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TREBALL FI DE GRAU

Grau en Enginyeria Mecànica

**DISSENY I VALORACIÓ DE L'ADAPTACIÓ I
ACONDICIONAMENT D'UNA FURGONETA H2L3 COM A
FORMAT DE VIVENDA CAMPERITZADA**



Volum I

Memòria

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DESIGN AND ASSESMENT OF THE ADAPTATION AND REFURBISHMENT OF A H2L3 VAN AS A CAMPER HOUSING FORMAT

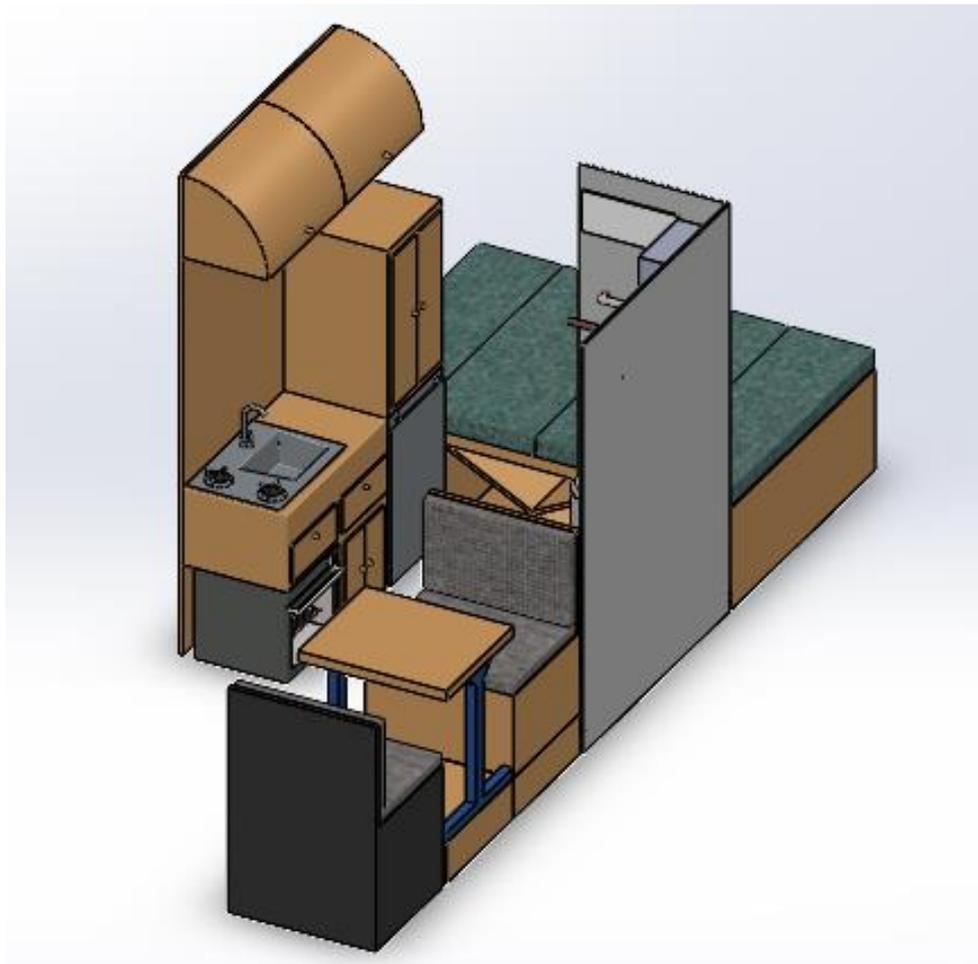


Illustration 1
Source: Own elaboration

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0 Glossary of signs, symbols, abbreviations, acronyms and terms.

- **Garage:** The garage refers to the storage space under the bed. There will be two spaces and they will be located one on each side of the bed.
- **To camp a van:** It consists of adapting a van to convert it into a house in which to live comfortably.
- **MAM:** Maximum Authorized Mass
- **MOT:** Ministry Of Transport

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1 Introduction

1.1 Objectives

The main objective of this project consists in the design and measurement of all the required furniture and internal installations to adapt a van as a place to live keeping in mind the van's geometry and volume. This process is also known as "camp a van". Besides, the objective was to not only make it fit to live in, but also no having to renounce to commodity and life quality.

Another fact has been kept in mind is the sustainability, using materials that are respectful with the environment and using the minimum quantity of fossils combustibles.

1.2 Reach

In this project I have developed this facts:

- Vehicle election
- Homologation:
- Materials election:
- Inside isolation:
- Furniture design and distribution:
- Electrical installation:
- Gas installation:
- Water installation:
- Commercial furniture:

In this project I have not considered this facts:

- External design of the van
- 3D design of the commercial furniture

1.3 Justification

The last few years has been increased the use of motorhomes and camper vans between those people that are looking for travelling and enjoying the nature in a simply, secure and comfortable way, because they offer the possibility to overnight at almost any place without the necessity of turning to hotel services and catering in general. They allow the possibility for sleeping in the camping trailer/van, cooking, using the bathroom, getting a shower even watching television and having access to the Internet. Furthermore, this 2020, that happened the world pandemic due to

COVID19, even more people has increased their interest in this way of live/travelling in order to avoid staying in the big cities and decrease the risk of infection.

While it is true that there are some business that offer full-equipped camper vans in a way of living there, there are lot of people that opt to the option of camp them themselves.

In this project has not been specified a maximum budget for being able to include the all the possible amenities. However, it is true that it has been tried that the final budget was not too high, in a way that it could be accessible to a bigger crowd of people.

An important fact to keep in mind has been the legality when manipulating the inside vehicle space and installing the necessary services.

1.4 Requirements

This project seeks to enable a van as a home without having to give up comfort, quality of life and commitment to the environment. That is why a long and high van will be chosen to enjoy more space inside it. Having said that, the intention is not to choose the biggest van possible, since we want to avoid the loss of manageability that increasing the size means.

On the other hand, no budget limit has been set to ensure comfort and well-being inside the van. However, the price of materials and furniture will be taken into account so that, without skimping on price, it will be an affordable van for a larger number of people.

Another aspect that will be considered is the climate impact that the manufacture, purchase and use of the materials and fuels of the van may have, in terms of reduce it as much as possible.

In addition, the project is designed so that two people can live and travel in the van with the possibility that a third person can spend the night in it as well. This will have to be taken into account when choosing the van, establishing the maximum load mass it can have and the interior design of the van.

Finally, the aim is to be able to travel for short periods, such as a week, as well as for long periods, such as months.

2 Previous concepts

2.1 Differences between motorhomes and camper vans

Is important to know the difference between this to vehicles to understand well the project. It is going to be compared a standard motorhome and a big-size camper van. It is true that there are full-equipped camper vans that are very similar to motorhomes, so it is going to be an average comparison. (1)



Illustration 2. Motorhome
Source: caravaningk2.es

2.1.1 Size

To talk about the size we need to talk first about how they are built. Both, camper vans and motorhomes, are built on the chassis of commercial vans. The difference is that the camper vans are built inside the original van. The same van that is used by load business is the one that is used to be camped.

Furthermore, the motorhomes only use the chassis, and above it, the unit home is built and installed. Then, aside from being the construction of the motorhome a 100% aimed to be lived in, there is more space, as there is not the van load zone original space limitation.

2.1.2 Customization

Motorhomes and already full-equipped camper vans are very difficult to customize, the options or modifications are limited or non-existent.

On the other hand, a camper van is possible to bring it to a professional to build or camp it inside totally to your taste. Is it possible to camp it yourself also.

2.1.3 Price

If we compare the price between buying a new big-size camper van and a new standard motorhome, the cost will be very similar. Maybe it could be a bit cheaper a big-size camper van (40.000 €) than a “basic” motorhome (45.000 €). However, is important to keep in mind that normally motorhomes are better equipped than camper vans from the same range, and that’s something that is paid also.

In a premium category, the price of both of them can be raised easily until 100.000€.

Furthermore, in the second hand market, camper vans are more accessible than motorhomes: it’s possible to find camper vans for 3.000 – 4.000 €. And, of course, if you camper your van yourself the price will be substantially smaller.



*Illustration 3. Camper van.
Source: manofmany.com*

2.1.4 Consumption

Generally, bigger size (especially width) implies a bigger consumption of diesel oil on the road, and that is a disadvantage to motorhomes. As it is true that it depends a lot on every vehicle, it can be established a range of consumptions: for big-size camper vans it goes from 8 L/100 Km to 10 L/100 Km, whereas for motorhomes, it goes from 9 L/100 Km to 12 L/100 Km.

So, in average, motorhomes will consume approximately 2 litres of diesel oil more every 100 Km.

2.1.5 Manoeuvrability and city

Driving on the road or on the highway, both camper van and motorhome are easy to drive. In addition, going higher than the other vehicles is more comfortable for the conduction.

Having said that, because its dimensions, on thin roads and on the city, a motorhome becomes a more difficult with more limitations vehicle to drive. It is 10-20 cm wider than a camper van and it is heavier, so it's difficult to drive in certain slopes.

In respect of parking, none of them can park in an underground parking because of the high. In public road, inasmuch as motorhomes are normally longer, there is more problem to find an adequate parking.

2.1.6 Adventure

As adventure I mean each vehicle's capacity to carry you to remote places and dirt roads.

Although there are some 4x4 motorhomes, it is really strange to find those kind of vehicles. And although it is neither common, it is easier to find four wheels traction vans with off-road capacity than motorhomes.

Either with four or two traction wheels, the capacity for moving on narrow roads or dirt roads on the mountain, is much higher in a van than in a motorhome.

2.1.7 Amenity

When I talk about amenity, I refer to everything that a vehicle has to make the stay inside it more delightful.

Even though there are exceptions, most of motorhomes are better equipped than camper vans. Being a bit bigger, the inside space is bigger and gives you the possibility of putting more things inside that can make your stay more pleasant.

Besides they have more warehousing space (motorhome's trunks use to be enormous), mostly all motorhomes has toilette and shower, against lot of camper vans.

In conclusion, in a comfortably way, especially to stay a long time inside it, or if there are more than two people staying there, motorhomes are more comfortable.

2.1.8 Conclusion

	Space	Price	Consumption	Amenity	Manoeuvrability	Adventure	Customization
Motorhome	✓			✓			
Camper van		✓	✓		✓	✓	✓

Chart 1. Comparison Motorhomes vs. camper vans.
Source: Own elaboration

2.2 Camper vans history

The birth of the campers took place in 1947 in post-war Germany, when the Dutchman Ben Pon, an importer of Volkswagen vehicles, came up with the idea of transporting pieces with one of the factory's vehicles. This gave rise to the first sketch he presented, designing a vehicle in the shape of a shoebox powered by the same engine as the Volkswagen Beetle. (42)

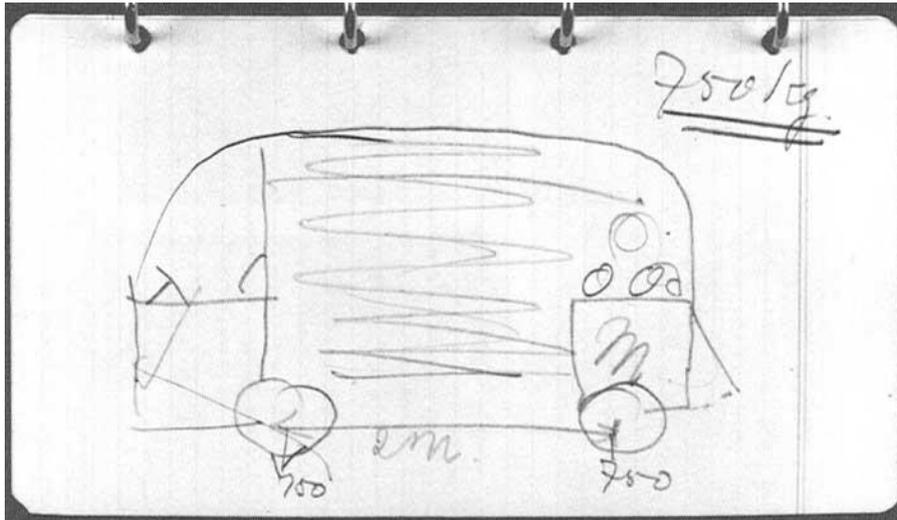


Illustration 4. First van sketch.

Source: <https://www.furgosfera.com/cultura-camper/volkswagen-transporter-el-origen.html>

The first model to be launched on the market in 1950 was the Volkswagen Type 2 (now known as the Type 1), commercially known as the Volkswagen Transporter. It was produced in Germany (1950-1967) and later in Brazil (1957-1975).



Illustration 5. Volkswagen T1.

Source: manuals.co

This first model was notable for having a lot of space, could carry a lot of load (750kg) and could reach a maximum speed of 80 km/h, with a 4-cylinder engine with 25 hp, which allowed low fuel consumption and great traction on snow and mud.

The van was high, could start on steep slopes and drive on almost any road. Moreover, thanks to the air cooling system of the engine, the circuit did not freeze at low temperatures or boil over at high temperatures.

It was very versatile, used both by families for travelling and by workers for transporting their equipment, and eventually ended up being used in ambulances, post offices, minibuses and police cars.

The prices were affordable for the society of the time, they were easy to drive, had a low consumption, so it was a great success worldwide. It attracted a large part of society, families, hippies, surfers, travellers, who turned the van into an icon of freedom. (43)

Volkswagen brought 2 models onto the market (1950): Panel Van, still without rear seats or side windows, and Kombi, already with these features. The models were gradually improved.



*Illustration 6. Volkswagen Kombi.
Source: carsguide.com.au*

From this point on, Volkswagen worked with the Westfalia company and together they produced the Camping Boxes model (1953). The first one already had a bathroom, kitchen and a platform that folded down to become a bed. (44)

New improved models came out, with better comforts such as a gas cooker, curtains, luggage racks, wood panelling, a competent electrical system and bigger furniture.

In 1967, the T2 was released, with more height, length and therefore more space. It was a heavier model, so the engine capacity had to be increased. Some models were fitted with a folding roof to be able to stand up inside the van, and to be able to put a bed in it. (45)



*Illustration 7. Volkswagen T2.
Source: honestjohn.co.uk*

They were followed by the T3, T4, T5 and even the T6 at the present time.



*Illustration 8. Volkswagen T5.
Source: honestjohn.co.uk*

2.3 Camper vans nowadays

Nowadays more and more people, when they travel, opt for the option of buying or renting a camper van. This is due to the ease of being able to stay overnight comfortably almost anywhere. Moreover, for those who are looking for more contact with nature, it is also a highly valued option.



*Illustration 9. Camper van.
Source: 16cimas.es*

Among the people who buy a van, there are those who buy it without being fitted out as a home and decide to camper it themselves. It is a long and complex process, due to all the installations that have to be done in the van, which can be a tedious task if you don't have some previous knowledge. They are usually in small vans and with simple and practical adaptations.



*Illustration 10. Self-camper van.
Source: weburbanist.com*

Other people who also buy it without it being fitted out, take it to a specialist who takes care of the van's camper. Very good results are often obtained, although it is not always the cheapest option.

Finally, there are people who decide to buy it already fully fitted out. This is the option that usually gives the best results. On the one hand, there are companies that are dedicated to buying vans of different brands, and they camper the vans themselves. An example of this would be the company Benimar, in Spain.



*Illustration 11. Benimar Benivan 119.
Source: benimar.es*

On the other hand, the major car brands are also increasingly offering camper vans with better features and facilities.

Until recently, Volkswagen and Mercedes-Benz were the only brands that offered factory-made camper vans in Spain, with their California and Marco Polo models, respectively. But the boom in the camper phenomenon in recent years has meant that several brands have decided to include vehicles adapted as living spaces in their range.



*Illustration 12. Volkswagen California.
Source: telegraph.co.uk*

In these cases, brands such as Nissan, Peugeot or Toyota have found the collaboration of companies specialised in the transformation of this type of vehicle to offer their customers a product that has the advantage - compared to an after-sales camper - of having the manufacturer's official guarantee.



*Illustration 13. Toyota Proace Verso Camper.
Source: periodismodelmotor.com*

2.4 Regulations and legislation

When you want to “camp” a van is important to keep in mind the country’s legislation where you want to do it. Due to the idea is to make this project in Spain I will follow Spain’s legislation and regulation.

In Spain, vehicles are classified into different types in accordance with the General Vehicle Regulations approved by Royal Decree 2822/1998 of December 23, 1998, Annex 2. (2)

To classify them, the vehicles are indicated with a numerical code, which can be found on the technical data sheet. In the case of vans, depending on the number, they will be designed to carry cargo, people or both. The first two digits of the code refer to the classification of vehicles by their construction. The last two refer to the classification by use.

Is important to know the difference between two concepts: cargo and furniture.

The cargo is the transported freight that is not fixed, so it cannot be anchored to the van, but will be fastened with bungee cords. It needs a separator panel that divides the space between the cargo and the passengers and the MOT must be passed without cargo.

On the other hand, furniture are those fixed structures anchored to the vehicle. This vehicle must be approved as a dwelling and will not be allowed to transport cargo, since it does not have a separating panel. In this case, the MOT has to pass it with the furniture that is integrated.

This is the classification of the vans:

- **Private car (1000):** Car set aside for the transport of people that have, at least, four wheels and, besides the driver seat, eight seats at the most. The maximum speed at which you can drive on the freeway is 120 Km/h. The MOT must be passed every year if the vehicle is more than 10 years old. (3)(4)
- **Van (2400):** Car with four wheels or more, developed and built for the freight transport, whose cabin is integrated on the rest of the body and with a maximum of nine seats, the driver’s one included.

It has a rigid load-bearing separator panel made of sheet metal, removing it is considered a major modification. Any bundle is considered a load and has

to be well fastened with bungee cords, therefore it cannot carry bolted furniture.

The maximum speed on the freeway is 90 Km/h. In case it is more than 10 years old, the MOT must be passed every 6 months.

- **Adaptable mixed vehicle (3100):** Car specially designed for the simultaneous or non-simultaneous transport of freight and persons up to a maximum of 9, including the driver, and in which the load can eventually be replaced, partially or totally, by persons by adding seats.

A safety grid is required if a load is carried. The load must not be screwed on, but fastened with bungee cords, otherwise it would have to be approved as housing.

The maximum speed on the freeway is 100 Km/h. The MOT has to be passed every 6 months.

- **Motorhome MAM 3500 kg (3248):** A vehicle constructed for a special purpose, including living quarters and containing at least the following equipment seats and table, beds or bunks that can be converted into seats, kitchen and closets or similar. This equipment shall be rigidly attached to the housing compartment and the seats and table may be designed to be easily removed.

Maximum speed on the freeway is 90 Km/h and the MOT must be passed every year, in case the vehicle is more than 10 years old.

- **Passenger car (3000):** Car intended for services or exclusive transport of freight, derived from a passenger car of which it retains the bodywork and has only one row of seats.

As the back of the vehicle is used for the transport of goods, it has a fixed load divider panel.

On the freeway, the maximum speed allowed is 100 Km/h. The MOT test has to be passed every 6 months, in case it is more than 10 years old.

- **Housing-car (1048):** Vehicle conditioned to be used as housing. At a minimum you must have a table and a bed. The MAM is 2500 Kg.

The maximum speed on the freeway is 120 Km/h. The MOT test has to be passed with the same frequency as the private car.

- **Housing-van (2448):** Vehicle conditioned to be used as a home. At a minimum you must have a table and a bed. The MAM is 3500 Kg.

The maximum speed on the freeway is 100 Km/H. The MOT test must be passed every 2 years and after 2 years, until it is 10 years old, it has to be passed every 6 months.

Another important point to consider is the reforms made to the vehicle, whose rules are regulated by Annex 1 of Royal Decree 866/2010 of July 2. The vehicle reforms refer to the modifications introduced in the functions listed below and, where appropriate, will be developed as appropriate in the manual of vehicle reforms.

Modifications to the following functions are considered to be vehicle modifications:

1. Identification.
2. Drive unit.
3. Transmission.
4. Axles.
5. Suspension.
6. Steering.
7. Brakes.
8. Bodywork
9. Lighting and signalling devices
10. Connections between tractor vehicles and their trailers or semitrailers
11. Modifications of the data appearing on the MOT card.

In addition, to homologate the vehicle, the following documents and procedures must be delivered and carried out, according to Article 7 of Royal Decree 866/2010 of July 2:

1. Vehicle modifications may be requested by the owner of the vehicle or by a person authorized by him.
2. If a vehicle modification involves simultaneously several of the reforms of vehicles in Annex I, its processing shall require compliance with the requirements set for each of them in the manual of reforms of vehicles.

3. The processing of reforms of vehicles may require all or some of the following documents:
 - a) Detailed technical project of the reform to be carried out and final certification of the work indicating that it has been carried out in accordance with the provisions of the said project, both signed by a competent qualified technician. The work certification shall expressly state the workshop and the date on which the work was carried out. This technical project must be presented to the issuer of the conformity report.
 - b) Conformity report according to Annex II issued by the technical service of reforms designated or alternatively by the manufacturer of the vehicle.
 - c) Certificate of the workshop where the repair was carried out, according to the model in Annex III, of the correct performance of the repair.
4. When issued by the manufacturer, the conformity reports in paragraph b) above shall be issued only by persons expressly authorized by the manufacturers for this purpose.
5. For each type of vehicle modification, the documentation to be submitted to the administrative bodies responsible for vehicle roadworthiness testing, the procedure and the specific requirements shall be those set out in the vehicle modification manual.
6. In the case of correspondence between the reformed vehicle and an approved type, the reform may be carried out without the provisions of paragraph 3.a) of this article.
7. In the case of an alteration covered by a functional assembly authorized by the approval authority, compliance with paragraph a) shall not be necessary and the vehicle shall be inspected in accordance with article 8 of this royal decree.

The owner of the vehicle, or the person authorized by him, who has had a vehicle refurbishment carried out, is obliged to present the vehicle for technical inspection within a maximum period of fifteen days, providing the above-mentioned documentation together with:

- Final certification of the work: The act by which, in the format of a document, the conformity is given by a technician to the work and/or installations carried out according to the project.
- Workshop certificate: The document that certifies the execution of a certain action of a workshop on a certain vehicle, as marked in Article 3 of Royal Decree 866/2010 of July 2.

In order for the van to be homologated as a car-housing or van-housing, the following requirements must be met:

- It must be thermally insulated.
- It must have some kind of ventilation, either with windows, skylights or grills.
- It must contain at least one sleeping seat in the order of travel.
- Have a kitchen module (may be portable) and additional furniture or closet.
- It must have an electrical installation with auxiliary batteries, which meets the legal requirements.
- The furniture must be well fixed.
- The furniture must have rounded edges, can not have dangerous corners or peaks.
- Gas installation that meets the legal requirements.

According to the Instruction 08/V/74 of the General Direction of Traffic, documents of obligatory compliance: <<...this Directorate General of Traffic considers that while a vehicle any is correctly parked, without exceeding the road markings of the parking area, nor the time limitation of the parking, if any, is not relevant on the fact that its occupants are inside it and the motorhome is not a exception, it is enough that the activity that can be developed in its interior does not transcend exterior by deploying elements that overflow the perimeter of the vehicle ...>>.

That said, it means we can:

- Eat or sleep inside the vehicle.
- Put the chocks to level the vehicle if the terrain is inclined (with clear justification).

- Raise the roof or open skylights (provided it does not exceed the perimeter of the vehicle)

It will be considered camping if we do any of the following:

- Remove chairs or tables
- Extend awnings or casement windows
- Put stabilizing legs
- Performing fluid discharges
- Emitting disturbing noises.

3 Design, materials and methods.

3.1 Van election

In the world of camper vans, there is a great variety of models and variants available in the market. Each model has its advantages and disadvantages. (24)

The world of camper vans can be divided into four categories depending on the size: small, medium, high volume and off-road.

3.1.1 Reduced size vans

We can define as reduced camper vans, also known as 'Mini Campers', to all those vans similar in size to a car, but that are conditioned to travel.

They are perfect vans for people who want to use them as their main vehicle, with which they can go to work for example, and who also want to use them for short weekend breaks. In addition, due to their small size and height, they are the model of camper vans that use less gasoline, with consumption similar to that of any car.

Another advantage they have is their mobility and ability to go unnoticed, allowing you to get anywhere and stay overnight without attracting attention.



*Illustration 14. Reduced size van.
Source: cars.co.za*

However, the storage capacity and comfort within this type of van is quite limited. Generally, these types of vans are designed for sleeping. The rest of 'daily life' has to

be done outside, like cooking. Of course, they do not have space for a bathroom or a shower.

Therefore, it would be mainly intended for trips of 2 people at most and for less than a week.

In this category we find models like the Volkswagen Caddy, the Ford Torneo or the Kangoo Berlingo.

3.1.2 Medium size vans

This category is the most "classic" of the camper vans. It is the origin of the current camper world that, as mentioned above, emerged thanks to the Volkswagen T1-T3 that became popular in the sixties and seventies.

This type of van is an intermediate step between the mini campers and the large volume ones. In other words, we still have a lot of mobility (most of them fit into any parking lot) and we already have more space available. The consumption is not usually excessively high, around 7-8 litres at 100km.

The main handicap of this type of van is the impossibility of standing, since the interior height rarely rises above 1.40 or 1.50 meters. However, this problem can always be solved by installing an elevating roof on the van.



*Illustration 15. Medium size van.
Source: vans.honestjohn.co.uk*

Depending on the model and the interior layout, it is already possible to have elements such as kitchen, bathroom and shower or water tanks.

Therefore, they are ideal if you want to use them as a daily vehicle and also have more space without compromising mobility.

In this category we can find models like the Volkswagen Caravelle, Transporter, Renault Trafic, Opel Vivaro or Mercedes Vito. Some brands even have models already camperized as standard, such as the Volkswagen T5 California or the Renault Trafic Generation.

3.1.3 Big volume vans

When we refer to "large volume" vans, we are talking about the larger vans. The mobility of a large volume van can be reduced (driving on some narrow roads is complicated, they can not get into almost any subway parking ...), but in return we will have much more space and comfort than in any other type of camper van. We can already put several instances, such as room, living room, kitchen or bathroom.

A large volume van is the perfect vehicle for long trips or family trips. However, depending on where you live and your lifestyle, it may be necessary to have a second vehicle.

Another thing to keep in mind is that within the world of large volume vans, there are different sizes where the L determines the length, and the H determines the height.



Illustration 1
Source: singlequiver.com

There are four varieties of length and height ranging from 1 to 4 (L1-4 and H1-4) and there are vans with all possible combinations.

HEIGHT	LENGTH
H1: 2.25 m	L1: 5 m
H2: 2.52 m	L2: 5.40 m
H3: 2.76 m	L3: 6 m
	L4: 6.40 m

*Chart 2. Height and length measures in big volume vans.
Source: Own elaboration.*

When choosing the size of a high-volume van, it is important to consider the following points:

- **Consumption.** What determines the consumption of a van, more than the total weight, is the height of the van. The height will make it less streamlined and more resistant to the wind, so the consumption will be higher.
- **Mobility.** A large volume is already largely limited by its size, so choosing one model or another is not going to make a big difference. However, it is always better for mobility to choose height rather than length, as this can limit parking in cities.
- **Space:** In a van, every centimetre counts, and the difference between an L2 and an L3, for example, is more than noticeable. However, it all depends on how many people are going to travel and especially on the distribution that you want. For example, if four people are going to travel, the beds can be on top of each other (choose height) or all at the same level (choose length).

As examples of high volume vans we can find Fiat Ducato, Citroen Jumper, Peugeot Boxer or Volkswagen Crafter.

3.1.4 Off-road vans

We can include in the category of off-road all those vans specially designed for adventure and also to travel in extreme conditions and places.

However, on the one hand, they cost much more than a comparable conventional van, and on the other hand, consumption is usually high. Nevertheless, they gain in the ability to reach places that other types of vans cannot.



Illustration 16. Off-road van.
Source: bangshift.com

An off-road van can be the Volkswagen T5 4x4 up to conditioned ranchers or military trucks.

3.1.5 Comparison of the different types

SIZE	NUMBER OF TRAVELLERS	TRIP DURATION	CONSUMPTION	PRICE	SPACE	FREEDOM
REDUCED SIZE CAMPER VANS	XX	Weekend	X	€	X	XXX
MEDIUM SIZE CAMPER VANS	XXX	Weeks	XX	€€	XX	XX
BIG VOLUME VANS	XXXX	Weeks/months	XXX	€€	XXXX	X
OFF-ROAD VANS			XXXX	€€€	XXX	XXXX

Chart 3. Different sized vans comparison.
Source: Own elaboration

3.1.6 Conclusion regarding the size of the van

As specified in the Requirements section, a very important aspect that is wanted to take into account in this project is not to lose comfort or quality of life. That is why the option of choosing a reduced size camper van is discarded.

On the other hand, another important aspect mentioned above is that the climate impact of the project is not very high. For that reason, off-road vans are ruled out for the project.

Being true that the consumption of the big volume vans is higher than the medium size camper vans, and that they imply more limitations due to the size of the van, a big

volume van will be chosen for the project. This is because the space they offer is considerably larger. In addition, they offer the possibility of travelling for long periods, which was one of the requirements mentioned above.

3.1.7 Big volume van brand comparison

The following table compares different models of large vans. (25) (26) (27) (28) (29)

	Citroën Space Tourer	Ford Transit Custom	Nissan NV300	Peugeot Traveller	Fiat Ducato	Mercedes Benz Marco Polo
Height (mm)	1900	1977	H1: 1970	1920	H1: 2250	1980
			H2: 2490		H2: 2500	
					H3: 2800	
Internal width (mm)	1920	1986	1950	1910	1870	1930
Length (mm)	M: 4950	5339	L1: 4990	L1: 4959	L1: 5000	5140
	L: 5300		L2: 5390	L2: 5309	L2: 5400	
					L3: 6000	
					L4: 6400	

Chart 4. Different vans brands comparison.
Source: Own elaboration.

Comparing the measurements of the different brands, it is decided that the chosen van will be the Fiat Ducato H2L3.



*Illustration 2. Fiat Ducato H2L3.
Source: nettialuto.com*

Firstly, because the height offered is greater than that of other brands, which allows you to stand comfortably. It is true that the interior width is slightly smaller than the other brands, but by optimizing the placement of the furniture inside the van, this fact may not be noticeable.

On the other hand, the lengths it offers are longer than the other brands, a fact that also helps the feeling of having a great space inside the van.



DUCATO CAMPER VANS RANGE

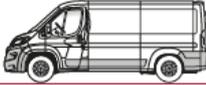
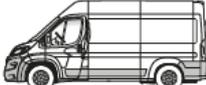
	L1 5,0 m	L2 5,4 m	L3 6,0 m	L4 6,4 m
H1 2,25 m	 8 m ³	 10 m ³		
H2 2,5 m	 9 m ³	 11,5 m ³	 13 m ³	 15 m ³
H3 2,8 m			 15 m ³	 17 m ³

Illustration 2

Source: <https://www.fiatcamper.com/Resources/files/van/schema.pdf>



DUCATO CAMPER VANS RANGE

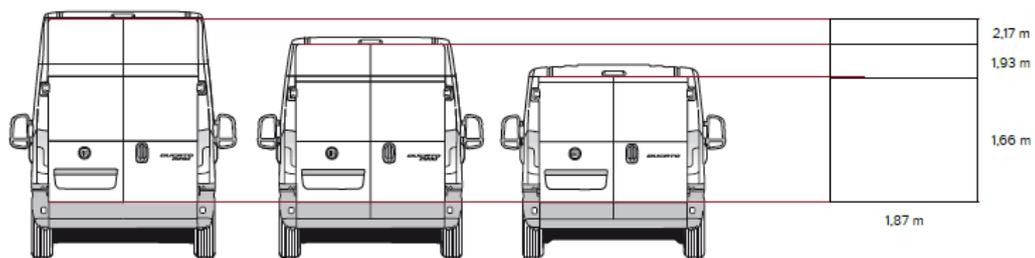


Illustration 3

Source: <https://www.fiatcamper.com/Resources/files/van/schema.pdf>

The L3 model is chosen because it allows for a considerably larger space than the L2. In addition, the L4 model is long enough to compromise the handling of the van.

3.2 Electrical installation

In modern camper vans, it is indispensable to have electricity to power all the devices that make life in the van easier and more comfortable. That is why it is important to make a good electrical calculation together with the diagram.

To know the power that will be necessary, first of all it is necessary to establish the devices that you will want to have in the van to know how many batteries and solar panels will be needed:

- Upper cabin light
- Kitchen light
- Van roof lights
- Work table lights
- Bathroom light
- Bed lights
- Fridge
- Water pump
- Garage lights
- Water level sensors
- Oven
- Boiler

Once we know what will need electricity, we proceed to establish how much power each device will need.

3.2.1 Upper cabin light

A 60 cm T8 LED tube will be installed, whose consumption is 9 w. (30)



*Illustration 17. Led tuve.
Source: microcom.com.mx*

3.2.2 Kitchen light

A standard E27 LED will be installed. Its consumption will be 5 w.

3.2.3 Van roof lights

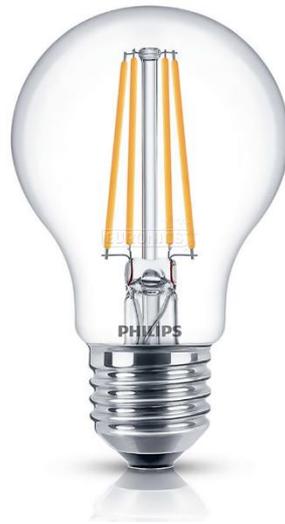
There will be 2 lights on the van's roof: one between the work table and the kitchen and one between the bathroom and the bed. There will be two standard E27 LEDs, each with a consumption of 5 w, which means a total consumption of 10 w.

3.2.4 Worktable lights

As mentioned above, there will be 2 lights on the work table. They will be two T8 LED tubes placed on the wall, with a consumption of 9 w each, being a total of 18 w.

3.2.5 Bathroom light

It will have a standard E27 LED light, with a consumption of 5 w.



*Illustration 18. E27 LED light.
Source: euronics.ee*

3.2.6 Bed lights

There will be two standard E27 LED lights on the bed, one on each side of the bed. The total consumption will be 10 w, 5w each.

3.2.7 Fridge

The chosen refrigerator is a Dometic RM 5330. The reason is that it has more volume (70 L vs. 60 L) and being a 70 L fridge it is not the most expensive. It also takes up what is considered a reasonable amount of space inside the van and has a freezer included.
(31)

- Volume (L): 70
- Freezer Volume (L): 5
- Mass: 24.3 kg
- Measures (cm): 48.6 x 82.1 x 47.4



Illustration 4
Source: werksverkauf.dometic.de

It has a consumption of 104.17 w.

3.2.8 Water pump

A Fiamma Wasserpumpe Aqua 8 - 12 v has been chosen. The choice was made because the dimensions and weight and comply with the requirements of the project.

- Flow (l/min): 10
- Pressure (bar): 1.5
- Mass (kg): 1.4



Illustration 5
Source: shop.hybridsupply.de

It will involve a consumption of 40.8 w

3.2.9 Garage lights

There will be two 20 cm T8 LED tubes, in case you need to access the garage at night to be able to search or handle something comfortably. They will have a consumption of 3 w each, being a total of 6 w.

3.2.10 Water level sensors

The MT Tanksensor FL water level sensors from Büttner Elektronik, which have a consumption of 0.084 w, will be installed.(32)

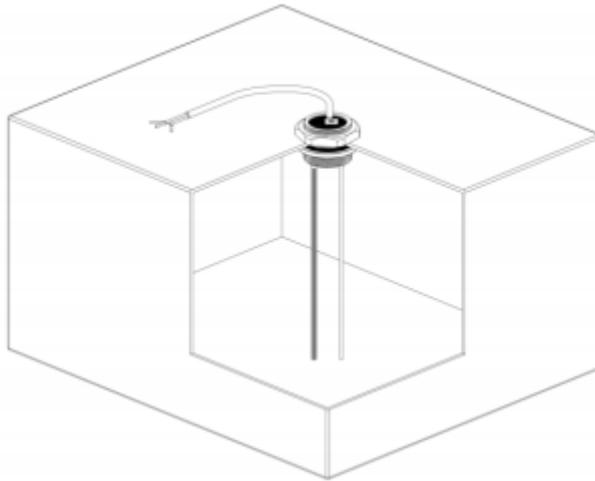


Illustration 6

Source: <https://www.buettner->

[elektronik.de/fileadmin/redakteurupload/downloads/Zubehoer/Tank_sensor_capteur_reservoir_MT_TK_EF.pdf](https://www.buettner-elektronik.de/fileadmin/redakteurupload/downloads/Zubehoer/Tank_sensor_capteur_reservoir_MT_TK_EF.pdf)

3.2.11 Oven

The oven to be installed is a Dometic Backofen- und Grillkombination Duplex. The choice is due to the fact that, being a good brand of ovens, it is cheaper and offers the same features as the others in its range.

- Volume (L): 36
- Mass (kg): 13.5
- Measures (cm): 44.5 x 45.6 x 44.0



Illustration 7

Source: [ideal.de](https://www.ideal.de)

Its consumption is 1.5 w.

3.2.12 Boiler

The boiler chosen is a Truma Boiler Gas/Elektro. It offers the possibility of being used by gas as well as by electricity, which is a plus for times when there may be a lack of gas or when the batteries are about to run out.

- Volume (L): 10
- Measures (cm): 34.9 x 34.7 x 26.1
- Mass (kg): 7.4
- Pressure (bar): 2.8
- Gas consumption (g/h): 120
- Time to warm the water by gas (min): 31
- Time to warm the water by electricity (min): 29
- Time to warm the water with both gas and electricity (min): 16
- Power supply: 220 V AC
- Consumption (W): 814



Illustration 8
Source: caravaning-shop.ch

Since it can run on both gas and electricity, it will normally be operated on gas. On the other hand, as it requires a 220V supply voltage, it can only be operated on electricity when connected to charging points in camping areas. For this reason the consumption of the boiler will not be taken into account in the electrical calculation.

3.2.13 Consumption calculation

Now that we know what each element will demand, we can make the consumption calculation to choose how many extra batteries will be needed and how many solar panels to install.

ELEMENT	POWER (Wh)	VOLTAGE (V)	INTENSITY (Ah)
Upper cabin light	9	12	0,75
Kitchen light	5	12	0,416666667
Roof lights	10	12	0,833333333
Worktable ligths	18	12	1,5
Bathroom light	5	12	0,416666667
Bed lights	10	12	0,833333333
Fridge	104,17	12	8,680833333
Water pump	40,8	12	3,4
Garage lights	6	12	0,5
Water level sensor	0,084	12	0,007
Oven	1,5	12	0,125
TOTAL	209,554		17,46283333

Chart 5. Total Power calculation.
Source: Own elaboration.

Therefore an Exide Equipment Gel ES 1200 extra battery is chosen. Its characteristics are:

- Intensity (Ah): 110
- Measures (cm): 28.6 x 22.6 x 26.9
- Mass (kg): 38.7 kg



Illustration 9
Source: bse-usv-technik.de

In addition, a solar panel Solarmodul TSPF110 halblexibel by Teleco will be installed, which will be able to supply a power of 110 W and the mass is 24 kg.



Illustration 10
Source: moverá.com

A charge regulator will be installed, the purpose of which will be to monitor the state of the batteries, the intensity of the energy coming from the solar panels and to prevent them from being overcharged or overdischarged. This will improve the functioning of the solar kit and extend the life of the batteries. The regulator will be of the PWM type, as they are more economical and suitable for small off-grid systems in camper vans, against MMPT types. (33)

It will be a 12V PWM Solar Victron LCD&USB 12/24V 10A solar charge controller and the mass is 1 kg.



Illustration 11
Source: <https://www.tutiendaenergetica.es/fotovoltaica/reguladores-solares/>

A power transformer will also be necessary to change from 220 V (obtained from the camping areas to recharge the batteries) to 12 V.

In addition, a circuit breaker will be installed to protect the installations in the case that the intensity exceeds 20 A. Moreover, a fuse box will be installed to protect the cables of the installations in case of intensity overloads.

Finally, a junction box will be installed on each side of the van in case any modification in the electrical circuit is required.

3.2.14 Electrical panel

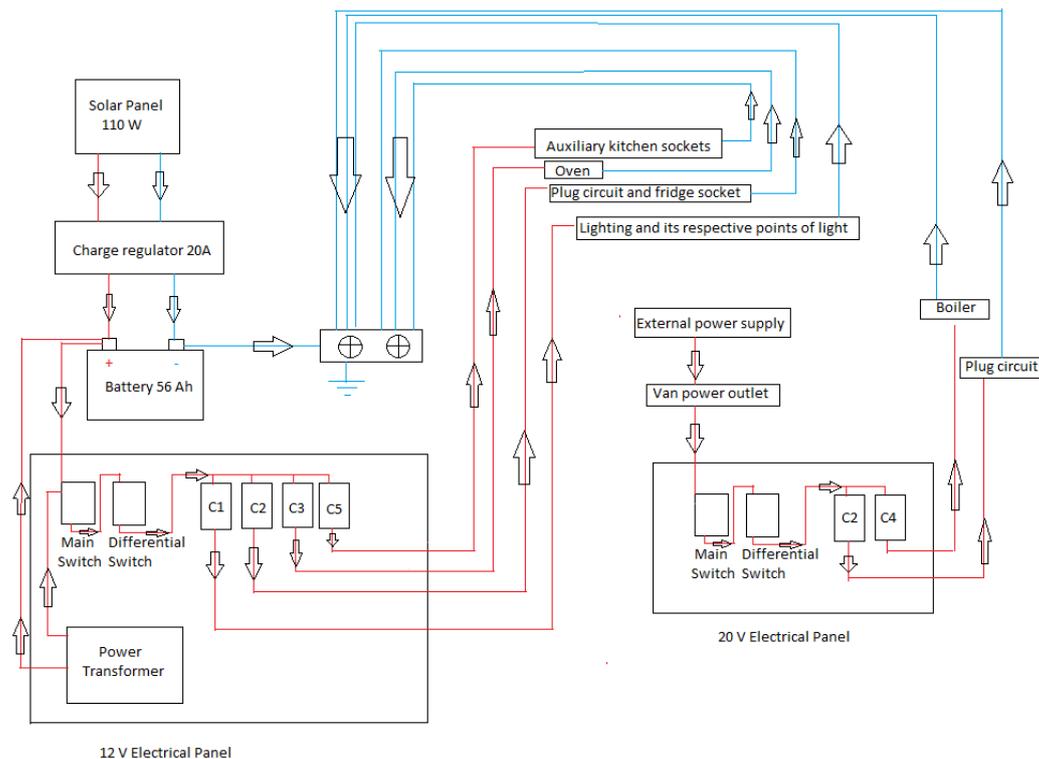


Illustration 12. Electrical circuit scheme.
Source: Own elaboration

To make the electrical panel, the indications established in the Spanish Low Voltage Electrotechnical Regulations (RBT) have been followed. (34)

The basic electrical circuits are indicated from C1 to C5, and are located inside the van's electrical panel. The electrical panel has already specified which element corresponds to which circuit. Its technical characteristics will now be displayed:

- **C1**
 - 1.5mm² cable
 - 10 A circuit breaker
 - 16mm external diameter conductor tube
 - Maximum of thirty lighting points
- **C2**
 - 2.5mm² cable
 - 16 A circuit breaker
 - 20mm external diameter conductor tube

- Maximum twenty power outlets
- **C3**
 - 6mm² cable
 - 25 A plugs and sockets
 - 25 A circuit breaker
 - 25mm external diameter conductor tube
 - Maximum three 25 A power outlets
- **C5**
 - 2.5mm² cable
 - 16 A circuit breaker
 - 20mm external diameter conductor tube
 - Maximum six power outlets.

3.2.15 Switches

The switches will be placed as follows:

- One switch for each LED tube on the work table. One will be placed on each side of the table.
- A switch for the kitchen light placed on the kitchen wall.
- Two switches for the two lights on the van's roof. They will be located next to the sliding door, so that the light can be switched on just as you enter. They will be placed on the side of the door that touches the kitchen. In addition, the light that is closest to the bed will have an extra switch on the wall of the bed, so that the ceiling light can be switched on from the bed.
- The bathroom switch will also be placed next to the door, next to the ceiling ones.
- A switch on each side of the bed for the bed lights.
- Two switches next to those on the ceiling and the bathroom, which will turn the garage lights on and off.

3.2.16 Plugs

At first the idea was to install four plugs:

- One at the work table
- One in the kitchen
- One on each side of the bed
- Two in the garage

The reasons are as follows:

- Having several plugs gives you the possibility to have several devices connected at once.
- On the worktable because, being an area that can be used for work, gives the possibility of being able to use the computer and, if necessary, to charge it without having to change location.
- In the kitchen to be able to plug in utensils such as a blender or a sandwich maker without having to be outside the kitchen "zone", which offers great convenience.
- On both sides of the bed so that you can charge any device (usually your cell phone) while you sleep and use it without having to get out of bed. In addition, there will be one on each side as the van is designed to accommodate two people.
- Two in the garage so the pump and the boiler can be connected.

This being the first idea, it was later thought to add:

- Two plugs will be installed on the worktable instead of one, since the van is designed for two people, and, if needed, both can charge devices.
- Two more plugs will be added, hidden in the kitchen to connect the refrigerator and the oven.

Thus, the total number of plugs would be as follows:

- Two plugs on the worktable
- Three plugs in the kitchen (two of them hidden).
- Two more plugs, one on each side of the bed.
- Two plugs in the garage

There will be a total of nine plugs in the van.

They will be divided into two groups: some will receive a 12 V power supply and others 220 V.

They will therefore be supplied with 220 V:

- The two plugs in the worktable
- One in the garage.

The two in the worktable is to charge the computers battery, and the one in the garage is to supply the boiler.

The others will be supplied with 12 V.

3.3 Water installatio

Having a water circuit in the van is one of the most basic facilities to be able to live in it comfortably. (35)

The water circuit will be equipped with:

- Two tanks, one for clean water and one for grey water.
- A water pump.
- A boiler.
- A sink.
- Two pressure switches.
- A showerhead.
- A toilette.

3.3.1 Water tanks

The clean water tank will be in one of the compartments of the garage, while the grey water tank will be in the lower part of the van. The grey water one will be installed in the rear undercarriage, behind the axle, by removing the spare wheel and fastened by means of plates. Their capacity will be 78 L, measuring 130 x 37 x 18 cm, from the brand Reimo. The mass is 5.7 kg.(36)



Illustration 13

Source: <https://todocampers.com/1236-deposito-de-agua-78-litros-para-ducato-jumper-y-boxer-1994-2006-18x37x130-cm.html>

3.3.2 Water pump and boiler

The water pump and the boiler will not be discussed here as it has already been discussed above in the context of the electrical calculation.

3.3.3 Sink

The sink to be installed will include two cookers. It will be a Dometic HSG 2445 model. Its mass is 5.0 kg.



Illustration 14

Source: vansicampers.com

This model has been chosen because living two people in the caravan, two fires will be enough. Moreover, its dimensions and weight are ideal for the van. Finally, this model has also been chosen because, including a cooker and sink, it is more economical.

3.3.4 Pressure switches

A pressure switch is an element that detects when the tap is open, and automatically activates the water pump, so that there is no need for a switch to turn it on and off manually. This element is installed in the pipe that connects the water pump to the water outlets.

Two pressure switches shall be installed: one for cold water and one for hot water.

Two Karcher electronic pressure switches will be installed.



Illustration 15

Source: <https://www.manomano.es/p/presostato-electronico-69973570-553843>

Its characteristics are:

- Measures (mm): 135 x 100 x 190
- Weight (kg): 1 (each one)

3.3.5 Showerhead

The showerhead to be installed will be a Reich Dushkopf Trend E.



Illustration 16
Source: obelink.de

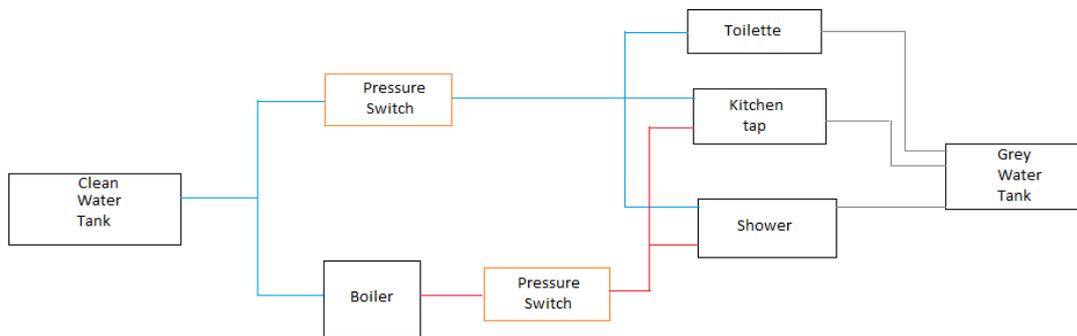
3.3.6 Toilette

The toilette that will be installed is a Thetford Casettentoiletten C220. Its mass is 6.8 kg.



Illustration 17
Source: thetford.com

3.3.7 Water circuit



3.4 Isolation

3.4.1 The importance of making a good isolation.

- **Avoiding condensation (37)**

Condensation is the change of a gas into a liquid state. In the van, condensation is produced by the difference in temperature between the outside and the inside. In the interior, the hot air that circulates very close to the sheet metal is cooled, producing the condensation of the water vapour it contains. Condensation can be a serious long-term problem for the van if the correct insulation is not installed, as the humidity will rust the sheet metal, which can become perforated after a few years.

The solution is to install an insulator that has a vapour barrier. This layer does not allow the vapour to pass through the insulator, so the sheet metal is always kept dry.

- **Avoiding cold weather**

Good insulation prevents the heat emitted by the stationary heating from escaping through the van's sheet metal.

- **Avoiding hot weather**

On very hot days the sheet metal can heat up to very high temperatures, producing an oven effect, making it practically impossible to be inside the van. If a good thermal isolation is made, the transfer of heat of the sheet to the interior will be minimized.

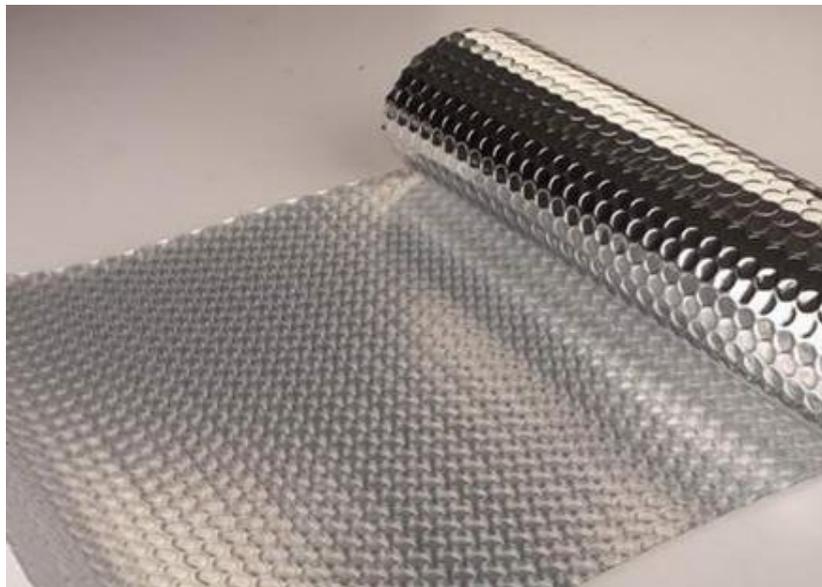
- **Less fuel consumption**

By installing good insulation, it will retain much more heat inside the van, so the stationary heating system will work less, so less fuel will be wasted. This also means a reduction in CO2 emissions.

3.4.2 Types of insulators

3.4.2.1 Reflective insulation

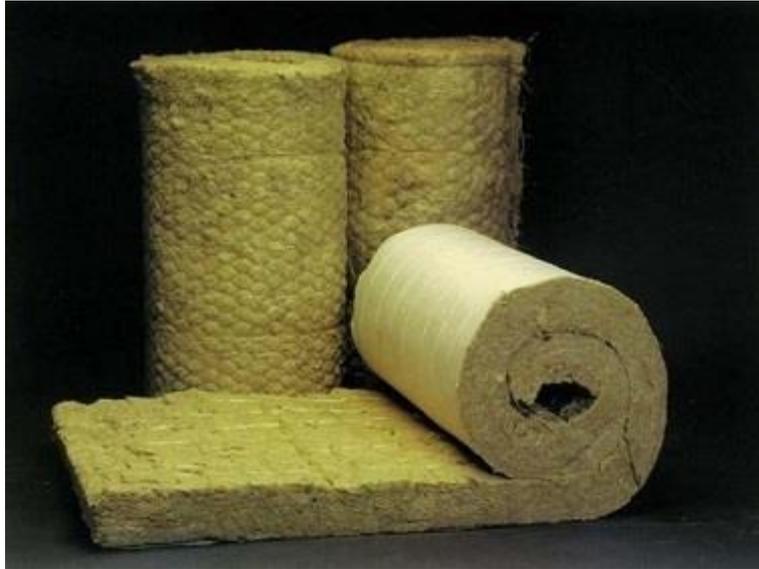
There are different types of reflective insulation, but the most common are those made up of layers of bubble plastic or polyethylene foam, separated by aluminium sheets. This type of insulation is more suitable for insulating from heat than from cold, but for it to be effective, an air chamber should be left between the van's sheet metal and the insulation and another air chamber should be left between the insulation and the coating that we put on it.



*Illustration 19. Reflective insulation.
Source: atumanspackaging.com.my*

3.4.2.2 Rock wool

It is a great acoustic insulator and, although it also has good properties as a thermal insulator, it is not the best. This insulation is made from fibres obtained from volcanic rock. The good thing about this type of insulation is that it is very easy to install and that it adapts to the structure of the van.



*Illustration 20. Rock wool.
Source: insulationreviewed.com*

3.4.2.3 Extruded polystyrene

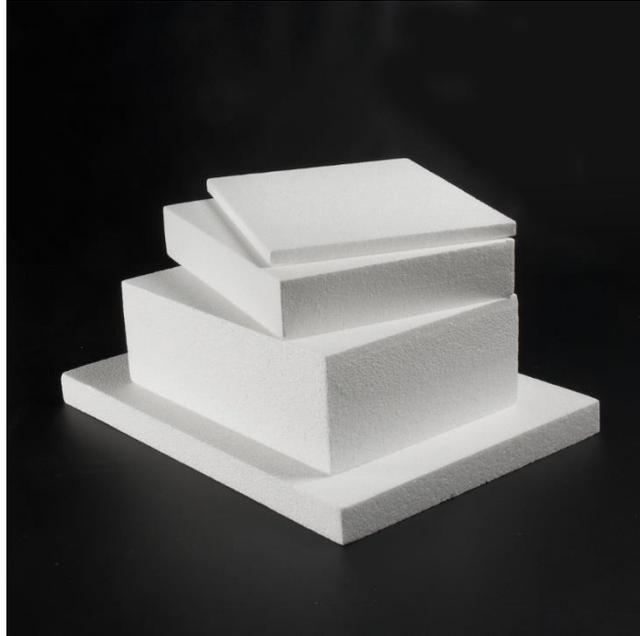
Although this is one of the best thermal insulators on the market, for vans they are not usually the best option. This insulation goes very well to insulate both heat and cold, and also has a vapor barrier. The bad thing about this insulation is that it comes in rigid sheets, so it is very difficult to adapt it to the sheet metal of the van, it is also flammable and produces very toxic gases. Furthermore, it is obtained from an oil derivative, and in its manufacturing process it is highly contaminating to the earth.



*Illustration 21. Extruded polystyrene.
Source: kimmu.com.my*

3.4.2.4 Expanded polystyrene

It shares the same chemical composition as extruded polystyrene, as well as its advantages and disadvantages, but in this case expanded polystyrene does not work as well as a vapour barrier.



*Illustration 22. Expanded polystyrene.
Source: mwmaterialsworld.com*

3.4.2.5 Polyurethane foam

Its basic composition is oil and sugar. For a good insulation, it must be done by a specialized professional and with the necessary machinery. There are different types of quality, and their chemical composition can change, having open cell polyurethane foam and others of closed cell. The first option is not recommended at all, as it does not act as a vapour barrier in the long run and the sheet will rust.



*Illustration 23. Polyurethane foam.
Source: cewheelsinc.com*

3.4.2.6 Kaiflex

Kaiflex is a flexible, self-adhesive thermal insulator made from synthetic rubber. Its closed-cell structure acts as a vapour barrier, thus preventing condensation. It is usually the best choice for insulating the van.



*Illustration 24. Kaiflex.
Source: caldo-izolacja.pl*

3.4.2.6.1 Kaiflex properties

- Flexible
- Easy to install
- Self-adhesive
- Easy to cut
- It does not produce dust or release fibres into the environment.
- Thanks to its closed cell structure it is totally waterproof.

- In case of fire, the kaiflex foam is self-extinguishing , does not drip and prevents the flame from spreading.
- It also works as an acoustic insulator.
- Reduced size. They are usually distributed in two thicknesses, 10mm and 20mm.

That said, 20mm thick Kaiflex foam will be chosen to insulate the van.

3.5 Inside walls

3.5.1 Materials study

3.5.1.1 Plastic (5)

Plastics are organic materials consisting of polymers made up of long chains of atoms containing mainly carbon. Depending on their origin they can be natural, if they are obtained directly from vegetable raw materials (e.g. cellulose), or synthetic if they are made from compounds derived from oil, natural gas or coal. In this section, I will focus on the latter.

They are a very used material nowadays because most of them, apart from being cheap, are transparent, colourless, fragile, tenacious, rigid and hard. In addition, they do not rot, do not rust and are lightweight.

All products made from plastic are marked with an arrow triangle and a number indicating what type of plastic it is.

According to their molecular structure, there are three large families of plastics.

3.5.1.1.1 Thermoplastic plastics (6)

Thermoplastics refer to the set of materials that are formed by polymers that are united by intermolecular forces, forming linear or branched structures.

The properties of thermoplastic materials are (7):

- They can melt before going into a gaseous state.
- They allow for plastic deformation when heated.
- They are soluble in certain solvents.
- They swell in the presence of certain solvents.
- Good resistance to the phenomenon of creep.

We can find the following types of thermoplastics:

- High Density Polyethylene (HDPE):

HDPE is translucent, strong and easy to process and is used to manufacture objects such as bottles, tanks and containers for transportation. In addition, it is very strong, versatile, cheap, transparent or white and has excellent isolation properties.



*Illustration 25. HDPE.
Source: piping-designer.com*

Advantages of using HDPE:

- Is elastic.
- Easy transportation.
- Long useful life.
- No permanent deformation.
- Can be recycled.
- Great flexibility.
- Cheap.
- Corrosion resistant.

Disadvantages of using HDPE:

- Low multi-axial stress properties.
- Easy cracking.

➤ **Low Density Polyethylene (LDPE):**

The LDPE can be either white, translucent or transparent and can be in contact with food. It is also strong, versatile and cheap.

Advantages of using LDPE:

- Easy processing.
- Soft.
- Impact resistance.
- Thermal resistance.
- Weather resistance.
- Cheap.
- Can be recycled.

Disadvantages of using LDPE: (8)

- Does not act as a gas barrier.
- Flammable.



*Illustration 26. LDPE.
Source: graylineinc.com*

➤ Polyvinyl chloride (PVC):

PVC is the most versatile plastic derivative and can be produced by four different processes (suspension, emulsion, mass and solution). It is a plastic that is very resistant to wear and chemical, atmospheric and fire agents. It is used in the paper industry and to create containers for food, credit cards, furniture, toys and clothing.



Illustration 27. PVC.
Source: mwmaterialsworld.com

Advantages of using PVC (9):

- It is very resistant as well as stable and durable.
- Isolating and waterproofing.
- Corrosion resistant.
- No maintenance required.

Disadvantages of using PVC:

- When its life is over it is difficult to get rid of it because when it burns it emits hydrochloric acid.
- Little flexibility when subjected to low temperatures.
- Releases plasticizing particles (except PVC for food use).
- Its resistance to abrasion is limited.

➤ **Polypropylene (PP):**

It has a higher softening temperature than polyethylene and a higher tendency to be oxidized. It is transparent, light and resistant and can be used for both plastic and fibre. It does not absorb water and is easy to apply. In addition, it has great resistance to environmental stress cracking.



*Illustration 28. Polypropylene.
Source: donkeunited.com*

Advantages of using PP (10)(11):

- High mechanical resistance to both impact and fatigue.
- High melting point.
- Low humidity absorption.
- Chemical resistance to both acid and alkaline substances.
- Highly versatile.
- Lightness, due to its low density.
- Good cost-benefit ratio.
- Good electrical isolator.

Disadvantages of using PP:

- Minimum resistance to abrasion.
- Easily oxidized.
- Poor resistance to low temperatures.

➤ **Polystyrene (PS):**

There are four main types of polystyrene. Crystal PS which is transparent, rigid and brittle. HIPS which is high impact polystyrene, so it is impact resistant and opaque white. EPS which is very light and finally the extruded PS, which is similar to the expanded one, but more dense and waterproof. It is one of the most important thermoplastics, transparent, hard and flammable, very shiny and inert against many corrosives.



*Illustration 29. Polystyrene.
Source: skillsupplies.com*

Advantages of using PS (12):

- Ease of use.
- Relatively low cost.
- Inert against many corrosives.
- Hardness.
- Recyclable.

Disadvantages of using PS:

- Flammable.
- Low resistance to high temperatures.
- Bad mechanical resistance.

➤ **Polyethylene Terephthalate (PET):**

It is a type of thermoplastic widely used in beverage and textile packaging. It is recyclable although its viscosity decreases with thermal history, and is approved for use in products that are in direct contact with food.



*Illustration 30. PET.
Source: ec21.com*

Once the material is obtained, it can be processed in different ways to obtain derived products: by injection, extrusion, thermoforming, injection and blow moulding, preform blowing, etc. If the transparency of the material is sought, it must be cooled quickly after being treated. (13)

Advantages of using PET:

- Waterproof
- Low moisture absorption.
- High resistance to folding.
- Excellent mechanical properties (resistant to wear and tear and bending).
- High chemical resistance and non-deformability to heat.
- Recyclable.

Disadvantages of using PET:

- Not biodegradable.
- It is not recommended to be outdoors.

➤ Others (14):

Includes all non-recyclable plastics. These cannot be recycled because they are usually mixtures of some of the above mentioned or they are others that are not treatable for technical reasons. They cannot be recycled, but they can be reused without problems and are very useful for many crafts and uses. Within this group, the most common are polycarbonate and ABS or Acrylonitrile Butadiene Styrene.

3.5.1.1.2 Thermoset plastics (15)

Thermosets refer to the set of materials formed by polymers joined by chemical bonds acquiring a highly reticulated final structure.



*Illustration 31. Thermoset plastic.
Source: opusplastics.com*

The highly reticulated structure that thermoset materials have is directly responsible for the high mechanical and physical resistance (efforts or loads, temperature ...) that these materials present compared to thermoplastic materials and elastomers. On the other hand, this highly reticulated structure provides a low elasticity, giving these materials their characteristic fragility.

Their properties are:

- They cannot be melted, as they go into a gaseous state before melting.
- Generally they do not swell in the presence of certain solvents.
- Insoluble.
- High resistance to the phenomenon of creep.

Polyamides, rigid resins and epoxy resin are examples of thermoset plastics.

3.5.1.1.3 Elastomer plastics (16)

The elastomers refer to the set of materials formed by polymers that are united by means of chemical bonds acquiring a slightly reticulated final structure.

The main characteristic of elastomers is their high elongation or elasticity and flexibility that these materials have against loads before they break or fracture.



*Illustration 32: Elastomer plastic.
Source: stockmeier.com*

Their properties are:

- They cannot be melted, as they go into a gaseous state before melting.
- Generally, they do not swell in the presence of certain solvents.
- Generally insoluble.
- Flexible and elastic.
- Less resistance to the phenomenon of creep than thermoplastics.

Silicones are an example of elastomers.

3.5.1.2 Comparison of different plastics.

	TERMOPLASTICS						TERMOSETS	ELASTOMERS
	HDPE	LDPE	PVC	PP	PS	PET		
Quality	X	X	XX	X	X	X	X	X
Humidity isolation	X	X	X		X	X	X	
High temperatures resistance	X		X	X			X	
Fungos resistance	X	X	X		X	X		
Weather resistance	X	X	X		X			
Deformable		X			X		X	
Flexible	X				X			X
Lightness	X	X	X	X		X	X	X
Ease of working	X	X	X		X		X	X
Price	€	€	€	€	€	€	€€	€€€
Recyclable	X	X		X		X		

Chart 6. Plastics comparison.
Source: Own elaboration

3.5.1.3 Natural wood (17)(18)

Wood as a building material is one of the oldest materials used by humans for construction. These are the advantages of wood as a building material:

- It is a natural product.
- It is 100% renewable if responsible logging is practiced.
- It offers good thermal insulation and sound absorption.
- Easy to modify and offers a variety of uses.
- Good preservation over time.
- Easy to find and relatively inexpensive compared to other materials.
- Reusable.
- High mechanical resistance. Capacity to resist both compression and traction efforts.
- Diversity of textures and finishes.

In the world of adapting vehicles for use as homes, it has also been used for furniture as well as wall and floor coverings. However, building with wood also has certain disadvantages to be taken into account (19):

- It is a material susceptible to attack by insects and fungi.
- It is very vulnerable to fire.
- It is sensitive to humidity and can increase or reduce its size notably.

Although there are many types of wood, only a few have the advisable characteristics to be used at industrial level. (20)

Wood presents many types of classifications since it is a material with a great variety of properties, uses or origins. Among these ways of classifying the wood the most extended is the one referring to its characteristics of hardness. This way we can include them all in two big groups: the soft woods and the hard woods.

3.5.1.3.1 Soft Woods

These types of wood are the lightest, cheapest and most common in most furniture and structures. They have a much lower durability than hardwoods and when treated they produce many more splinters.

Among the most used ones are:

- **Pine**
It has a uniform texture, is less expensive than hardwoods and is easy to work with. It is one of the most used woods by professionals and it is advisable in terms of quality and price. Pine is widely used in carpentry, panels, furniture and mouldings.



*Illustration 33. Pine wood.
Source: exportersindia.com*

- **Cedar**
It is reddish in color, well known for its sweet smell. Cedar is widely used in chest of drawers, roofs and tiles. It is widely used in construction, to cover furniture, etc.



Illustration 34. Cedar wood.
Source: wisegeek.com

- **Fir tree**

Light and soft wood, comparable to pine. Relatively low weight with good resistance and elasticity. Easy to work with in all aspects. Relative to chemicals it is much more resistant than most woods. Free of resins. Used extensively in the construction of wall and ceiling coverings for interiors.



Illustration 35. Fir tree wood.
Source: craftsmenhardwoods.com

3.5.1.3.2 Hardwoods

They are more expensive and usually more resistant. Working with this type of wood is more complicated because they are less smooth and have more irregularities, but shaping them with a machine is usually easier.

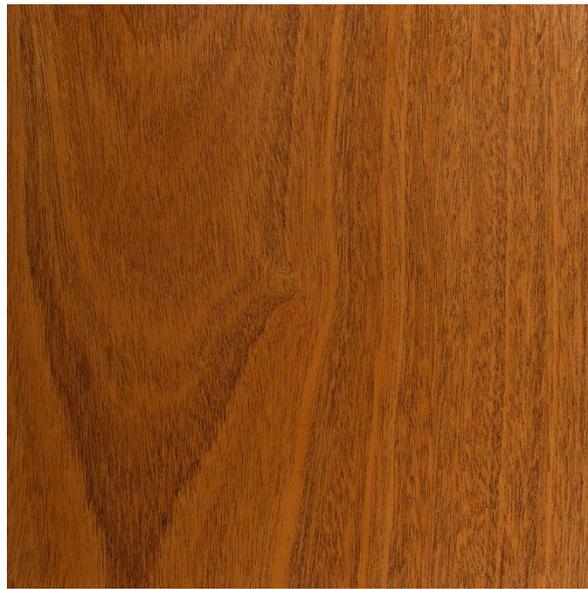
They are used for construction and joinery, producing as a result high quality furniture with excellent finishes. They have a more complicated treatment, but a better visual

power, hardness and resistance to the passage of time. These facts make the price of hardwoods higher than softwoods.

Among the most used ones are:

- **Mahogany**

This very resistant fine grain wood has a beautiful reddish brown colour. It is one of the most popular woods in joinery, as it is largely used for quality furniture, such as closets, wood panelling and veneers. Due to its high density and durability it is widely used in tropical areas that have high humidity.



*Illustration 36. Mahogany wood.
Source: wallbedsbywilding.com*

- **Oak**

The oak is within the hard woods, but it does not have fine grain like mahogany or cherry. It has excellent bending qualities, so it is popular for parquets, wood floors, along with some furniture and cabinets.



Illustration 37. Oak wood.
Source: woodcuttorder.co.uk

- **Walnut**

Walnut is one of the hardest woods in existence. They offer a beautiful chocolate brown colour with a precious grain. Walnut is not as dense as cherry or mahogany, but it is still highly sought after for luxury panelling, furniture, cabinets, doors and ornaments.



Illustration 38. Walnut Wood.
Source: woodcuttorder.co.uk

- **Teak**

Teak is a hard, moisture-resistant wood. It is resistant to warping, cracking and decay and is best used in thin furniture, doors, window frames, flooring and general construction.

It is especially used in outdoor furniture and humid areas.



Illustration 39. Teak wood.
Source: diamondtropicalhardwoods.com

- **Olive tree**

The veins of the wood of this tree are very attractive and decorative, especially those near the root. It is used a lot for artistic and decorative works among many others. Its wood is usually thick and resistant, of yellow, clear or reddish tones depending on its origin.



Illustration 40. Olive wood.
Source: smartuk.net

- **Cherry**

Originally it is pinkish brown, although it darkens over time, taking on a mahogany red colour. It is a delicate wood that must be well dried since it tends to be twisted. It is used much in the manufacture of furniture, chairs, coatings, given its great decorative contribution.



Illustration 41. Cherry wood.
Source: homestratosphere.com

- **Elm**

It is light brown, sometimes with a reddish tint or, as in the mountain elm, with a greyish hue. Resistant to decay, elm wood is highly valued in marquetry and cabinetmaking, as well as in shipbuilding, engraving and sculpture.



Illustration 42. Elm wood.
Source: wood-database.com

- **Ash**

It is used in joinery and carpentry: often in the manufacture of skis, furniture and curved items, as it is a very elastic and nervous wood.



*Illustration 43. Ash wood.
Source: woodcuttoorder.uk*

3.5.1.4 Artificial woods (21)

Since the beginning of the 20th century, artificial woods began to be manufactured as an alternative to the wear and tear and defects that natural woods have, in addition to being easier to obtain.

On the other hand, the creation of artificial wood has been considered as an alternative for the environment, since these are made from the remains of various natural woods.

It is made from bark, branches, shavings or any part of the tree that is discarded when extracting natural wood panels. Even that which has defects are used to create this prefabricated wood. This makes it a more ecological and economical alternative.

Artificial wood is manufactured by people, in factories or with tools that work them. Due to the process of unification of the remains of wood, artificial wood is easier to work with. There are artificial wood panels of all sizes and types.

Advantages of using artificial wood:

- They are usually thicker and larger than those made of natural wood.
- They do not decay, rot or deform when treated.
- Having a lower density, they are lighter and easier to work with than natural woods.
- They are not victims of the attack of parasites and termites.

Disadvantages of using artificial wood:

- When it is wet for a long time, it can start to fall apart.
- They do not have the characteristic smell of natural wood.
- It is not weather resistant, as humidity and extreme temperatures often affect the structure.

Although artificial wood is manufactured from natural wood, it has its own classification. It is not carried out according to the material that is made, but according to the process with which it is manufactured.

There are three types of artificial wood, according to this classification:

3.5.1.4.1 Chipboard

It is made from shavings and/or pieces of wood, which are mixed by means of pressure. It is usually an easy wood to work, because of its smooth surface. In spite of being a consistent material, it usually breaks easily; to avoid this, the boards are usually covered with thin sheets of natural wood or plastic, avoiding that the humidity cracks them. It is a process used to make furniture, due to its light weight.



*Illustration 44. Chipboard.
Source: beesleyandfildes.co.uk*

3.5.1.4.2 Fiberboard

This process consists of compressing dry wood fibres by means of high temperatures and high pressure, that is to say, the wood is reduced to fibres to later reconstruct them in homogenous boards. This type of artificial wood is resistant to humidity.



*Illustration 45. Medium density fiberboards.
Source: yubaowood.en.made-in-china.com*

Depending on the pressure and the binder that is applied during its manufacture, panels of low, medium or high density can be made. (22)

- **Hard density fibreboards (HDF)**
It is a type of board whose density ranges between 800 and 1000 kg/m³. In this case the fibres are impregnated in thermosetting phenolic resins and other substances that allow to obtain a strong, waterproof and abrasion resistant board.
- **Medium density fibreboards (MDF)**
This medium density fibreboard has a density that varies between 600 and 900 kg/m³. Its fibres are joined by a synthetic resin adhesive.
- **Low density fibreboards (LDF) (23)**
LDF have a density of approximately 500 kg/m³. They are manufactured using the dry filtering technique.

3.5.1.4.3 Plywood

This is one of the most resistant artificial woods. It is manufactured from thin sheets of natural wood. In order to create homogeneous and consistent boards, they are joined transversely one over the other with pressure and heat, using synthetic resins.

As it is made with a greater quantity of whole natural wood, it is more likely that they will be curved or their thickness modified by external agents. Because of this level of sensitivity, it is recommended that it be used for interiors.



Illustration 46. Plywood.
Source: buildgp.com

3.5.1.5 Comparison of different woods

	Natural wood		Artificial wood		
	Soft	Hard	Chipboard	Fiberboard	Plywood
Quality	XX	XXX	X	X	X
Water resistance				X	
Crack resistance				X	X
Insect attack	X	X			
Irregularities	X	X			
Unlimited size			X	X	X
Deformable	X				
Flexible					X
Lightness	XX				
Chips generation	X	X			
Durability	X	XX	X	X	X
Maintenance	XX	XX			
Ease of working	X		X	X	X
Price	€€	€€€	€	€	€
Environmentally friendly			X	X	X

Chart 7. Different woods comparison.
Source: Own elaboration.

3.5.2 Materials comparison

Having analysed the different materials and their qualities and shortcomings, a material will now be chosen for the interior walls of the van and the furniture.

It is difficult for one material to meet all the desired requirements, so the one that meets the greatest number of requirements will be chosen.

Firstly, plastics have been discarded as their manufacture and recycling is environmentally unfriendly.

Secondly, among the types of wood, chipboards have been discarded. The reasons for this are that: (38)

- Limited humidity resistance. In contact with water they swell and do not return completely to their original shape.
- They do not offer a completely smooth surface.
- Formaldehyde content. This is a chemical product classified as harmful to health in certain concentrations and is used as a component in adhesives used in the manufacture of chipboard.
- There is no possibility of repair.
- Veneering is necessary. If we did not do this, the exposed edges of the chipboard would offer a poor result, not only from an aesthetic point of view, but would also be a weak point against humidity and the possibility of the board chipping.

Between fibreboard and plywood, plywood will be chosen because, although they have similar qualities, plywood is more flexible, which makes it easier to install and assemble in the van.

3.6 Stationary heating

A stationary heater is an independent heating system added to the van which, from the van's own fuel, is able to generate sufficient heat to warm the interior of the van. (39)

The one that will be installed is a Diesel Air Heater Planar 2D-HA-PU27.



Illustration 18

Source: <https://planarheaters.com/product/diesel-air-heater-planar-2d-ha-pu27/>

Its characteristics are:

Heat Output; kW (BTU):	0.8 (2.700-6,850)
Fuel Consumption; l/h (gal/h):	0.10-0.24 (0.03-0.06)
Nominal Supply Voltage; V:	12 or 24
Power Consumption; W (A):	10-29 (0.8-2.42)
Airflow Rate; m ³ /h:	34-75
Weight; kg:	7.0
L x D x H; mm:	324 x 118 x 119
Operating Modes:	Temperature/Power

Chart 8. Stationary heating characteristics.

Source: <https://planarheaters.com/product/diesel-air-heater-planar-2d-ha-pu27/>

It shall have two exits to the van, one at the front and one at the rear. The two outlets shall be 10 cm in diameter and will be placed at the bottom of the van, so that the heat is directed upwards and the efficiency is optimised.

3.7 Van's inside distribution

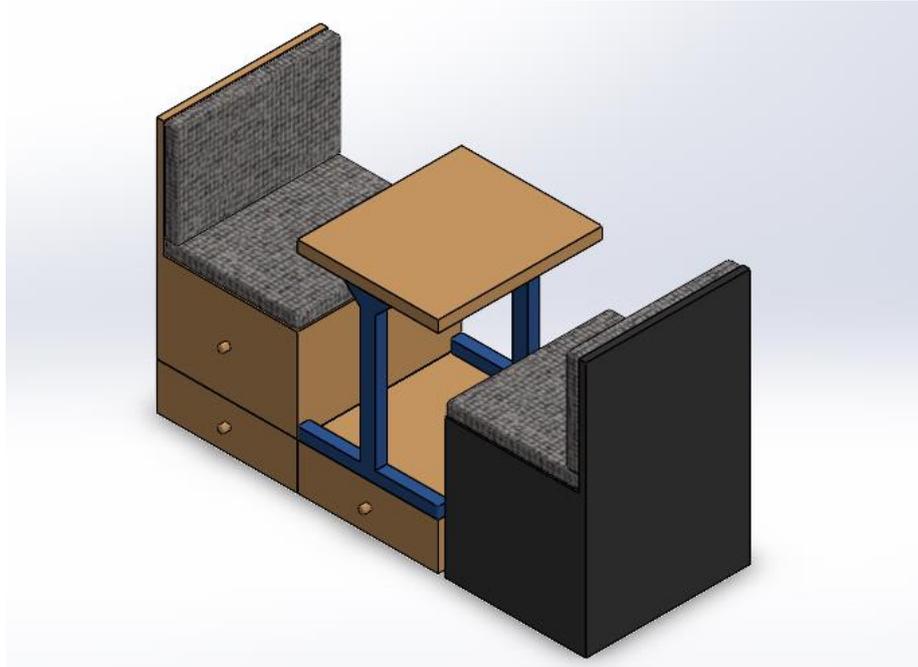
The van will be divided into five spaces:

- Driver's cab
- Worktable
- Kitchen
- Bathroom
- Bedroom

The driver's cab will not be discussed as the focus of the project is on the part of the van that is intended to be used as a living space.

3.7.1 Worktable

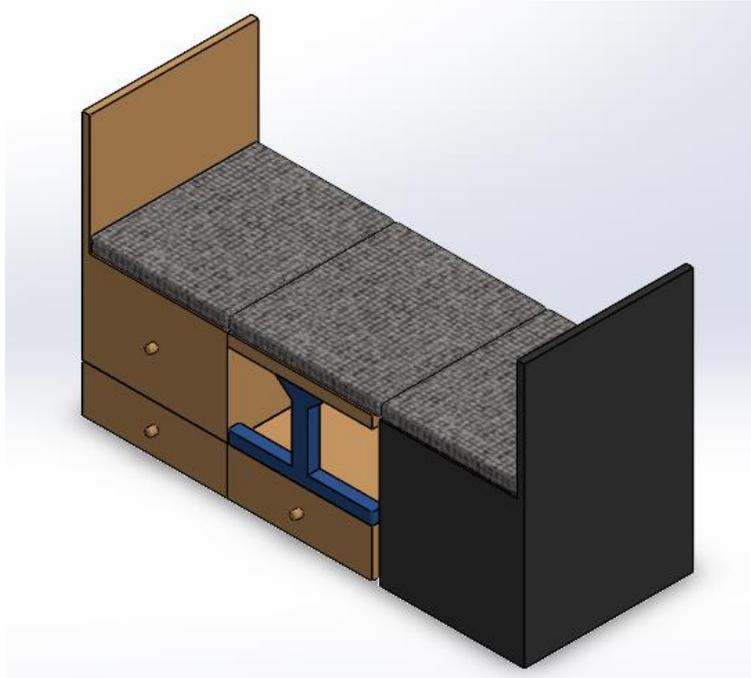
The bench area shall consist of a fixed seat with its back to the toilet, a table and the driver's seat, which shall have the ability to swivel through 180°.



*Illustration 47. Working table.
Source: Own elaboration*

Both under the seat facing away from the toilet and under the table, there will be drawers in which to store things, making the most of the space available in the van. The drawers, the table and the seat with the back to the bathroom will be made of plywood.

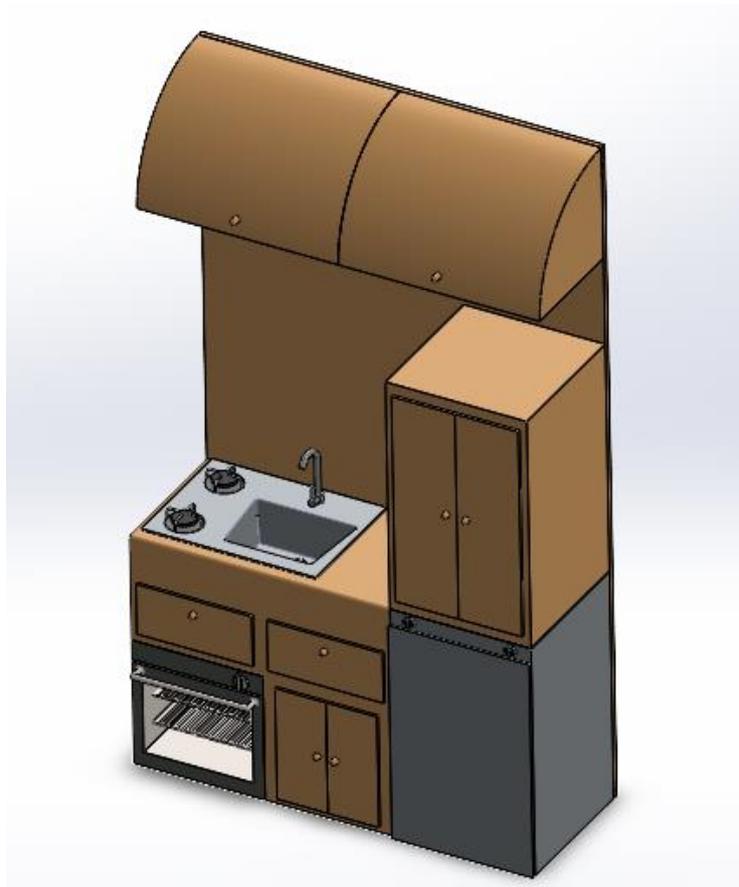
On the other hand, there is also the option, by lowering the table to the height of the seats and placing a cushion on top, to convert this space into a relaxation area or a possible extra 1.80 m bed.



*Illustration 48. Working table – Extra bed.
Source: Own elaboration*

3.7.2 Kitchen

The kitchen will consist of an oven, a fridge, a sink, two burners, two drawers, two small cupboards and two shelves at the top.



*Illustration 49. Kitchen.
Source: Own elaboration*

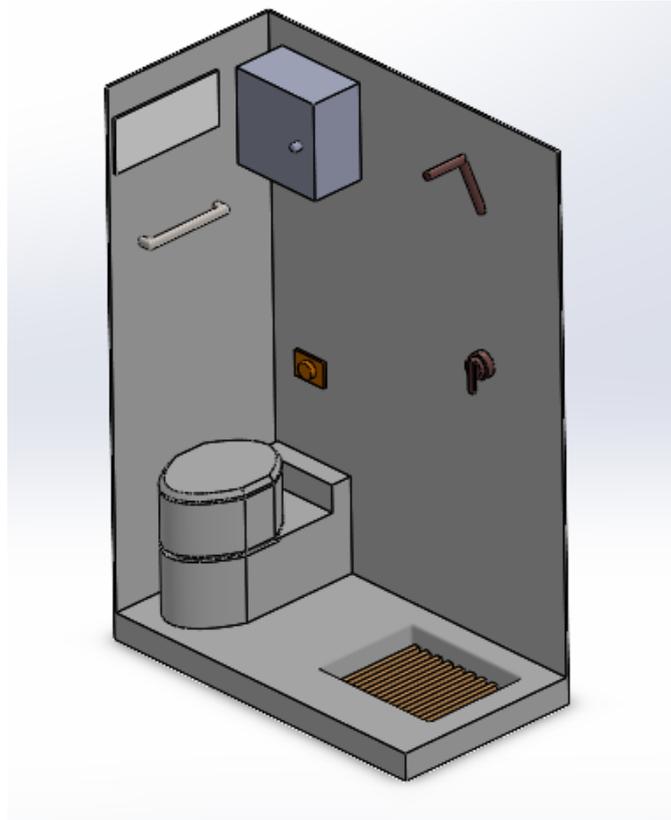
The drawers are intended to store cutlery and other small kitchen items. The lower cupboard will hold the waste bins, with different sections for recycling, and pots and pans. The cupboard above the fridge will be used as a pantry. Finally, the upper shelves will be used as storage for various kitchen utensils.

In addition, a space has been left between the sink and the pantry cupboard where food can be cut or handled.

Drawers, cupboards and shelves shall be made of plywood as well as the food handling area.

3.7.3 Bathroom

The bathroom will consist of a shower, a toilet, a towel rail, a mirror and a small cupboard in which to store bathroom utensils and medicines.

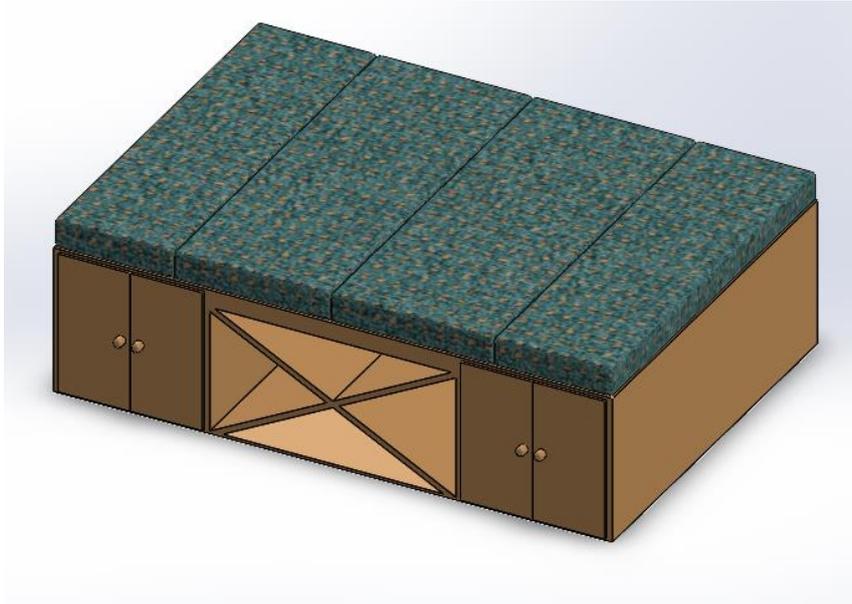


*Illustration 50. Bathroom.
Source: Own elaboration*

In the 3D drawings of the bathroom, one of the side walls and the front wall have been omitted so that the whole can be seen clearly. However, if this work were to be carried out in reality, it would have to have the mentioned walls.

3.7.4 Bedroom

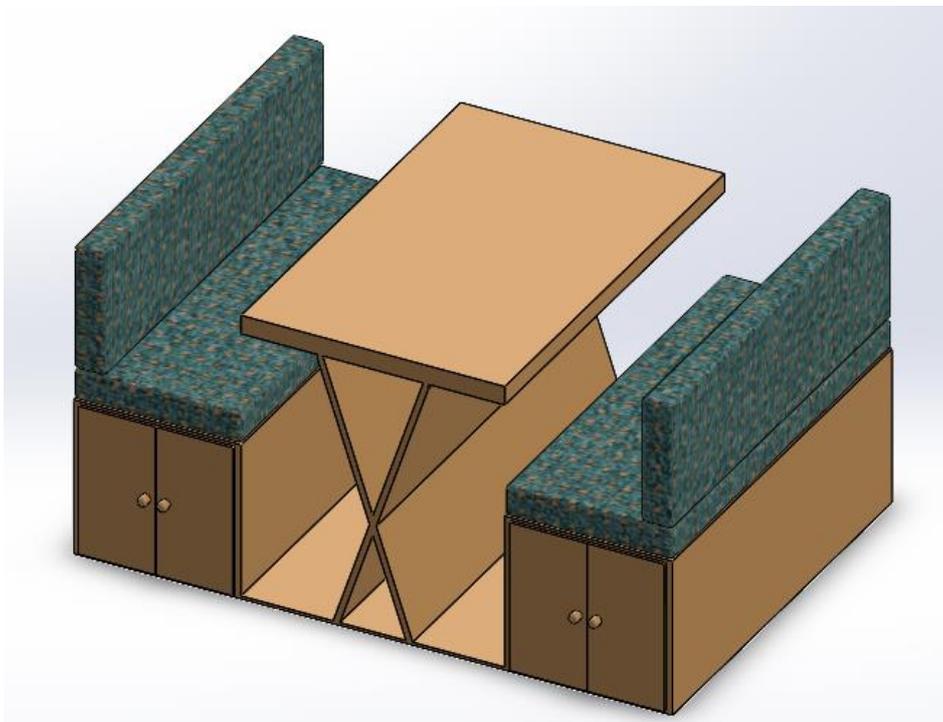
The bed area shall consist of the two spaces used as a garage between which there shall be an X-shaped mechanism on which a plywood plank shall be supported. Both the garage and the X-shaped mechanism shall also be made of plywood.



*Illustration 51. Bedroom.
Source: Own elaboration*

On top of the garage and the plywood board a mattress will be placed, consisting of 4 different modules, two of 400 mm and two of 523.3 mm. This mattress will be used as a bed of 1300 x 1870 mm so that two people can sleep on it.

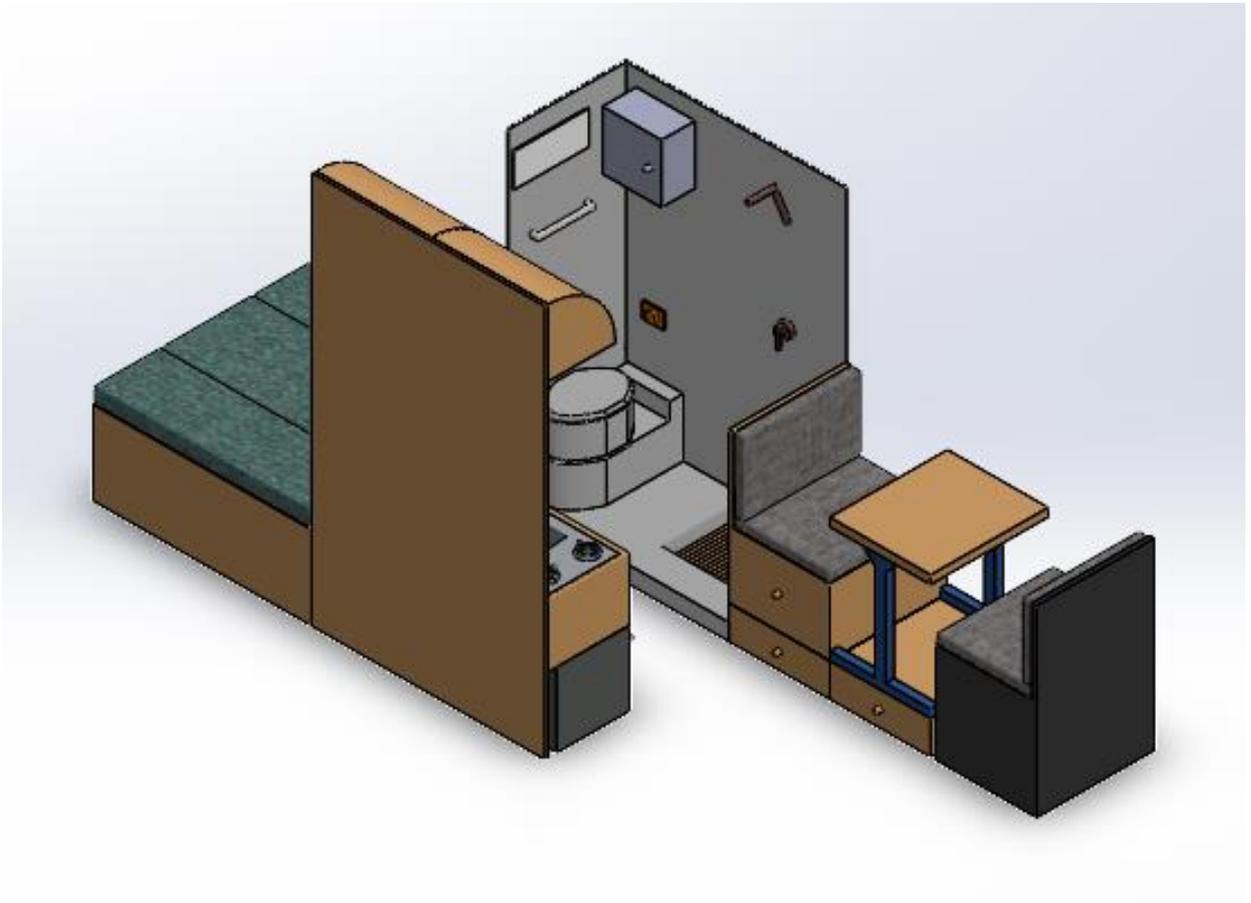
On the other hand, if the two 400 mm modules are placed vertically against the wall, and the two 523.3 mm modules are placed above the garage spaces, the X-shaped mechanism can be raised.



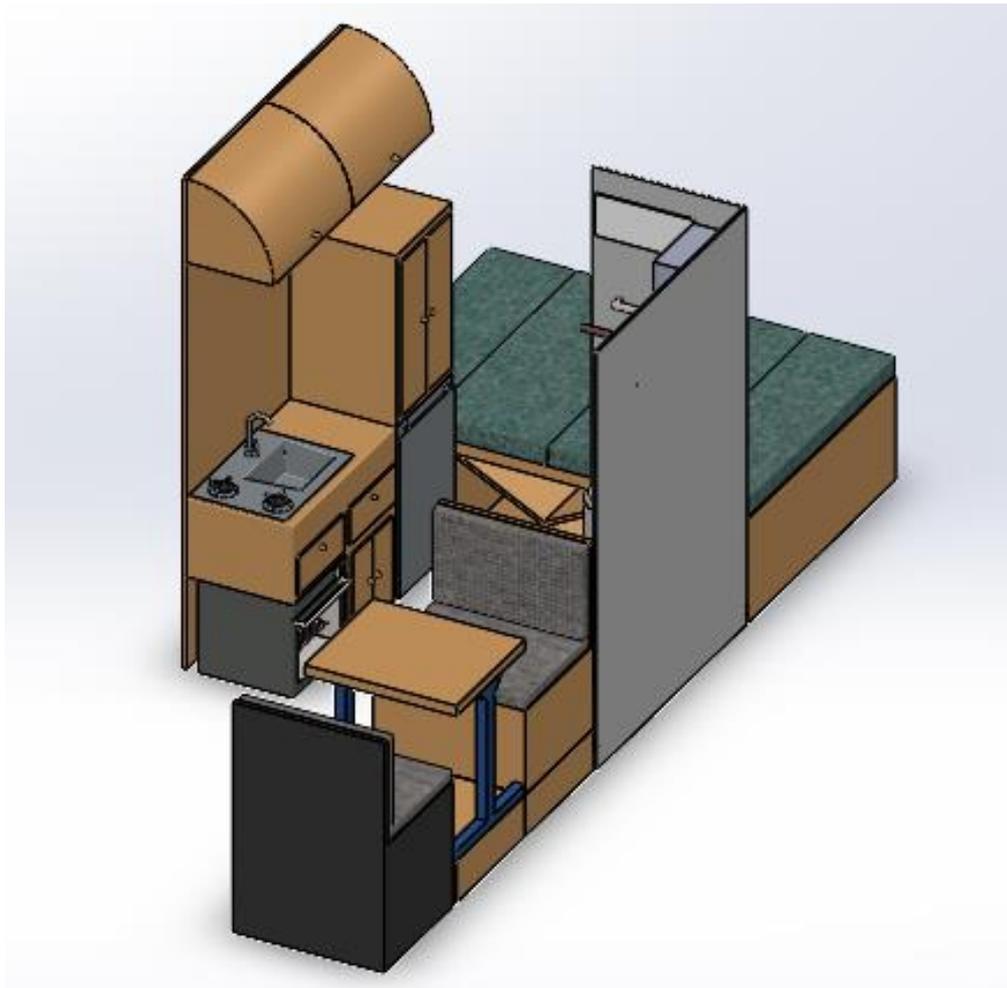
*Illustration 52. Bedroom – Sofas and table.
Source: Own elaboration*

In this way, the bed can be converted into a table with two sofas where you can spend time with up to six people.

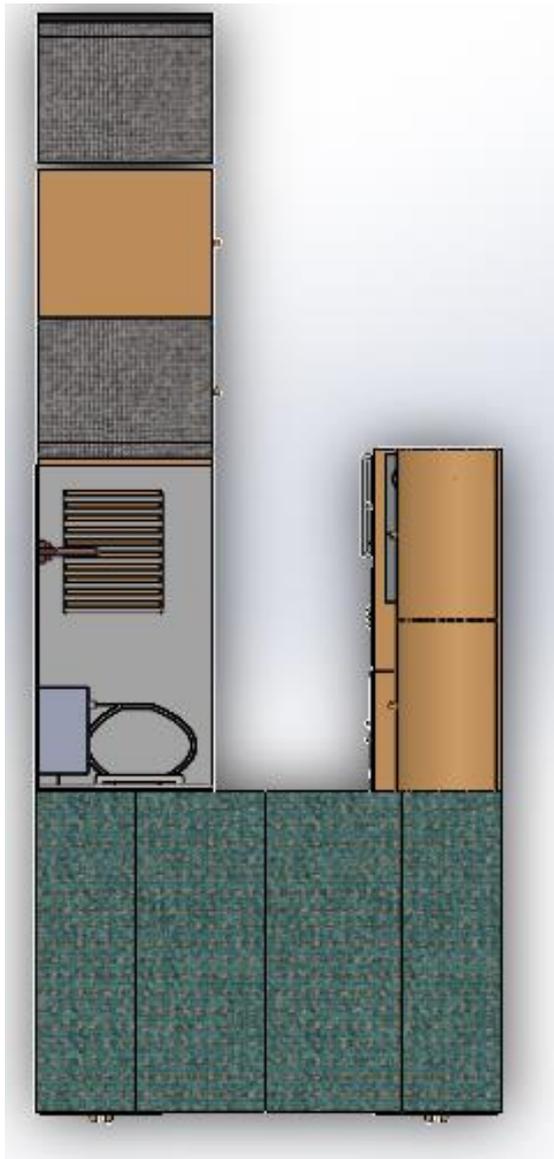
3.7.5 Set



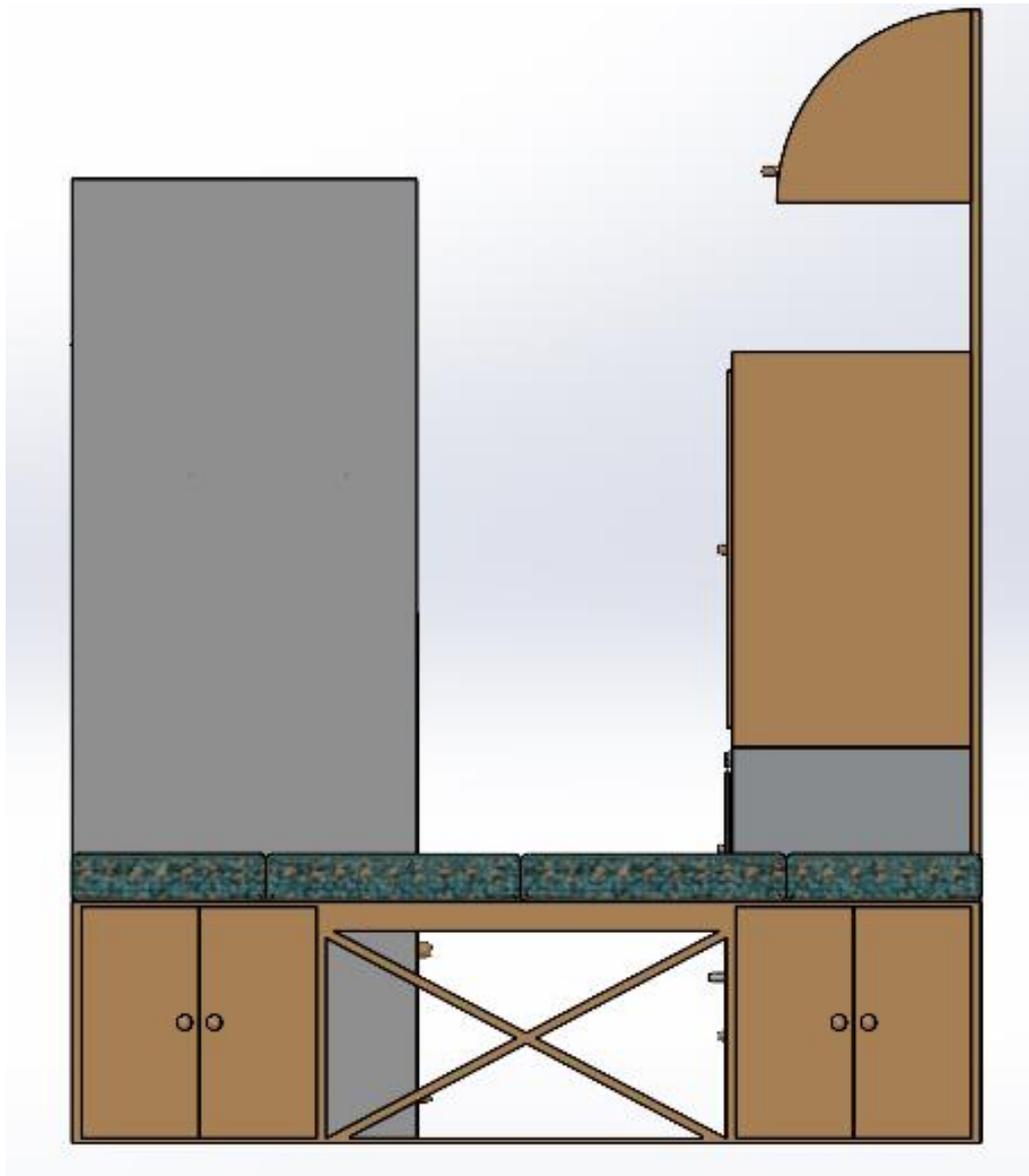
*Illustration 53. Set 1.
Source: Own elaboration*



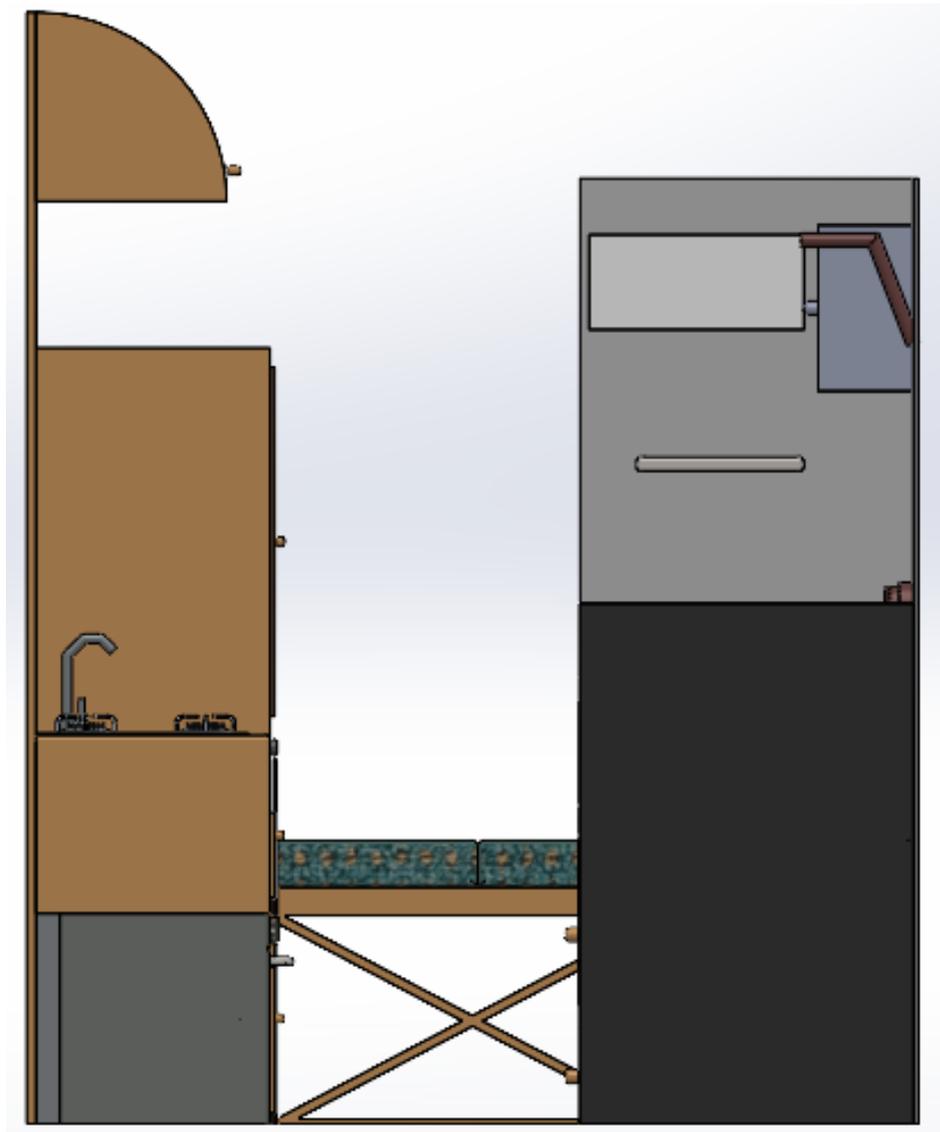
*Illustration 54. Set 2.
Source: Own elaboration*



*Illustration 55. Set 3.
Source: Own elaboration*



*Illustration 56. Set 4.
Source: Own elaboration*



*Illustration 57. Set 5.
Source: Own elaboration*

3.8 Methods

Four steps were followed to design the furniture and interior layout of the van.

1. First of all, it was drafted how was the van wanted to look like, what furniture it would have and what features it could offer.
2. Then, the commercial material to be installed was sought out and its technical characteristics and dimensions were noted down in order to analyse how it would be placed in the interior space.
3. This was followed by a freehand drawing of the different spaces in the van, the variations they would have and their dimensions.

4. Finally, the spaces of the van were drawn, together with the variants, in the 3D editing programme SolidWorks for the subsequent drawing of their respective plans.

4 Discussion on the maximum authorised mass.

4.1 Approach

A very important aspect to be taken into account when camping a van is the maximum authorised mass that it can carry.

The maximum permissible weight indicates the maximum load (kg) that can be added to the van without being detrimental to its safe operation and safe driving.

This value is usually given by the make of the van, and when it is homologated, the person in charge of the process will check that the load weight does not exceed the maximum authorised weight.

The maximum authorised weight for a Fiat Ducato H2L3 is 4083 kg. (41)

The weights of the lights, cables, plugs, switches, showerhead and the water level sensor shall not be considered as they have a low mass.

The weight of the furniture shall be calculated taking into account its dimensions and the density of the poplar plywood (420 kg/m³).

Element	Mass		Element	Mass	
Fridge	24,3		Pantry cupboard	5,293176	
Water pump	1,4		Drawer 1	1,364145	COMMERCIAL MATERIAL
Oven	13,5		Drawer 2	1,364145	KITCHEN
Boiler	7,4		Lower cupboard	2,709	WORKTABLE
Extra battery	38,7		Upper shelves	4,65696	BATHROOM
Solar panel	24		Lower drawers	4,704	BEDROOM
Charge regulator	1		Big drawer	8,82	
Clean water tank	5,7		Table	29,96595	
Grey water tank	5,7		Showers floor	7,319256	
Clean water tank water	78		Garage 1	9,828	
Grey water tank water	78		Garage 2	9,828	
Sink	5		Table	24,18081	
Pressure switch 1	1		X-shaped mechanis	19,4732	
Pressure switch 2	1		TOTAL	428,0066	
Toilette	6,8				
Stationary heater	7				

Chart 9. Mass calculation.
Source: Own elaboration.

4.2 Conclusion of the discussion on the maximum authorised mass

As can be seen in Chart 9 the total weight of the installation is 428 kg, which is less than the limit of 4083 kg. This means that, at homologation, the vehicle would pass the mass test.

5 Conclusions

The following conclusions can be drawn from the project:

- For the requirements of available space inside the van and good value for money, the best option, between van and motorhome, was to choose a van. And among the vans, the big size vans with dimensions of H2L3. After evaluating the different brands that offered this caravan, it was decided to choose the Fiat Ducato, again because of the quality/price ratio and the space available.
- With regard to the regulations, it's been learned how extensive they are and the importance of always complying with them due to the safety deficiencies, both in driving and in coexistence, that failure to comply with them can cause.
- In the electrical installation, first of all, a specific list of all the elements that were going to consume power had to be made. Subsequently, commercial models of these same elements were chosen to find out their technical characteristics. Finally, knowing which elements were needed and how much each one consumed, the electrical calculation of the power to be supplied was made. With this information, it was decided to install a solar panel and a battery to provide an extra electricity supply.
- For the water supply it was decided to install two water tanks: one for clean water and one for grey water. When water is needed, either from the kitchen tap or from the shower, the water comes out of the clean water circuit and goes to where it is needed. After being used, the water goes through another pipe to be stored in the grey water tank.
- Regarding insulation, the importance of installing a layer of interior insulation was learned. The different options most commonly used today were assessed and it was decided that the best, in terms of quality and environmental friendliness, was a 20mm layer of Kaiflex.
- It was decided to install central heating as it was realised that it was important to install it in order to be able to live more comfortably in the van.
- The interior layout of the van was divided into 4 zones: desk, kitchen, bathroom and bedroom. In addition, the work table and the bedroom, could be converted into an extra bed or a table with sofas, respectively. For the design of the interior layout, the 3D design program SolidWorks was used.

- The total weight of the installations for the van was calculated and found not to exceed the maximum authorised weight.
- As a final conclusion, I can say how much this project made me learn, not only about the world of campers, but also about aspects related to the characteristics of different materials, light and water installations and interior design. In addition, it was a test for me to have to face a project of this level, which gave me great satisfaction to see that I was able to do it and enjoy the process of doing it.

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7 Plans

7.1 Worktable

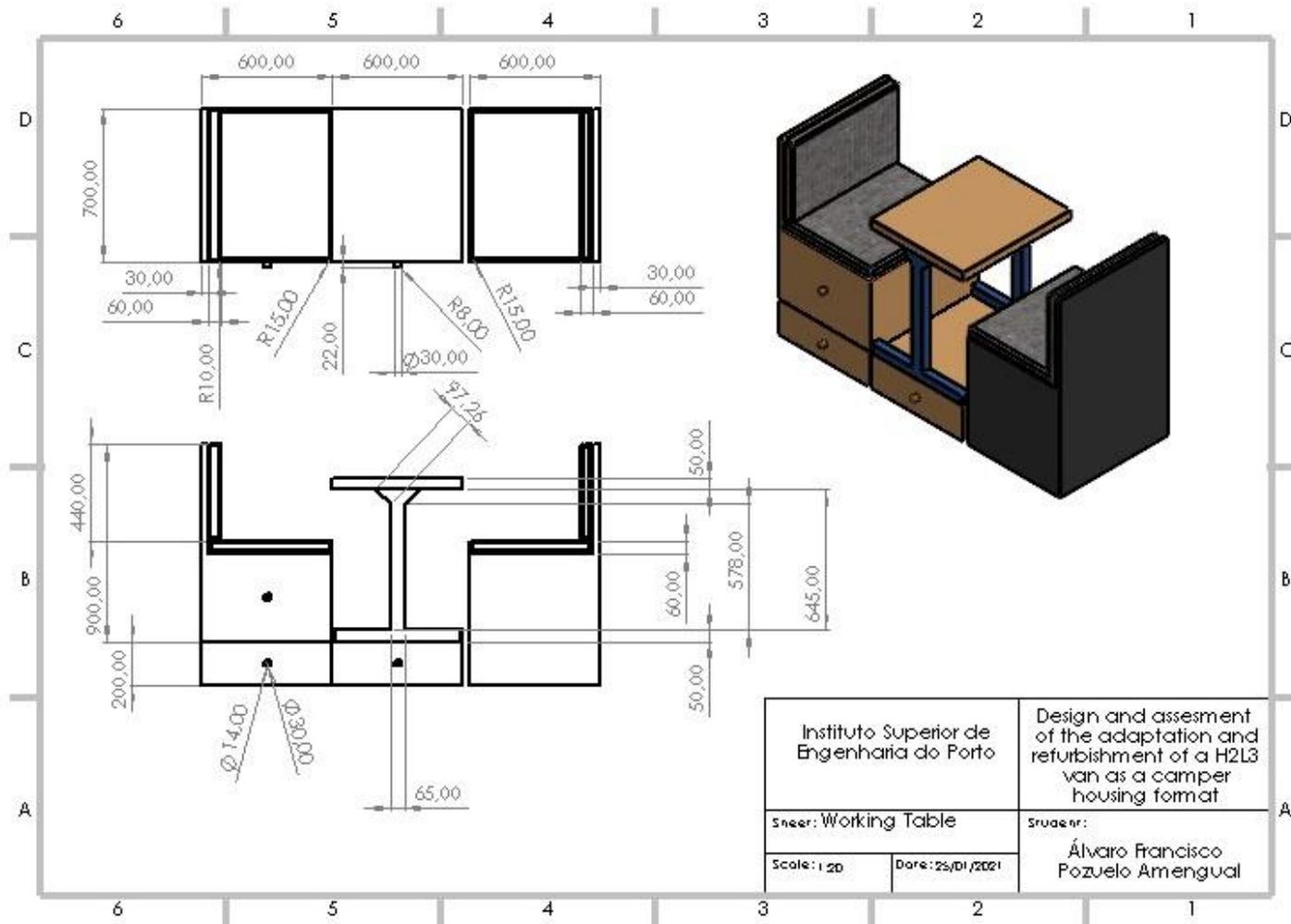


Illustration 58. Worktable.
Source: Own elaboration

7.2 Worktable converted to extra bed

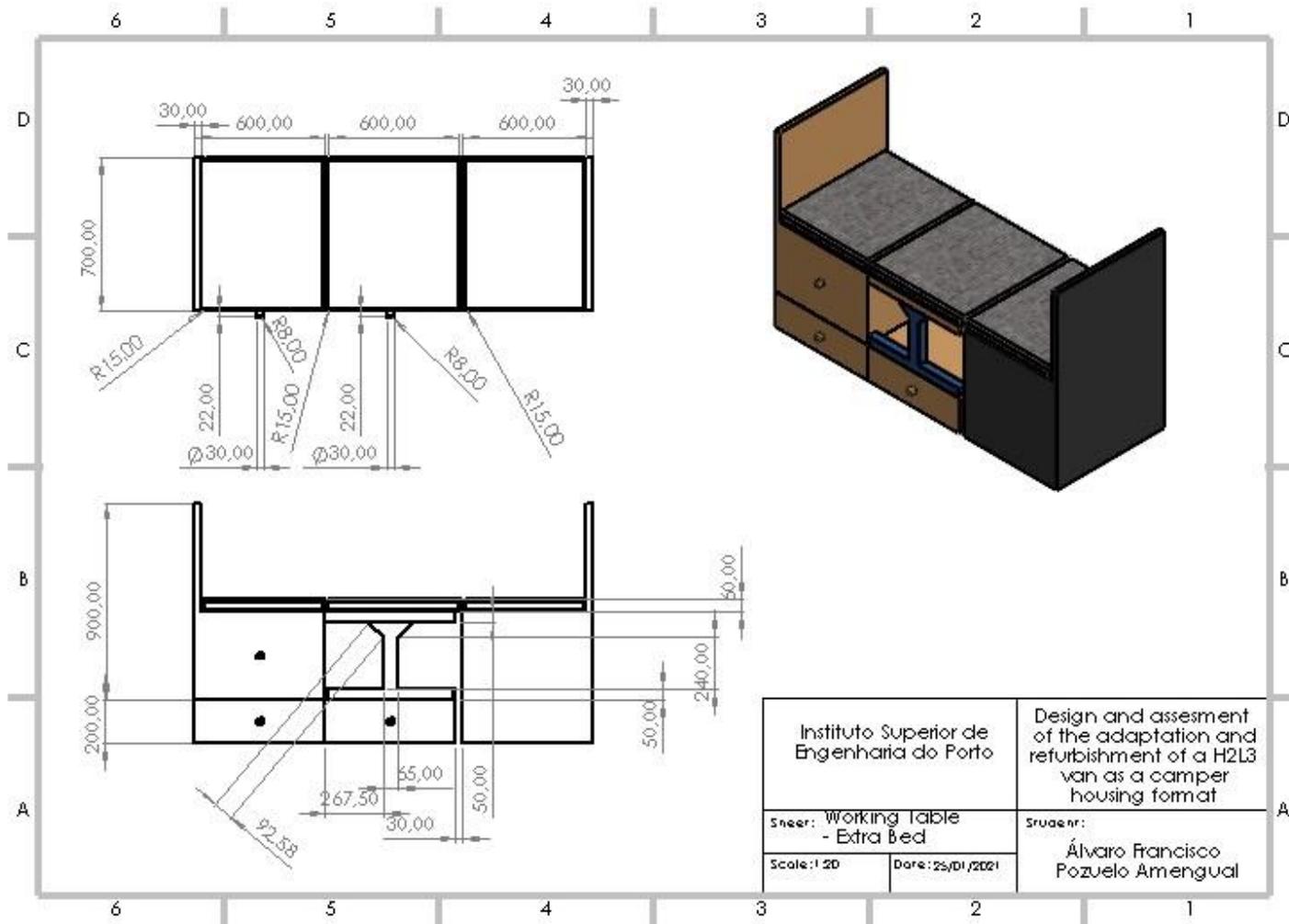


Illustration 59. Worktable – Extra bed.
Source: Own elaboration

7.3 Kitchen

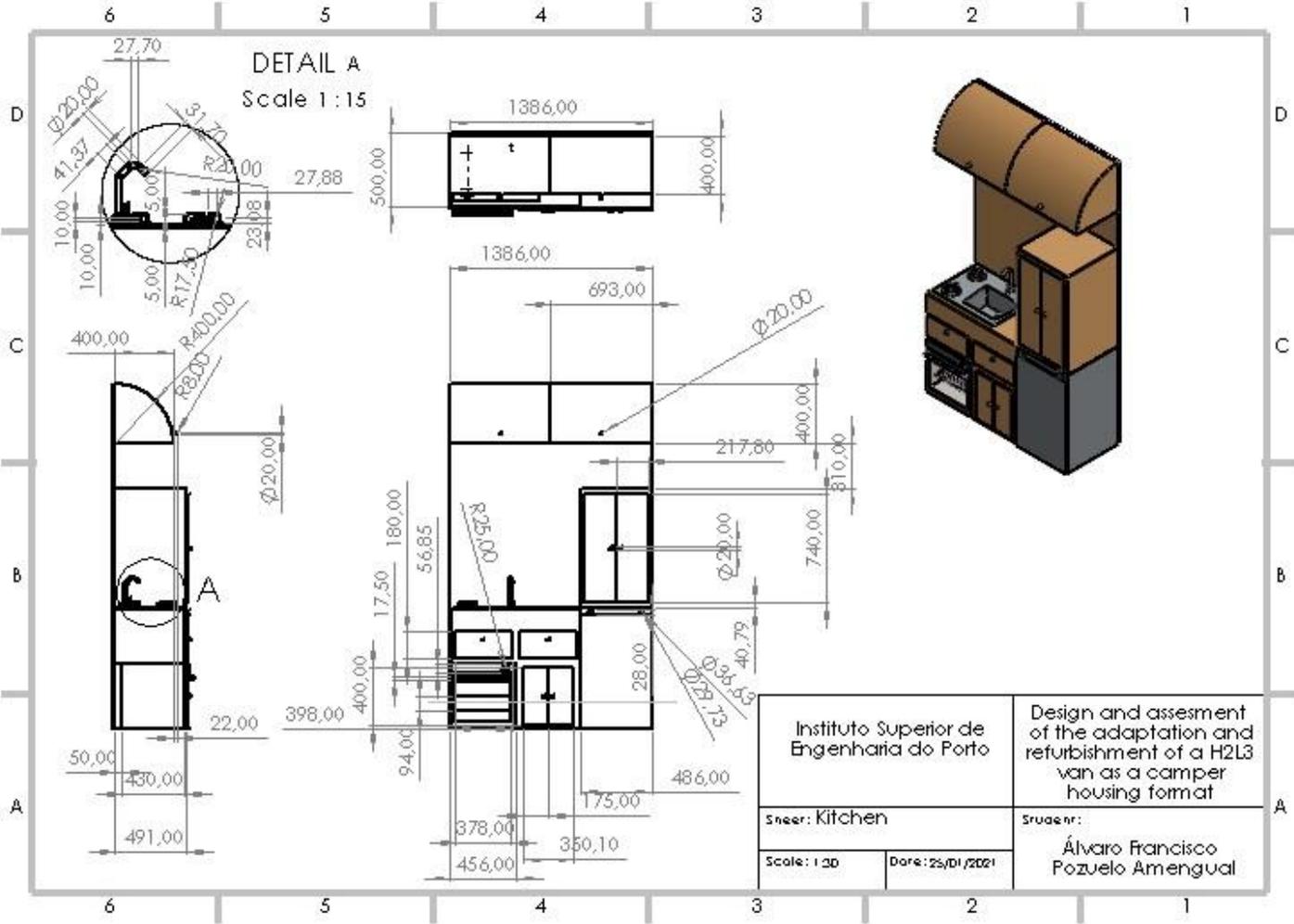


Illustration 60. Kitchen.
Source: Own elaboration

7.4 Bathroom

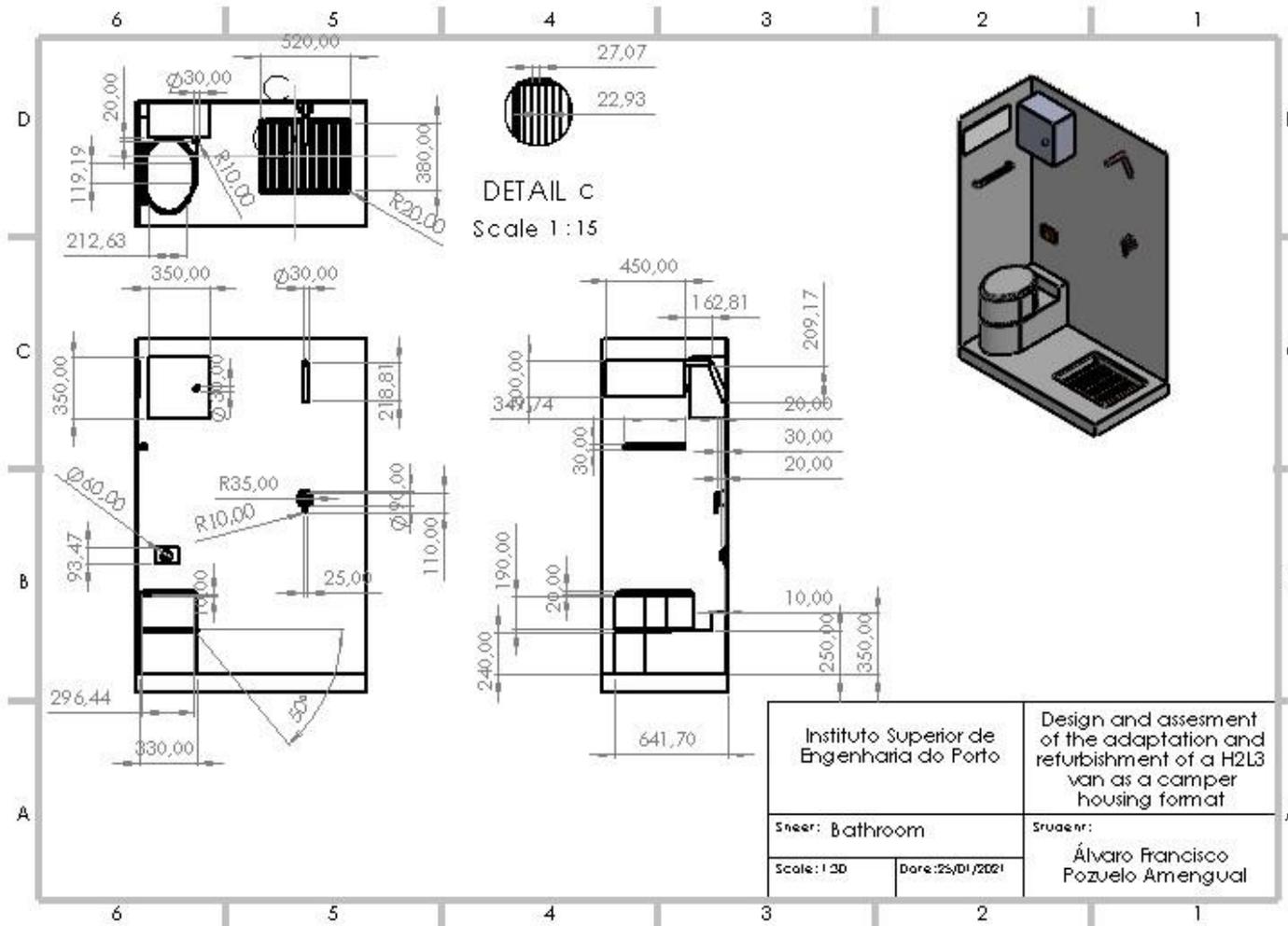


Illustration 61. Bathroom.
Source: Own elaboration

7.5 Bedroom

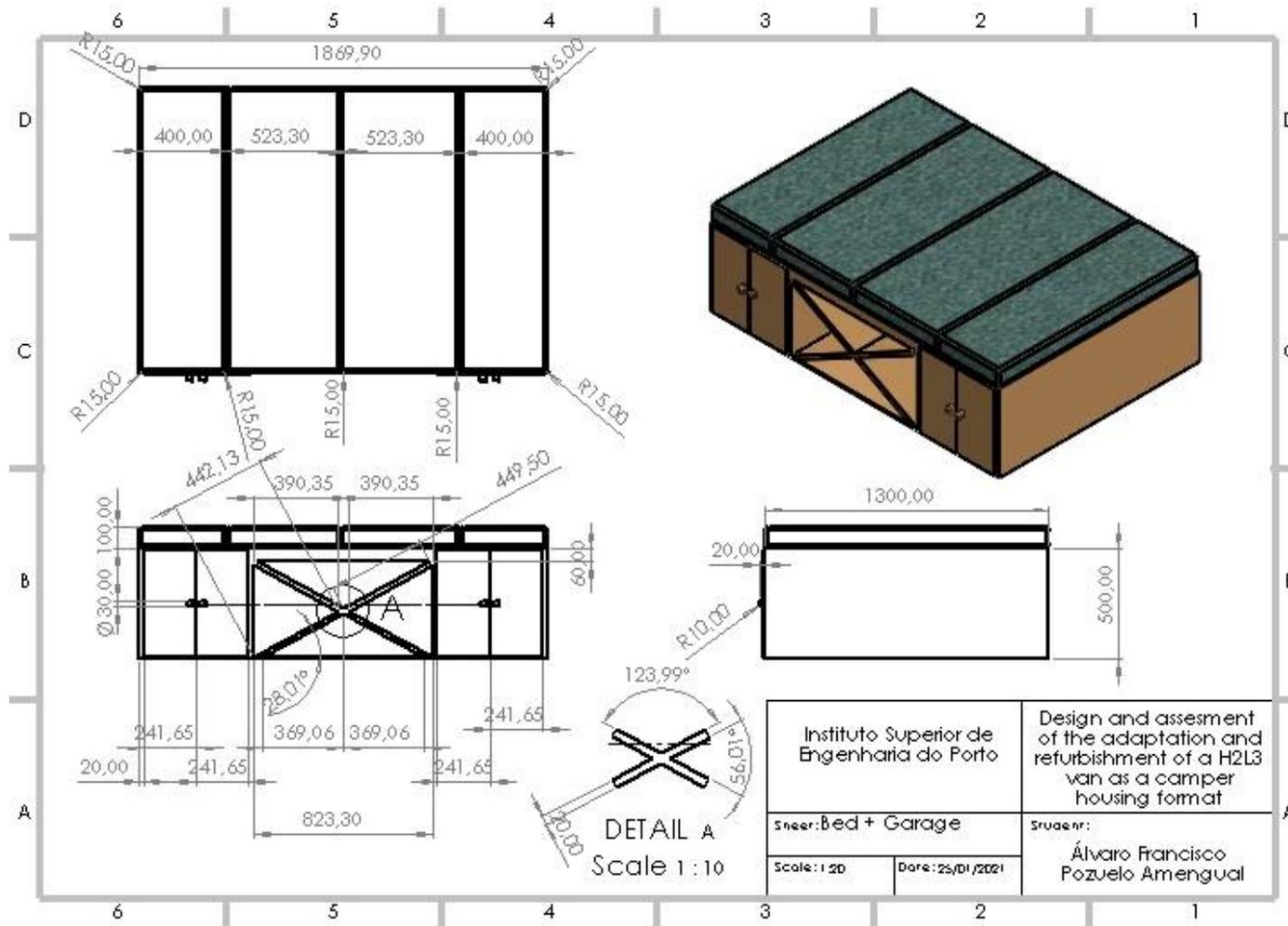


Illustration 62. Bedroom.
Source: Own elaboration

7.6 Bedroom converted to sofas + table

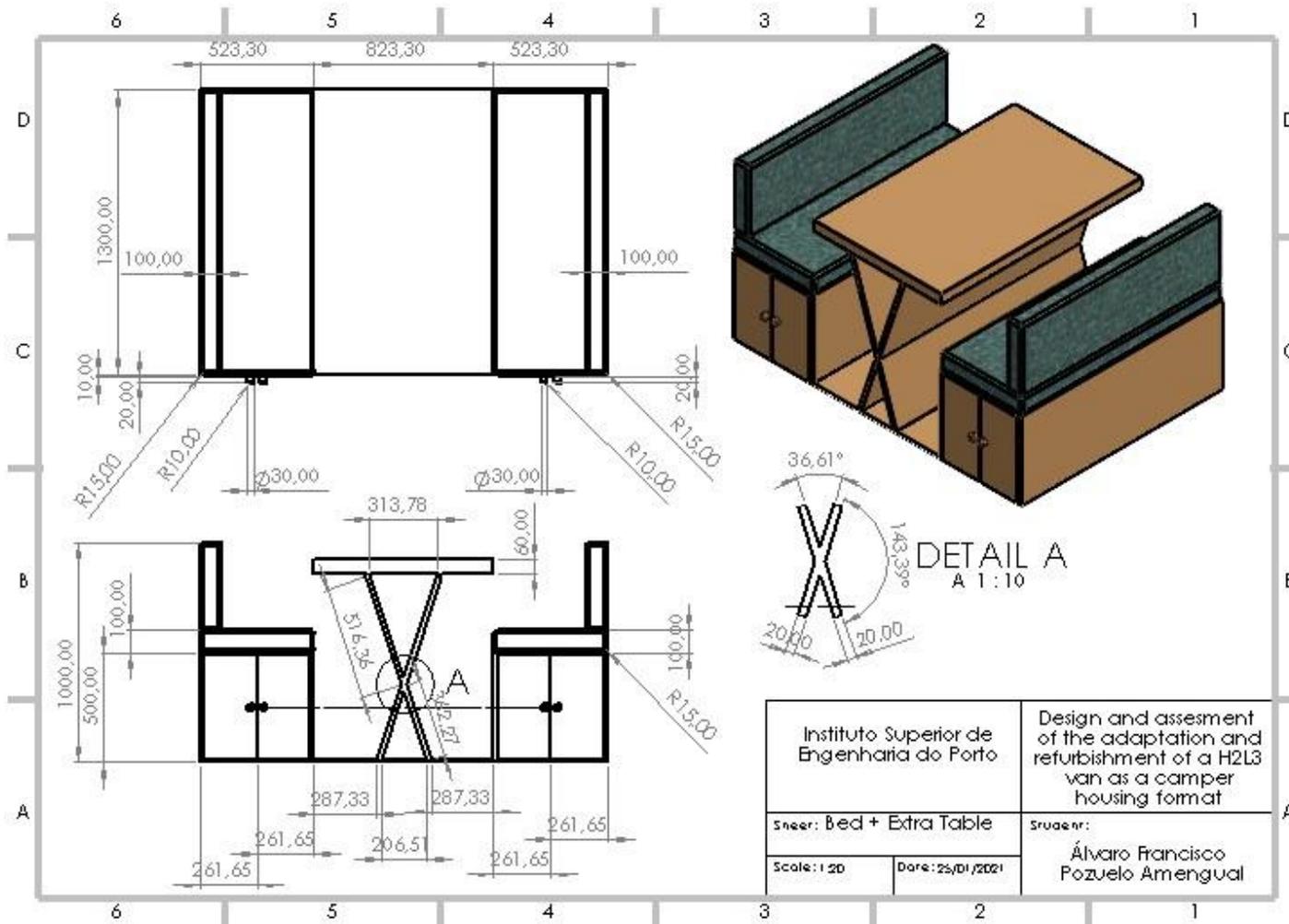


Illustration 63. Bedroom – Sofas and table.
Source: Own elaboration