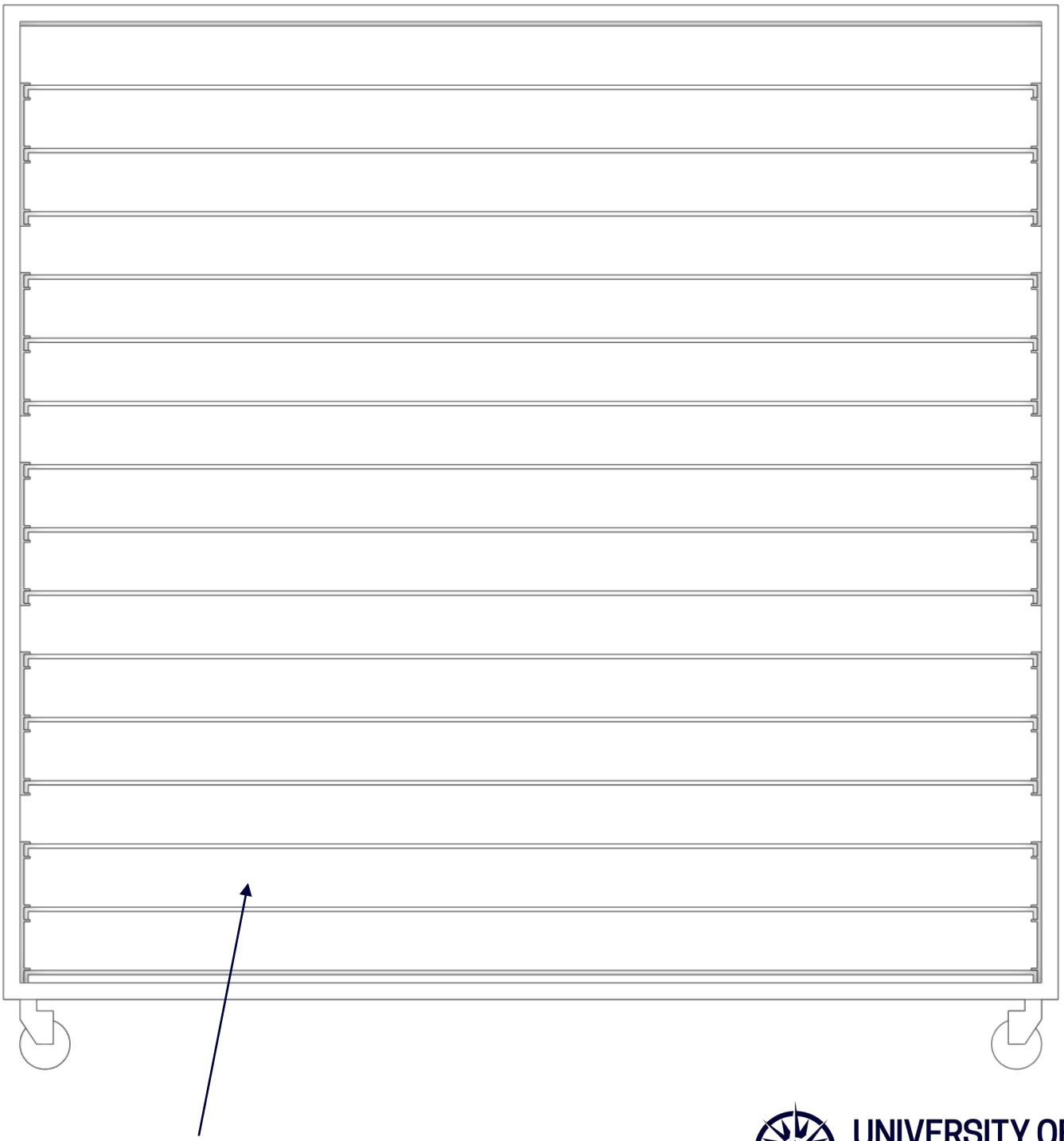
Trolleys

The ideal number of trays per cart is around 15, but this may vary depending on the height of the trolley. The trays should be at least 90 mm apart from each other, to allow enough space for air circulation and heat transfer. The material should be spread evenly on the trays, leaving some space between the pieces.



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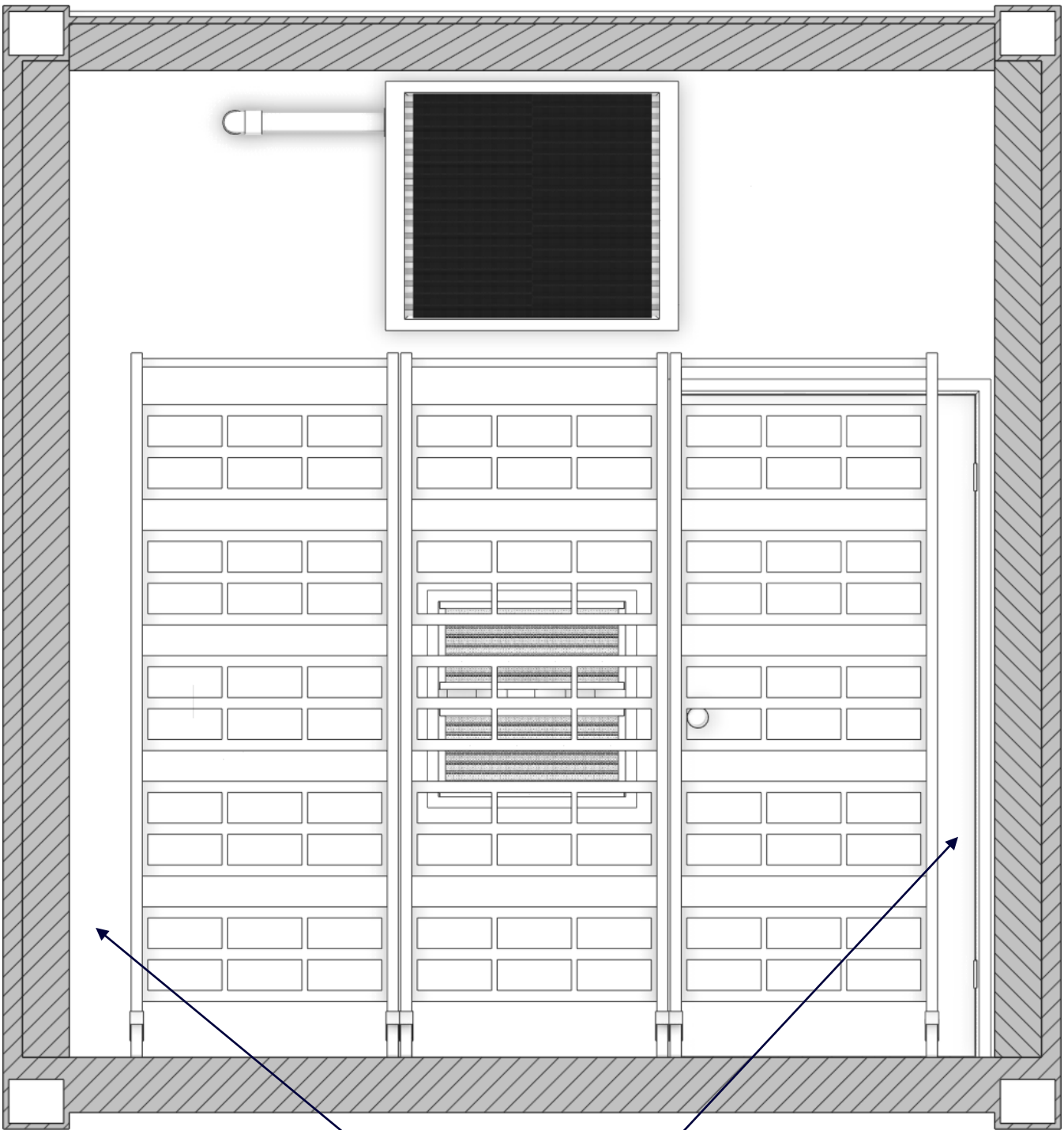
Trolleys

The trolley width has some flexibility, as long as when all are loaded to the dryer it leaves a space of 142 mm between the side of the trolley and the side walls of the container. This value has been obtained from CFD-DEM simulation.



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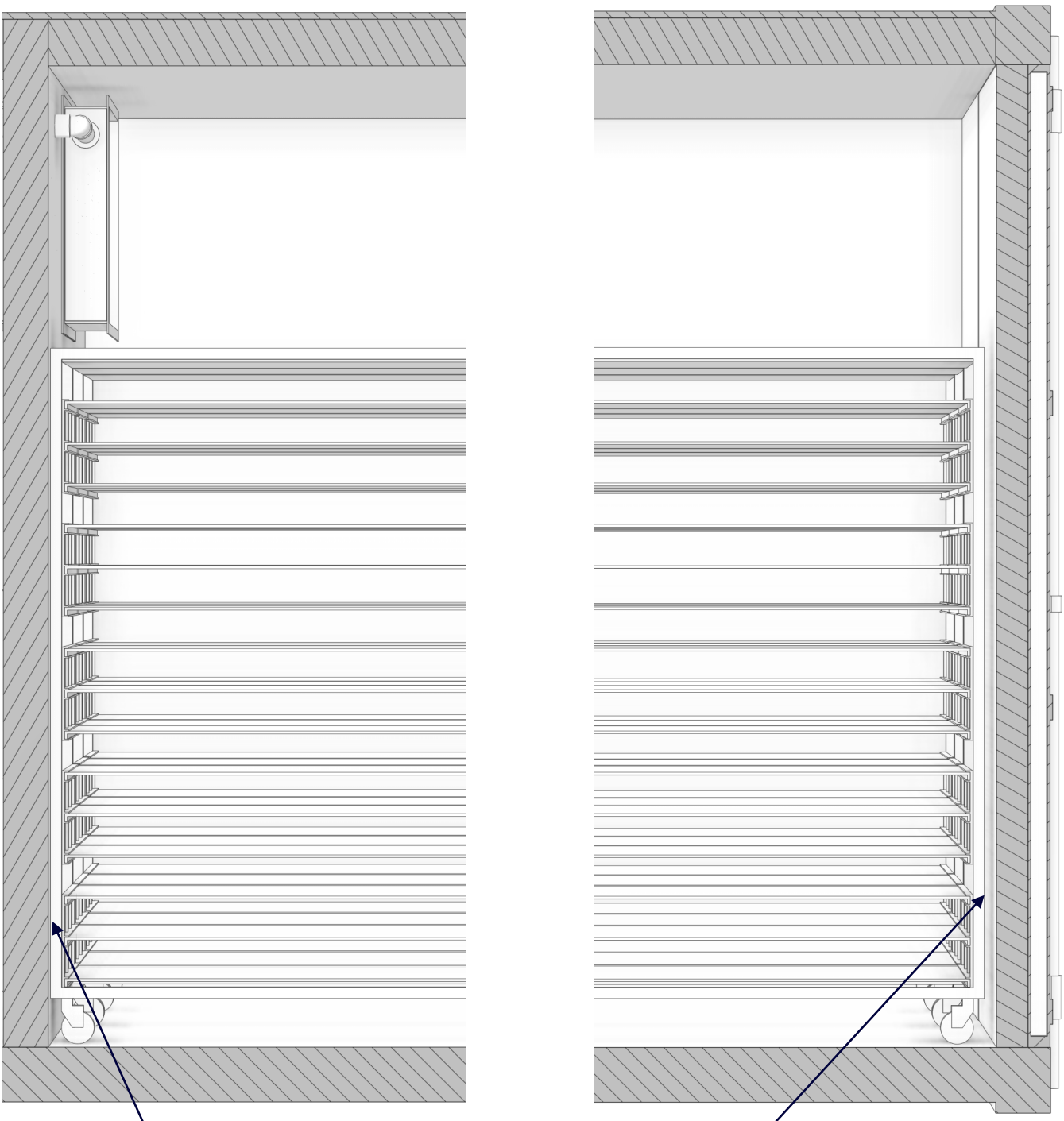
Trolleys

The trolley length has some flexibility, as long as when all are loaded to the dryer, it must touch the back insulated wall and leave a 23 mm gap from the door insulation on the front.



No gap should be left between the back insulated wall and the trolley

A 23 mm gap should exist between the trolley and the door's insulation.

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CAD files

The CAD files of the 3D model of the dryer are available online for visualization and download. The CAD files provide a detailed and accurate representation of the dryer's structure, components, and dimensions. The links will take you to a web page where you can view the 3D model of the dryer interactively. You can zoom, rotate, pan, or measure the model using the tools provided on the page. You can also switch between different views, such as front, top, side, or perspective. To download the CAD files, please click on the download button.

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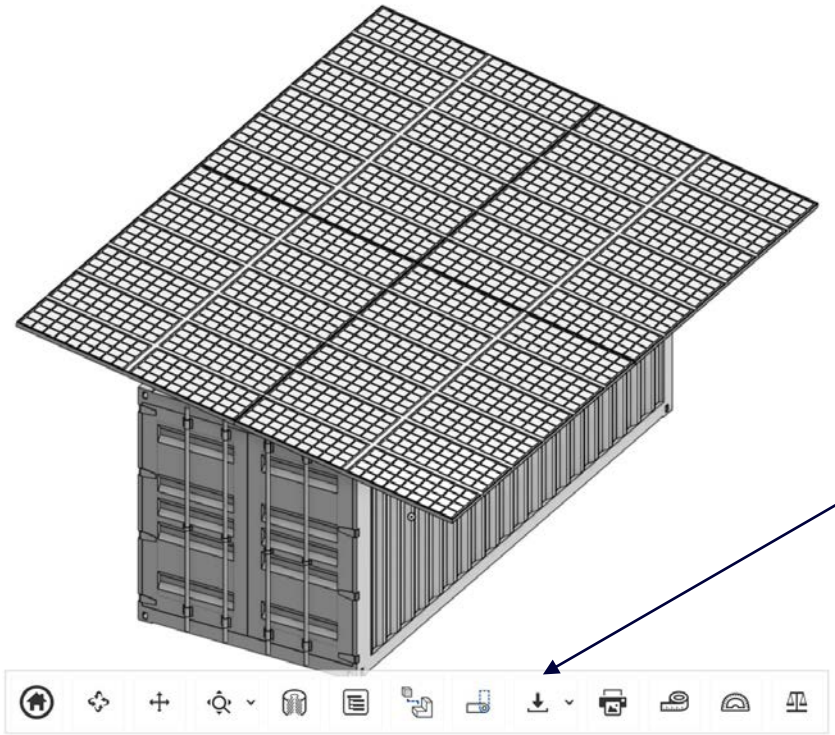

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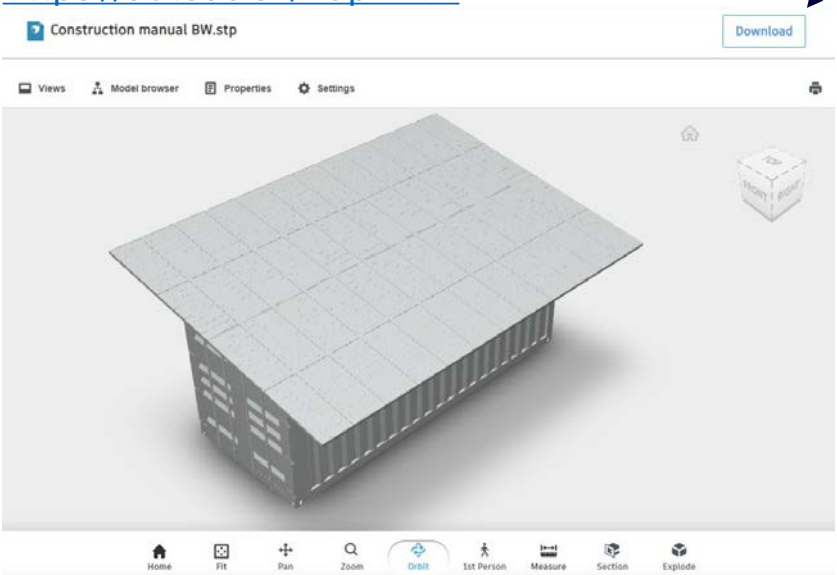

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