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LOW-TECH HOME

A project LOW-TECH LAB

PRESENTATION

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SUMMARY

Abreviations list and acronyms

LCA : Life Cycle Analysis

DEP or EPD : environmental declarations of products

EH : inhabitant equivalent

GHG : greenhouse gas

LTH : low-tech house (name of the project)

HP : heat pump

LOW-TECH HOME

GLOSSARY

Unit List

g : gram

kg : kilogram

t : tonne

mm : millimeter

m : meter

km : kilometer

m^2 : square

m^3 : cubic meter

L : liter

kgCO2eq : kilogram of CO2 equivalent

W : Watt

W.h : Watt x hour

kW.h : kilowatt x hour

s : second

min : minute

h : hour

j : day

LOW-TECH HOME

GLOSSARY

The **Low-tech Lab** believes in the power of useful, accessible and sustainable innovation to meet the challenges of today and tomorrow: low-technologies offer to everyone, everywhere, the means to meet everyone's needs while respecting Humans and the Planet!

For this, the **Low-tech Lab** conducts concrete experiences that test technological solutions in various contexts and fields. These feedbacks and testimonials raise awareness by showing that alternatives and a better living exist.

The **Low-tech Lab** made it his mission to share these solutions and the low-tech spirit in order to allow everyone to meet their basic needs independently and durably.

LOW-TECH LAB

How to

give the desire and the means
to the greatest number to have a sober way of life
in harmony with the environment?

How to

to consume, produce and create
in a simple and responsible way?

How to

make sustainable and appropriate
technological choices that contribute to a world
where everyone can be an actor of this world?

How to

facilitate and concretely contribute to change,
to societal transition
at the scale of individuals and communities?

PRINCIPLES OF ACTION

Open-source sharing
Because common intelligence must return to common, because everyone must be able to access these solutions and because it is necessary and urgent to encourage incremental innovation, the results of the actions are open source under *Creative Commons licenses*.

Subsidiarity and adaptation to the local context
To be suitable and appropriate, actions must be brought as close as possible to concrete issues,and to the needs of the communities and actors of the territory.

Coherence
Because our humanist values of simplicity, sharing, equity and ecology must be integrated, embodied and real, consistency is essential between the Why and the How, between the Speech and the Action.

The collaboration
To encourage the exchange of skills and experiences, to catalyze the commitments of actors and citizens from various horizons, to stimulate a synergy around low-tech, the *Low-tech Lab* works in an apartisan and secular manner, open and collaborative.

A positive alternative
Because it is better to change out of envy with a smile rather than out of fear, the Low-tech Lab has chosen to highlight constructive solutions rather than problems!

LOW-TECH

"Low-tech" are technologies, services and know-how that meet the following criteria:
Useful: A low-tech meets essential needs in the fields of energy, food, water, waste management, construction materials, housing, transport, hygiene or health.
Sustainable: Robust, repairable, recyclable, it has been designed so that its ecological and social impact is optimal from theproduction to the distribution, use and until its end of life.
Accessible: Unlike high-tech, its cost and technical complexity are not prohibitive for a large segment of the population.

The discovery of many low-tech initiatives around the world, particularly during our Nomad des Mers expedition, has strongly reinforcedour convictions in favor of a more sober and low-tech way of life.
Back in France, we were confronted to a gap between the solutions discovered in tropical contexts and the needs associated with our Western lifestyles. Indeed, we do not cook on wood fires and we have an unlimited access to water, electricity and gas.
Systems we had documented poorly suited our needs.
This dissonance gave rise to the desire to study low-tech solutions specific to the French context.

Low-tech principles can be applied to all sectors.
In this project, we focused on housing for several reasons.
Initially, the residential-tertiary sector has a heavy environmental impact: it is one of the main emitters of greenhouse gases (17%)[1] and in second position behind transport. In addition, in France, it is the most energy-intensive sector, consuming 43% of final energy[2].
Housing is also at the heart of social issues. For example, more than 5 million households suffer from fuel poverty[3].
Finally, at a time of a very dark media coverage on climate change, more and more individuals are looking for solutions to enter into transition.
Housing is an excellent gateway because everyone has an important field of action.

1. General Commissioner for Sustainable Development, *Key climate figures*, p37 (2019).
[online] https://www.statistiques.developpement-durable.gouv.fr/sites/default/files/2019-05/datalab-46-chiffres-cles-du-climat-edition-2019-novembre2018.pdf (consulted in 12/2019).
2. ADEME, *Tertiary residential* (2011).
[online] https://www.ademe.fr/sites/default/files/assets/documents/cahier-2_le-residentiel-tertiaire.pdf (consulted in 12/2019).
3. ADEME, *Fuel poverty* (2018).
[online] https://www.ademe.fr/expertises/batiment/quoi-parle-t/precarite-energetique (consulted in 12/2019).

Low-tech can respond holistically to social and environmental issues of the western housing.

Let's create a low-tech home.

Phase 1

Discover and document the low-tech used

→ *Low-tech Tour France project*

Phase 2

Validate or invalidate the interest of these systems ecologically, financially and ergonomically through experimentation on an individual scale

→ *Low-tech Home Experiment*

Phase 3

Participate in widely disseminating the systems and the low-tech philosophy through awareness-raising, networking and supporting activities for associations or housing professionals

→ *To come up*

LOW-TECH HOME

GOAL

Measurement of the ecological, financial and ergonomic impact of low-tech in the home

Through this experience, we wish to demonstrate and share, as inhabitants and through calculation, the interest of systems that we have identified and installed.

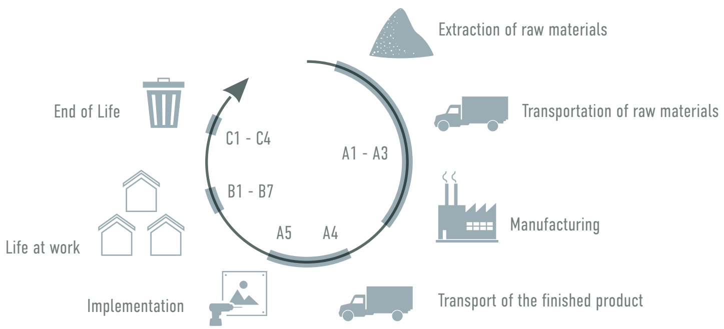
PROTOCOL AND OBSERVATION TOOLS

The multitude of parameters influencing a house (seasonality, sunshine, hygrometry, precipitation, temperature, number of people, lifestyles ...) quickly moved us away from pure technical system characterization (performance, efficiency). This study can be carried out in the laboratory with controlled environments.
We rather wanted to study the quality of life in a Low-tech Home and the ecological and financial impacts from a set of hypotheses.

For each study criterion (ecological, financial and ergonomic) we used a dedicated tool.

For the **environmental impact** (ecological criterion), we mainly relied on the Life Cycle Analysis (LCA) with the emission of greenhouse gases. This study of the global warming potential is significant but only represents part of the impact of human activity on the biosphere (see below).
In addition, it is necessary to remain critical of this tool, particularly for energy studies in France. The French energy mix is mainly nuclear (78%[4]), it emits very little greenhouse gas but it nevertheless remains a source of many problems, particularly in terms of safety and ethics, which cannot be modelled through LCA.
The life cycle phases present in the following study are detailed as follows:

A1-A3 : Production step
A4-A5 : Construction stage
B1-B7 : Use stage
C1-C4 : End of life stage
D : Benefits beyond system boundaries



→ *Schematic diagram of the life cycle and its different stages*[5]

For systems that reduce water consumption, we have counted the water saving.

According to the work of ***Stockholm Resilience Center***[6], the concept of planetary limits designates the limits that humanity must not exceed so as not to compromise the favourable conditions in which it was able to develop and be able to live sustainably in a secure ecosystem, avoiding sudden and difficult to predict changes in the planetary environment[7].

According to their work, climate change is a big risk factor, however it is behind the risk of erosion of biodiversity and disruption of biochemical cycles of nitrogen and phosphorus.

4. EDF, *Energy mix* (2018).
[online] https://www.edf.fr/mix-energetique (consulted in 12/2019).
5. SIPEV, *Environmental and health declaration sheet* (2014).
[online] https://docplayer.fr/20790708-En-conformite-avec-la-norme-nf-en-15804-a1-et-son-complement-national%20-xp-p01-064-cn-novembre-2014.html (consulted in 12/2019).
6. Stockholm resilience center, *Planetary boundaries research* (2015).
[online] https://www.stockholmresilience.org/research/planetary-boundaries.html (consulted in 12/2019).
7. Wikipedia, Planetary Limits (2019).
[online] https://fr.wikipedia.org/wiki/Limites_plan%C3%A9taires (consulted in 12/2019).

We also looked at the systems **financial interest**.
In our opinion, an ecological approach must be economically interesting not to remain marginal, reserved for the luxury of an elite.

The material cost necessary for the realization and the installation of the low-tech has been accounted for. By studying the savings made thanks to the reduction in consumption, we were able to determine a return on investment time, that is to say, to calculate the duration necessary for the reimbursement of the system and from which daily savings are made. In these calculations, we did not simulate the cost of labour. However, we have indicated the time we have invested for the realization of each systems. These times can be easily reduced with minor modifications to the systems and an experienced workforce.

For environmental and financial impacts, when the study was possible and relevant, we compared:

→ Our frugal consumption associated with a low-tech system

→ Our frugal consumption associated with a conventional system

→ The average consumption of a French person associated with a low-tech system

→ The average consumption of a French person associated with a conventional system

This reasoning makes it possible to dissociate the impact of a frugal lifestyle from the impact of the systems installed.

For the **use**, we kept a logbook to record our level of comfort, our consumption and our production of waste.
Each week we also carried out an ergonomic assessment of each system installed: usefulness, functionality, efficiency and compatibility[8]. with our lifestyles were evaluated throughout the duration of the experiment.

8. Utility: How necessary was low-tech to meet a need?
Functionality: How possible was it to use it / it fulfilled its function?
Efficiency: How efficient has low-tech been?
Compatibility: How compatible is the use of low-tech with everyday life and lifestyle?

→ *Low-tech Home Concarneau summer 2019* © Clément Chabot

EXPERIMENTAL CONTEXT

THE "GUINEA PIGS"

We (Pierre-Alain, 29 years old and Clément, 30 years old) both come from engineering studies (ICAM).
As a result of our several years spend in the low-tech world, we are "biased" in the study of the uses. Thus, we are not a representative sample of the population. Some elementary ecological behaviours have since a long time integrated our daily lives and are not considered as efforts but as sources of satisfaction (reduction of packaging and heating instructions, composting, short showers, dry toilets, bicycle trips, etc.).
However, testing on and by ourselves is one of the main means of action at the Low-tech Lab, we wanted to be the first "guinea pigs" in this disconnected house.

When the project was designed, we planned to live in a shared apartment in the Low-tech House. As a result of a mutual desire for individual autonomy, we quickly set up a work-study program, a "shared custody" of the house, each of us living in the house every other week.

CHOICE OF HOUSING

We have a culture of fast and relatively economical projects.
We wanted to be able to implement all the low-tech in a home in a few months and for a total cost lower than 50,000 €.
In addition, we wanted this housing project to become an educational support and therefore be visitable so that everyone could discover these low-tech in real life and in use.

These parameters led us to the choice of a "tiny-house", a small ecological and nomadic house, on a trailer chassis, produced within the "Atelier Bois d'ici"[9], from local wood.
Obviously not very representative of the French habitat, this small house allowed us to quickly build the "low-tech laboratory" necessary for the experimentation.
The choice of this type of housing opened up the opportunity for us to be off-grid (electricity, water and sanitation), allowing us to study the potential of the low-tech as good as possible.
During the experiment, we settled in a meadow generously lent by Gildas, a former organic market gardener from Concarneau.

The objective of the project is not to promote the housing in micro-house in the fields but to study the interest of low-tech in housings in general, in order, ultimately, to be able to transpose them to existing buildings, or to integrate them into the design of new individual or collective housings.

TIME CONTEXT

The construction of the Low-tech Home began in January 2019, the experiment began in March and ended in December 2019.
This period allows us to observe the use of low-tech over the different seasons.

GEOGRAPHICAL CONTEXT

As the Low-tech Lab is being hosted at the Explore base[10] in Concarneau, it is there that our lives have developed in recent years.
We did not want to carry out this experiment in an "aboveground" way. The project is therefore taking place in Concarneau, in southern Finistère, in an oceanic climate, characterized by rather beautiful and mild summers and often rainy, windy and mild winters (but with regularly beautiful calm and bright days). Temperature variations are small, and it rarely drops below freezing temperature[11].

LEGAL CONTEXT

This project is being carried out on an experimental basis to offer sustainable and economical alternatives to conventional systems. By being different from the usual uses of its time, it is logically out of step with the regulations in force:

- Today, it is not legal to install light housing on agricultural land
- It is at first glance not legal to use rainwater for bodily uses and consumption
- It is not legal to sanitize your gray water via a system that is not certified for individual sanitation.

9. Jean-Daniel Blanchet, *Tiny house Bretagne* (2019).
[online] https://tiny-house-bretagne.fr/#(consulted in 12/2019).
10. Explore, *Positive impact exploration incubator* since 2013.
[online] https://www.we-explore.org/ (consulted in 12/2019).
11. Wikipedia, *Geography of Brittany* (2019).
[online] https://fr.wikipedia.org/wiki/G%C3%A9ographie_de_la_Bretagne (consulted in 12/2019).

APPROACHES STUDIED

In view of the various parameters shared previously, we have selected a set of low-tech and approaches adapted to the context of the experiment.
Approaches from **negaWatt** and **Zero waste** were fundamental in the design of the project. They are presented below.

ENERGY CONSUMPTION

SOBRIETY

Prioritize essential energy needs
in individual and collective uses of energy.

Turn off store front windows and unoccupied offices the night. Limit urban sprawl, reduce packaging, etc.

EFFICIENCY

Reduce the amount of energy necessary for the satisfaction of the same need.

Insulate buildings, improve the efficiency of electrical appliances, vehicles, etc.

PRODUCTION

RENEWABLE

Focus on renewable energies
who thanks to an **ambitious but realistic development**

can gradually replace fossil and nuclear fuels.

→ *Diagram of the negaWatt approach*

NEGAWATT APPROACH

Based on the principle that the least polluting energy is the one that we do not consume / produce, negaWatt proposes to rethink our vision of energy by relying on a three-step approach:

→ sobriety

→ efficiency

→ renewable energies

The idea is not to "go back to the candle" but to reduce at the source the quantity of energy necessary for the same service, that is to say having a better use of energy with a constant quality of life.

Several examples can illustrate the notion of sobriety:

In urban areas, do you need a 1,200 kg vehicle to transport an 80 kg person over 5 km, all at an average of 25 km/h?
Since this same vehicle is also capable of transporting 5 people over 800 km at 150 km/h, shouldn't we use new modes of transport in town?

Is it normal to wear T-shirts all year round?
Today, we frequently measure temperatures above 21°C in homes or offices, in the middle of winter. Is this really reasonable?

These examples show us that all around us, in our daily lives, there is a deposit of energy savings, called negawatt.
This negaWatt deposit is much larger than other energy sources; it must therefore be used as a priority!
"Producing negaWatts" is therefore breaking with our (bad) habits by preferring energy sobriety to waste.
It is about seeking the best possible use of energy, rather than c ontinuing to consume more and more.
Energy sobriety is not a step backwards, it is simply a smarter use of energy[12].

12. Negawatt, *Achieving the energy transition* (2017).
[online] https://negawatt.org/ (consulted in 12/2019).

"The best waste
is the one we don't produce"

ZERO WASTE APPROACH

99% of the resources taken from nature are relegated to waste in less than 42 days[13]. In respect of this, greatly reducing our generation of waste makes it possible to limit our heavy environmental footprint. Very close to negaWatt ideologically, the zero waste approach of reducing waste is based on five principles:

• Refuse all single-use products.
The first rule is to refuse anything you do not need.

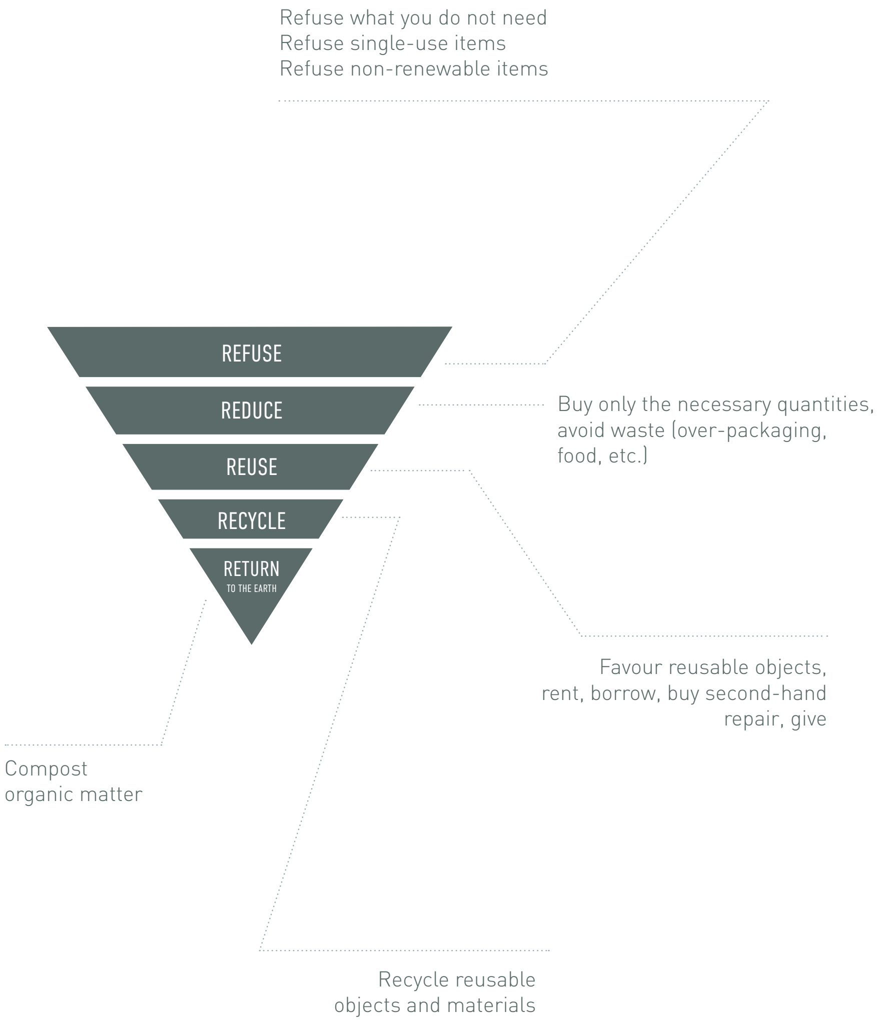
• Reduce the consumption of goods.

• Reuse anything that can have a second life.

• Recycle whatever can be.

• Compost the various organic wastes. [14 & 15]

13. Jérémie Pichon and Bénédicte Moret (pref. Nicolas Hulot), *Almost zero waste family*, Vergèze, Thierry Souccar Éditions, 2016.
14 Zero Waste Paris, *Zero wast* (inc).
[online] https://zerowasteparis.fr/wp-content/uploads/5R-03.jpg (consulted in 12/2019).
15. Radio Canada, *The 5 rules for a good start* (2018).
[online] https://ici.radio-canada.ca/nouvelle/1123887/zero-dechet-5-regles-refuser-reduire-reutiliser-recycler-composter (consulted in 12/2019).



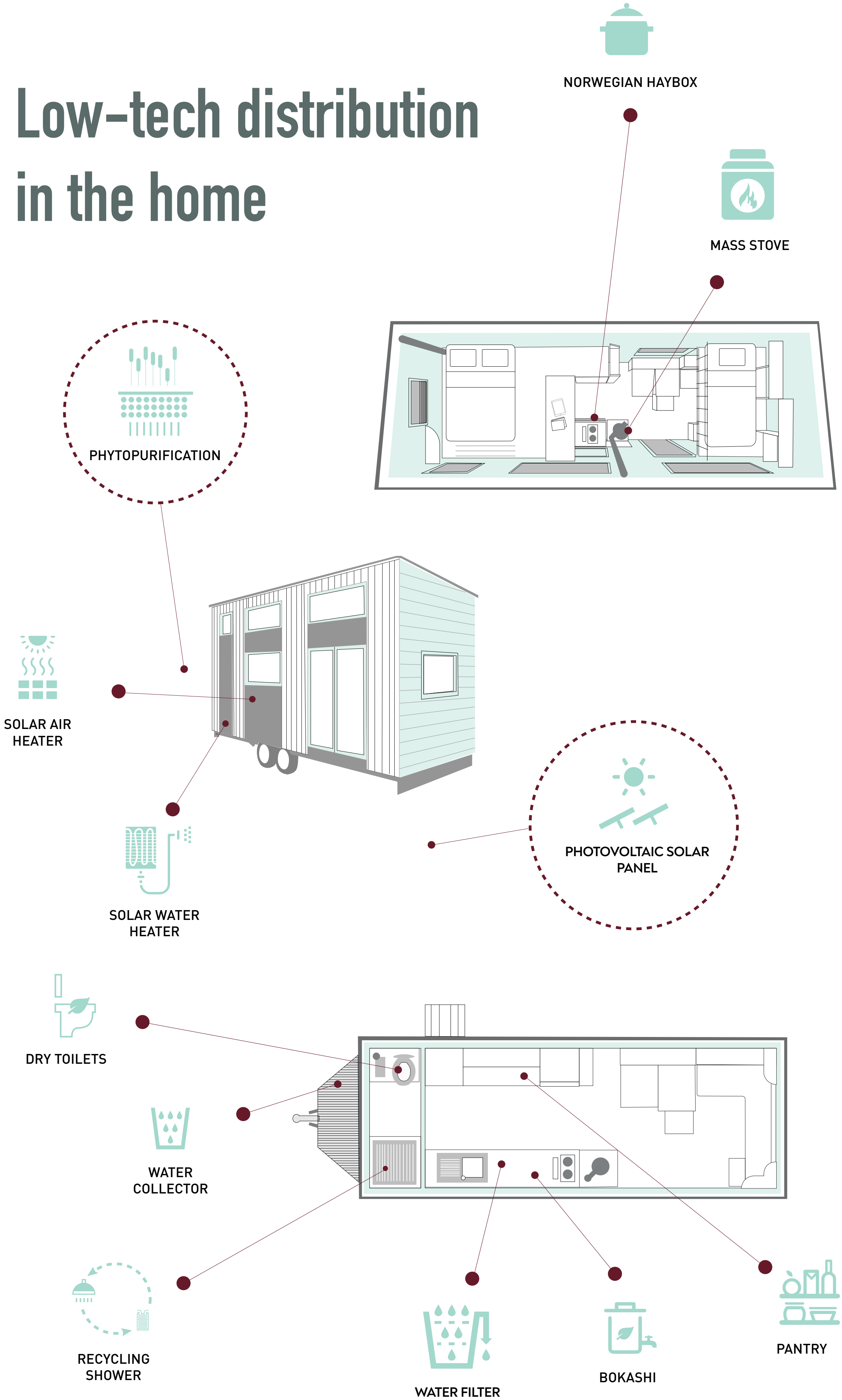
→ *Diagram of the 5R principle of the Zero waste appro*

LOW-TECH HOME

EXPERIMENTATION REPORT

RESULTS

Low-tech distribution in the home



Assumptions applicable to all systems

For the study of the cost, return on investment and life cycle analysis of each low-tech we have taken many calculation assumptions.

Each time they are expressed to allow everyone to redo the calculations and potentially add or modify assumptions to be as close as possible to reality.

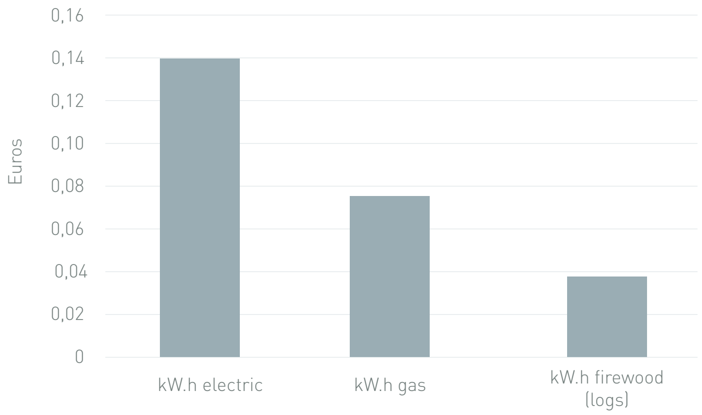
Some hypotheses come up very often, to simplify the document, we have extracted them from the low-tech files to present them below.

FINAL ENERGY

For all the calculations, we reasoned on the scale of the household, therefore in final energy corresponding to the amount visible on the bills.

For a study on a territorial scale, it would be interesting to work with primary energy.

COSTS



→ ***Price per kW.h in France in 2019***

In France, in 2019, the cost of kilowatt-hour (kW.h) is:

- 0,14€/kW.h electric
- 0,075€/kW.h gas[1]
- 0,038€/kW.h firewood (logs)[2].

→ ***The average price of water in France is 3,98€/m³***[3].

ENVIRONMENTAL IMPACT

For the global warming potential and water savings, the study is carried out over 10 years of use.

LIFE CYCLE ANALYSIS AND CLIMATE WARMING POTENTIAL

To carry out the life cycle analyses we used the Environmental Product Declarations (DEP) or the Environmental and Health Declaration Forms (FDES) compliant with ISO14040 standards[4] and EN15978[5]. Database (BDD): INIES[6], Okobaudat[7].

Small quantities and products for which no EPD/FDES document could be found were excluded from the calculations. The actual transport carried out is excluded. The distances and means of transport are already estimated in the EPD/FDES documents.

Only the impacts of the stages of production, construction and end of life are extracted from the files. The use phase is estimated separately, based on the resources consumed (water, wood, gas, etc.), over a lifespan of 10 years for each of the low-tech, using "conventional" systems for comparison. These calculations use the ADEME emission factors presented later in this chapter.

For each system, the three most impactful elements, in global potential warming, are indicated. Calculations are based on new materials.It makes it possible to identify the major impact stations and thus to look for alternatives or to ways to supply yourself via revaluation circuits.

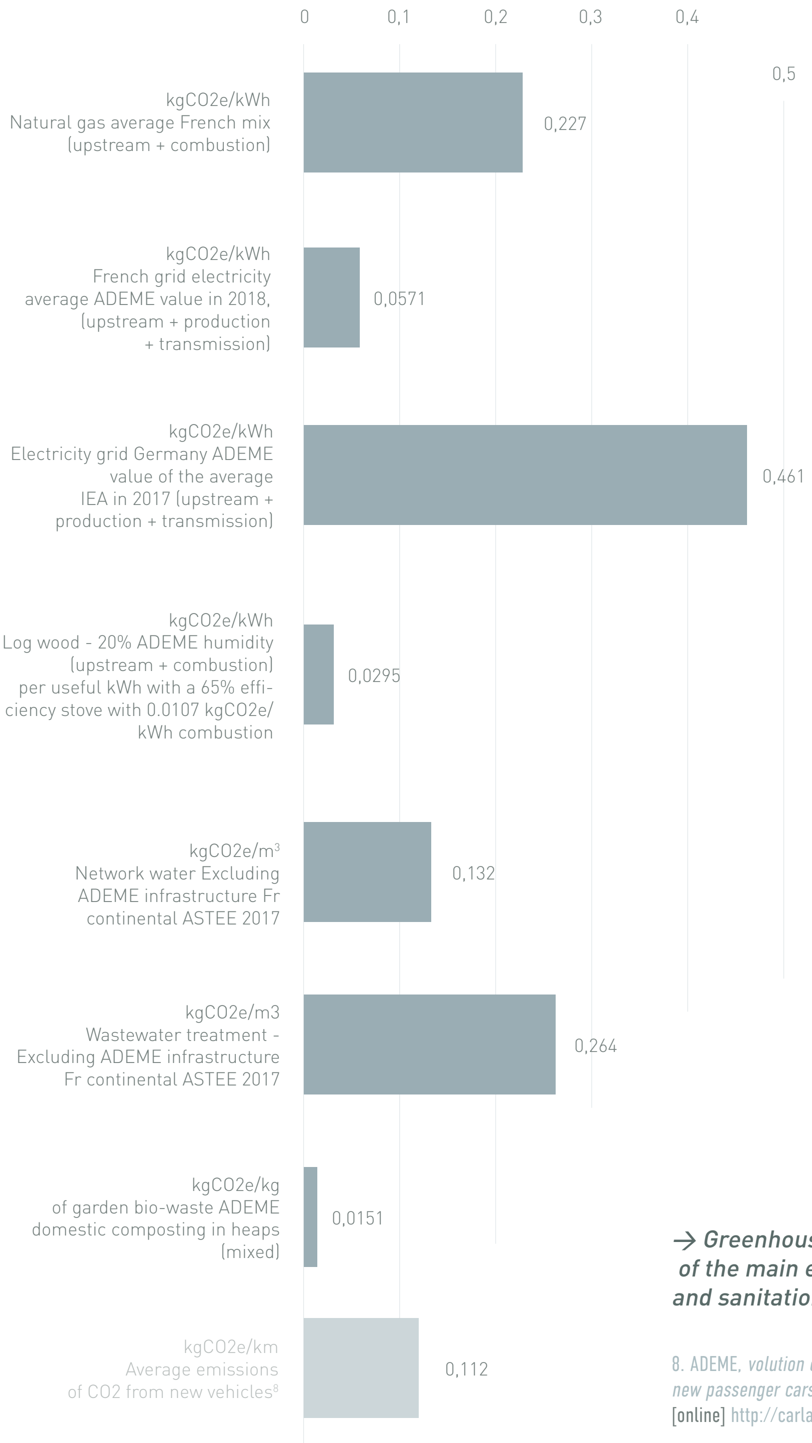
1. ELWAT, *What is the price of a kilowatt hour (kWh) of gas?* (2019).
[online] https://www.kelwatt.fr/enquete/prix-kilowattheure-gaz (consulted in 12/2019).
2. What energy, *Energy prices* (2016).
[online] https://www.quelleenergie.fr/prix-energie(consulted in 12/2019).
3. Water France, *The price of water* (2019).
[online] https://www.eaufrance.fr/le-prix-de-leau (consulted in 12/2019).
4. ISO, *Environmental management - Life cycle analysis - Principles and framework* (2006).
[online] https://www.iso.org/obp/ui/#iso:std:iso:14040:ed-2:v1:fr(consulted in 12/2019).
5. NSAI Standards, *Sustainability of construction works. Assessmentof environmental performance of buildings* (2011).
[online] https://infostore.saiglobal.com/preview/is/en/2011/i.s.en15978-2011-lc-2011-11.pdf?sku=1500481 (consulted in 12/2019).
6. INIES, *Reference environmental and health data for the building* (2019).
[online] https://www.inies.fr/accueil/(consulted in 12/2019).
7. ÖKOBAUDAT, *Reference environmental and health data for the building* (2019).
[online] https://www.oekobaudat.de/datenbank/browser-oekobaudat.html(consulted in 12/2019).

CONSERVATIVE HYPOTHESES

In some cases, we have not found an Environmental Product Declarations representative of the installed system. We have therefore taken an DEP of similar but larger products.

Sometimes these systems are much better than our use case, for example the pump studied is 5 times more powerful than ours. In these cases, we have indicated that the hypothesis is conservative (conservative hypothesis), therefore to the detriment of our evaluation.

EMISSION FACTORS



→ ***Greenhouse gas emission factors of the main energies, network water and sanitation***

8. ADEME, *volution of the average rate of CO2 emissions in France, new passenger cars sold in France* (2018). [online] http://carlabelling.ademe.fr/chiffrescles/r/evolutionTauxCo2

CO2EQ BUDGET [8]

On average, a French person emits nearly 12 tonnes of CO2 per year; the goal, to keep global warming under 2°C by 2100, would be to emit less than 2.5 tonnes/citizen/year.
It is a “budget” that applies equally to all citizens on earth[9].

CONSUMPTION

→ *French averages in housing:*
In France, on average 2.2 people make up a household[11]:

• 4,770 kW.h / year / household consumed in France in 2018[12]

• 143 liters of water per day, 40% of which in the shower,
20% in the toilets 800 kW.h/year to heat domestic hot water[13]

• 135 kW.h/year of useful energy* for cooking
(*useful energy means the energy actually transmitted to the receptacle, after losses in the efficiency of the cooking appliances, on the basis an annual consumption of an induction hob for 1 to 2 people of 150 kW.h/year with an efficiency of 90% in the conservative hypothesis[14])

8. Government, *The new indicators, Carbon* (2016).
[online] https://www.gouvernement.fr/indicateur-emprunte-carbone (consulted in 12/2019).
& *Carbon brief* (2019). [online] https://www.carbonbrief.org/ (consulted in 12/2019).
9. Government, *The new indicators, Carbon* (2016).
[online] https://www.gouvernement.fr/indicateur-emprunte-carbone (consulted in 12/2019).
10. Elec price, *Electricity consumption 2018 in France: Statistics and Analysis* (2018).
[online] https://prix-elec.com/energie/comprendre/statistiques-consommation-france (consulted in 12/2019).
11. INSEE, *Household size in 2016* (2016).
[online] https://www.insee.fr/fr/statistiques/2381486 (consulted in 12/2019).
12. ADEME, *Water and energy : What consumption?* (2019).
[online] https://www.ademe.fr/sites/default/files/assets/documents/infographie-economiser-eau-energie-2019.pdf (consulted in 12/2019).
13. Thomas Véron, *Hot water tank: consumption, settings to save* (2019).
[online] https://selectra.info/energie/guides/conso/regler-ballon-eau-chaude (consulted in 12/2019).
14. Selectra, *Electric devices : what consumption in kWh and in euros?* (2019).
[online] https://selectra.info/energie/guides/conso/appareils-electriques (consulted in 12/2019).

LOW-TECH HOME DIMENSIONING

The calculations are made based on our experimentation, for two people (Clément and Pierre-Alain) in the Low-tech House which has a surface area of 14 m², approximately 46m³.

• We have an energy requirement to heat the house of 1400 kW.h per year, based on a classic housing with a demand of 100 kW.h/m² per year.[15]

• We consume an average of 250 Wh of electrical energy per day (measurement by wattmeter)

• We need 1600 kW.h to heat domestic hot water over a year[16]

• We consume an average of 25 liters of water per day each, or 50 liters per day for two (measurement on the storage tank)

• We consume on average 15 liters of water per shower (measurement by flowmeter, amphiro[17])

• We consume, to drink and cook, 5 liters of water per day each (counting potabilisation vessel)

• Sanitation treats an average of 40 liters of water per day (measurement on graduated tanks at the sanitation outlet)

SPIDER DIAGRAMS

On these summary diagrams of each low-tech, the "use" axis is noted in absolute terms, while the financial and environmental axes are relative to an existing system.

15. Selectra, *Average electricity consumption of a house* (2019).
[online] https://selectra.info/energie/guides/conso/consommation-moyenne-electricite/maison
(consulted in 12/2019).
16. Thomas Véron, *Hot water tank: consumption, settings to save* (2019).
[online] https://selectra.info/energie/guides/conso/regler-ballon-eau-chaude (consulted in 12/2019).
17. Amphiro, *Save energy in the shower* (2019).
[online] https://www.amphiro.com/fr/(consulted in 12/2019).

Solar air heater

Heating the housing represents 67% of a household's energy consumption[1]. The use of renewable energy for this type of consumption can therefore be very interesting.

**Using solar radiation to directly heat the air entering the house is a relatively simple operation.
The efficiency is 4 to 5 times higher than photovoltaic.**

Explored since the 1950s by Félix Trombe, the principle of the Trombe wall makes it possible to heat the air in the home using direct solar radiation via the principle of a "black body" placed behind glass.

Thus, depending on the context, it is possible to greatly reduce the share of fossil and nuclear energy used for heating.

GUY ISABEL'S SOLAR AIR HEATER

Guy Isabel's solar air heater[2] is a kind of Trombe wall adaptable to the existing building when a vertical place on the south facade receiving winter sun is available.

It is a wooden frame whose bottom is pierced with a low hole, communicating with the habitat for the arrival of «fresh» air and a high hole for the outlet of hot air in the housing.

The air is made to circulate in a zigzag using wooden baffles.
Slates cover this wooden path, finally a window closes the whole.

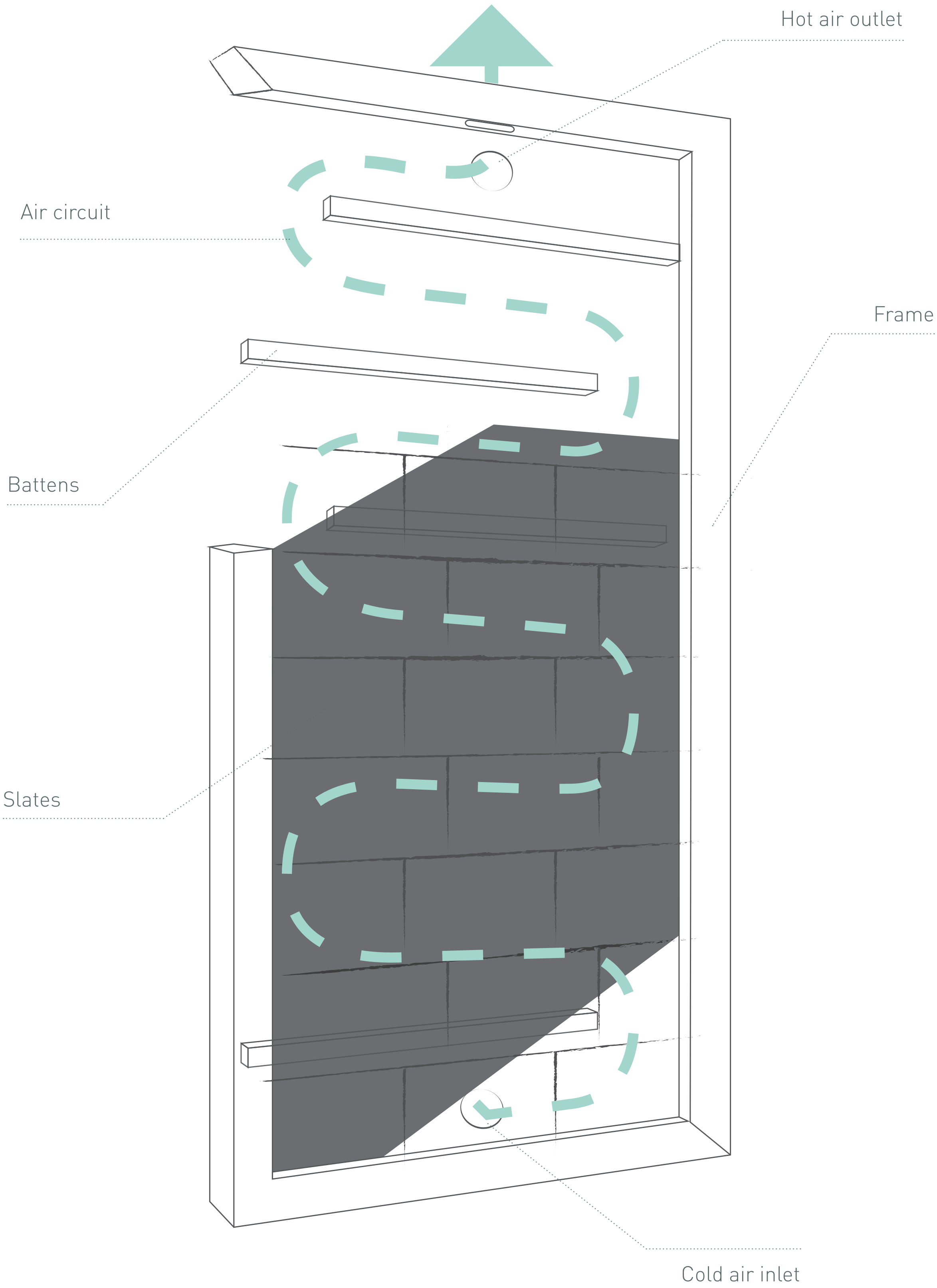
The slates receive solar radiation which heats them up to a high temperature, and the glass creates a greenhouse effect, which limits heat loss.

According to Guy Isabel's results, around 2m² of heated surfaces are needed (about 300W/m² over the useful period) for a room of 15 m² in winter to heat up by an average of 6 to 7°C the temperature (measures taken in Cholet) [3].

LOW TECH HOME DIMENSIONING AND HYPOTHESIS

The surface area of the low-tech housing being 14m², the installed heated surface is 2m². It is positioned south-facing and clear of any shade.
The hot air reaches the level of the kitchen worktop, in the middle of the house.
A thermostatic actuator, connected to a ventilation valve, only allows the air from the solar air heater to enter the home when it is superior at 25°C.
A summer hatch allows the evacuation of hot air to the outside.

1. [online] https://www.ademe.fr/particuliers-eco-citoyens/dossiers-comprendre/dossier/lenergie-france/consomme-plus-denergie-france
2. [online] https://wiki.lowtechlab.org/wiki/Chauffage_solaire_version_ardoise
3. [online] https://www.eyrolles.com/BTP/Livre/les-capteurs-solaires-a-air-9782212140170/



Hot air outlet
Air circuit
Frame
Battens
Slates
Cold air inlet

8h

COST AND SOURCE OF MATERIALS

FONCTION	THEORETICAL COST NEW (Euros)	LTH COST (Euros)
Canalisation	20	0
Black body	19	19
Greenhouse effect	101	1
Insulating	12	12
Hardware store	21	21
Thermal selection	10	10
Structure	81	81
Other	74	70
Total	**338**	**214**

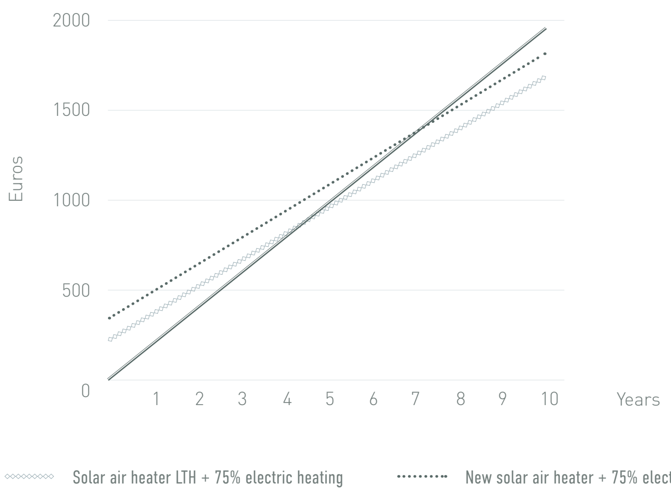
CALCULATION ASSUMPTIONS

• The solar air heater measures 2 m²
• Using the solar air heater reduces heating energy consumption by 25%[4]
• The solar air heater can be used to heat in the presence of sun, an electric heater takes over during dark days and at night
• No maintenance for 10 years
• The solar air heater does not replace another mean of heating but its use in period of sun, thus the investments in heating devices are not taken into account, only the energy saving is counted.

4. A 2m² sensor for a 15m² room = +5 to 6°C; reduce the heating by 1°C = approximately 7 savings";
Sources : Guy Isabel, *Solar air collectors,* France, Eyrolles, 2014.
What energy, Everything about solar air collectors, 2019.
[online] https://www.quelleenergie.fr/economies-energie/aerovoltaique/capteurs-solaires-air (consulted in 12/2019).

RETURN ON INVESTMENT

→ ***Cost of heating methods over the course of 10 years***
See Annex II - ROI



FINANCIAL OVERVIEW

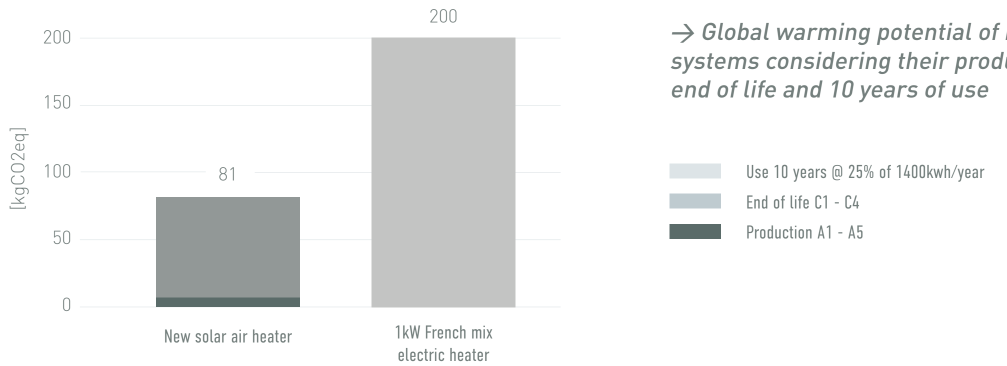
According to our hypotheses, the use of a solar air heater supplemented by electric heating becomes profitable in 5 years in comparison with the use of electric heating alone. If it was only built with new equipment, the profitability in 9 years, although longer, remains interesting.

It is therefore obviously interesting to exploit the maximum of available surface exposed in the winter sun to increase the share of solar thermal in the heating.

ENVIRONMENTAL IMPACT

LIFE CYCLE ANALYSIS
GLOBAL WARMING POTENTIAL

See Annex I - LCA



→ Global warming potential of heating systems considering their production, end of life and 10 years of use

THE 3 ELEMENTS WITH THE HIGHEST GLOBAL WARMING POTENTIAL

See Annex I - LCA

Glass → 30% Stainless steel sleeve → 17% Slates → 16%

ENVIRONMENTAL ASSESSMENT

From a greenhouse gas (GHG) emissions point of view, a solair air heater installed in the Low-tech Home is very relevant compared to electric heating, despite a low GHG emitter nuclear mix in France.
Gas or oil boilers being even more polluting in use[5], the solar air heater is even more interesting for homes heated by those systems.

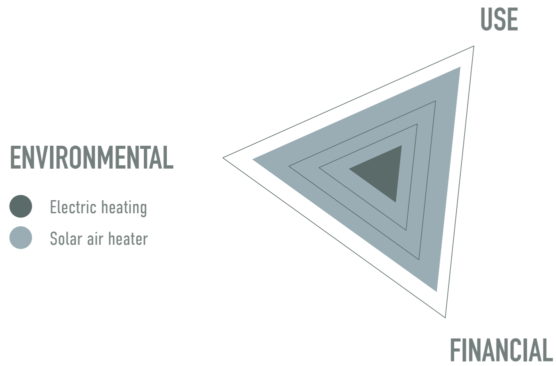
Regarding the materials that make up the system, 3 elements (glass, stainless steel sleeve and slates) clearly stand out. It is therefore interesting to think about less impactful alternatives, mainly for stainless steel which can simply be replaced. Glass and slates can be collected in resource centers.

5. Carbone4, *Are gas boilers compatible with the fight against climate change?* (2019).
[online] http://www.carbone4.com/analyse-chaudieres-gaz-climat/ (consulted in 12/2019).

COMFORT AND USE

\+ In use, the solar air heater is one of the most passive low-tech, that is to say that it does not require any special attention, works very well and independently.
The only quick interventions are to be done in early fall and late spring, to open or close the hot air outlet to the outside, allowing the house to be heated or not.
In winter, as long as there has been enough sun during the day, it is a real plus to be able, in the evening, to enter the house which has been heated and kept out of humidity thanks to the solar air heater.

− However, due to its southerly orientation, the heater does not start to heat until late morning, when the sun really shines on the solar air heater.
So on weekends, for example, when it's sunny, a fire may be needed in the morning while waiting for the solar air heater to take over.



Summary

Due to its simplicity, efficiency and maturity (Guy Isabel has proven it for decades) the solar air heater is one of the most successful low-tech that we know. The installation of a solar air heater in the east would be interesting to test, in order to meet a need for heating in the morning, during weekends for example.
Our geographical context, in a plain clear of all trees, allowed an ideal operation. It is obvious that the system's relevance is completely linked to the installation's context.
It would, a priori, be very effective in mountainous contexts in the South of France, where winters are cold but sunnier than in Brittany.

**More generally, we see that the system is very relevant from all points of view. For example, today in France,5 million households are in a context of fuel poverty (12 million individuals) of which more than one million are owners of individual houses[6], the most favourable context for the installation of hot air sensors.
A significant potential of beneficiaries therefore exists on the territory, making it possible to validate the importance of a wide dissemination of this system and, more widely, of the use of solar thermal energy.**

6. ADEME, *Fuel poverty* (2018).
[online] https://www.ademe.fr/expertises/batiment/quoi-parle-t/precarite-energetique
(consulted in 12/2019).

AREAS FOR IMPROVEMENT

Design • Whether for its mass or its components from petrochemicals (mastic, rain screen, etc.), an optimization work of the sizing would be interesting to make it more compact and even more relevant on the economic aspects and ecological.

Exposure • It would be interesting to test an additional solar air heater to the east when the facade receives the winter sun in order to start the heating earlier in the day.

Materials • Slate serving as a black body is one of the most impactful materials, thusbeing able to replace it with another healthy and lighter material would be a good improvement, especially for regions where slate is not traditionally used for roofing.

Day/night phase shift • When the system heats up during the day, the sun entering through the windows also contributes to the heating, which can even cause overheating in the home. However, as soon as the sun goes down, the solar air heater no longer supplies heat.
It would be interesting to think of a thermal accumulator complementary to the solar collector to store heat during the day which could be restored in the evening or even at night and thus better smooth the temperature curve of the habitat.

Solar water heater

Converting solar energy into heat is simple and efficient. With an efficiency three to four times higher than photovoltaic panels, thermal solar panels make it possible to produce heat, the leading source of energy consumption for housing in France (79% of energy consumption)[1].

Domestic hot water is a basic need in our climate; it is mainly used for the shower, the dishes and washing clothes. Among the French, it represents 13% of energy consumption at home.

A solar water heater can produce 60 to 90% of annual domestic hot water depending on the region and year. Associated with an alternative heat source (biomass, electricity, gas, fuel oil) which takes over during periods of low sunlight, it greatly reduces the energy bill.

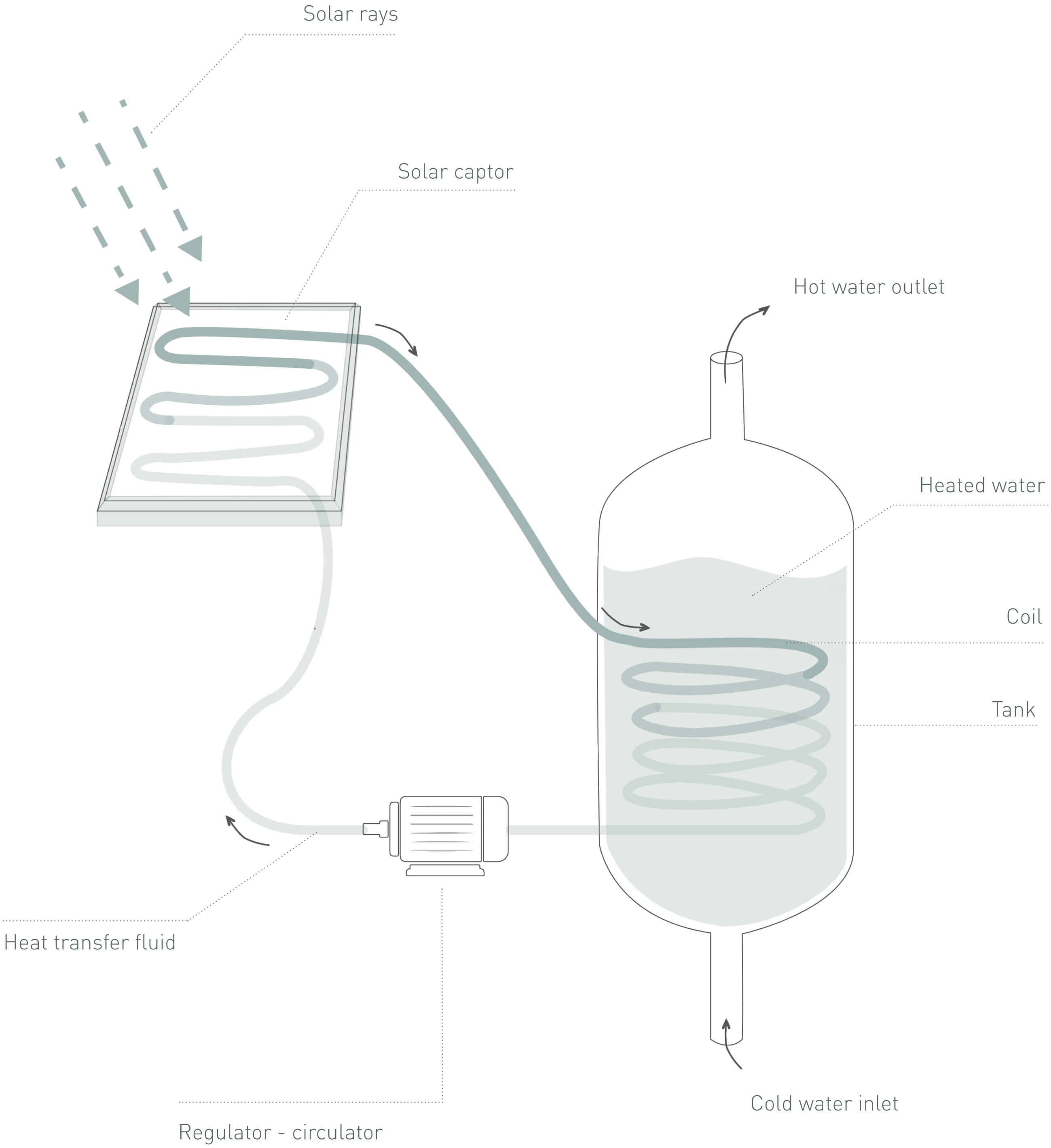
THE THERMAL SOLAR PANEL BY ÉRIC LAFOND[2]

Placed between glass and insulation, a heat transfer fluid flows through a refrigerator heat exchanger. Solar radiation is transformed into heat which will be transmitted to the domestic hot water in a heat exchange balloon.
The fluid runs in a closed circuit thanks to a circulator. Domestic hot water does not pass through the panel.
Be careful with the heat exchanger grids. When they are retrieved from a refrigerator, they can release refrigerant gases, some have a global warming potential 2000 times greater than CO2!
You must get closer to depollution and recycling organizations of household appliances to recover them cleanly.
According to studies by Eric Lafond, this system produces an average of 500W / m² per year in France.

LOW-TECH HOME DIMENSIONING AND HYPOTHESIS

In our case, the panel is 1m² (55x175 cm²). Since the origin of the project, it was planned to adapt the surface of the panels in order to use them in a bioclimatic setting.
The overall system consists of a 90 liter hot water tank, a circulator, a regulator and an Overpressure system.
The 90-liter tank allows you to have inertia over two days for two people.
A day without sun but not without hot water!

1. ADEME, *Water and energy: What consumption?* (2019). [online] https://www.ademe.fr/sites/default/files/assets/documents/infographie-economiser-eau-energie-2019.pdf (consulted in 12/2019).
2. Low-tech Lab, *Solar water heater* (2018) [online] https://wiki.lowtechlab.org/wiki/Chauffe_eau_solaire(consulted in 12/2019).


Solar rays
Solar captor
Hot water outlet
Heated water
Coil
Tank
Heat transfer fluid
Regulator - circulator
Cold water inlet

COST AND ORIGIN OF THE MATERIALS

1M² THERMAL SOLAR PANEL (€)

	THEORETICAL COST NEW	LTH COST
Glue	5	5
Painting	2	2
Glass	100	0
Exchanger	0	0
Insulation	10	10
Plumbing	2	2
Hardware	10	10
Wood structure	50	50
Total	**179**	**79**

INSTALLATION TOTALE (€)

	THEORETICAL COST NEW	LTH COST
Solar thermal panel	179	79
Circulator - Regulator	400	150
Hot water tank	395	395
Plumbing	131	131
Total	**1 105**	**755**

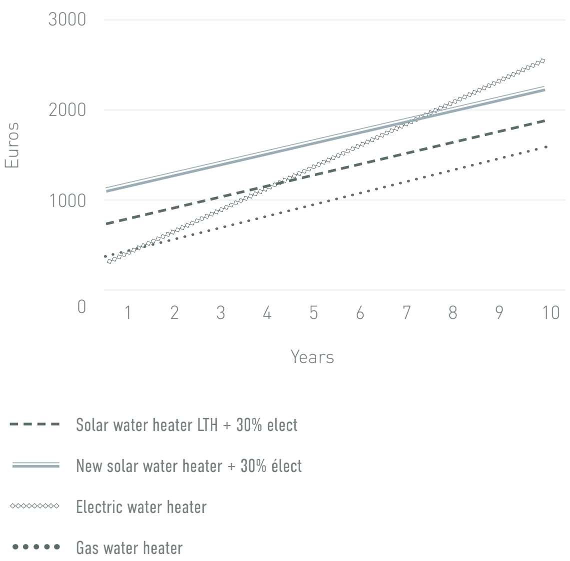
CALCULATION ASSUMPTIONS

- Production of 70% of domestic hot water with the solar water heater, supplemented by electricity or gas (conservative hypothesis)
- The equivalent of 5% of the energy production is necessary for the electrical supply of the regulator and circulator.
- The cost and impact of the heat transfer fluid are not taken into account. We use water.
- Comparison with a 100 liter electric water heater (300€)[3]
- Comparison with an 11l/min, 17kW instant gas water heater (350€)[4]
- Electric and gas water heaters have an efficiency of 70%[5]
- No maintenance for 10 years

3. Leroy Merlin, *Electric water heater* (2019).
[online] https://www.leroymerlin.fr/v3/p/produits/chauffe-eau-electrique-vertical-mural-equation-titane-electronique-100-l-e180184 (consulted in 12/2019).
4. Leroy Merlin, *Gas water heater* (2019).
[online] https://www.leroymerlin.fr/v3/p/produits/chauffe-eau-gaz-instantane-elm-leblanc-ondea-lc-11-11-l-min-e56331 (consulted in 12/2019).
5. ADEME, *Domestic hot water* (2016).
[online] https://www.ademe.fr/expertises/batiment/passer-a-laction/elements-dequipement/leau-chaude-sanitaire (consulted in 12/2019).

RETURN ON INVESTMENT

→ *Cost of domestic hot water production resources over 10 years*
See Annex II - ROI

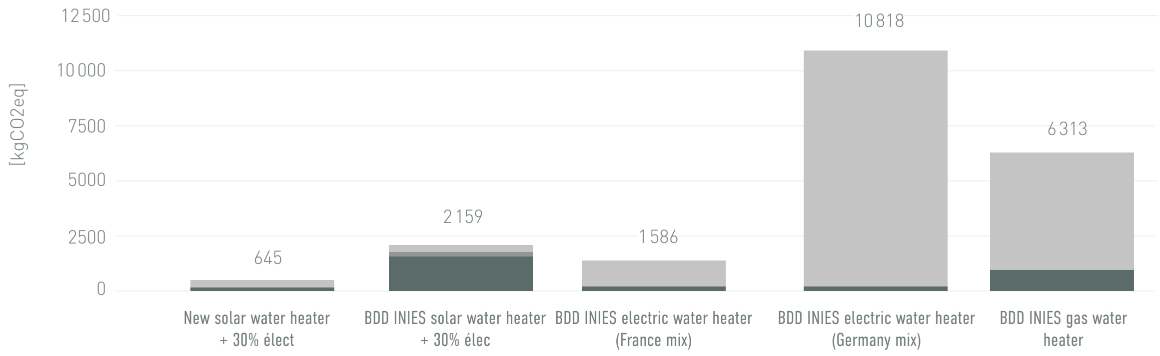


FINANCIAL OVERVIEW

It takes 4 years for the installation, if installed as we have in the low-tech house, to be economically profitable compared to an electric water heater.
If we had done everything with new materials, it would have taken 7 years.
Gas is more economically profitable than thermal solar.
The price of a turnkey solar thermal installation on the marketranges is between 5,000 to 7,000 euros.
The return on investment is not obvious given the lifespan of the systems.
Aid to reduce purchasing costs and installation can make the system competitive.
The 70% efficiency for thermal solar is low, it is "challengeable". We met people (in Brest!) who produce on average 90% of their domestic hot water in solar by reducing the hot water tank temperature setpoint and increasing the system inertia. The larger a solar installation, the lower its cost per user and therefore the faster the return on investment, hence the interest to pool these sorts of systems if possible.

ENVIRONMENTAL IMPACT

LIFE CYCLE ANALYSIS
GLOBAL WARMING POTENTIAL



→ Global warming potential of heating methods, including production, end of life and 10 years of use

See Annex I - LCA

Use 1600 KWH/2 people/year for 10 years — End of life C1 - C4 — Production A1 - A5

THE 3 ELEMENTS WITH THE HIGHEST GLOBAL WARMING POTENTIAL

See Annex I - LCA

Hot water tank → 46%
Circulator/Regulator →15%
Glazing → 12%

ENVIRONMENTAL ASSESSMENT

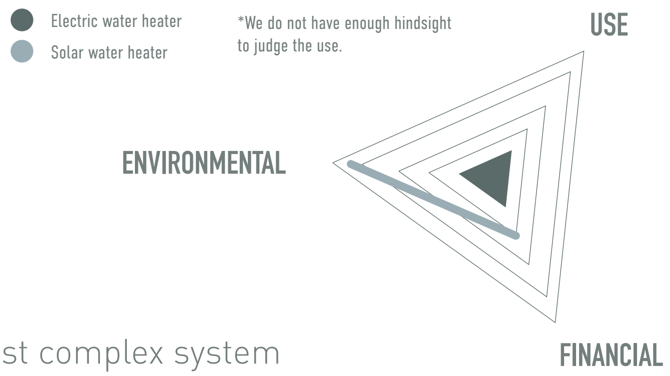
These initial calculations show that over a period of 10 years the low-tech solar water heater would have a potential of reducing greenhouse gas emissions from 60% to 90% compared to an electric and gas water heater respectively. However, the French energy mix, with a lot of nuclear, allows French electric water heaters to generate very little greenhouse gas and to be very competitive in this area.

We realize that with the German energy mix, which uses a lot of coal, the environmental impact of solar is much lower than electric across the Rhine.
The same is true for gas boilers or water heaters.

There are many sources of end-of-life glazing; the reuse of windows makes it possible to reduce the cost and environmental impact of the system. Less obviously, it is possible to do the same with the hot water tanks and then add a heat exchanger to them.

COMFORT AND USE

In this short-term project, hot water was not our priority compared to other needs (electricity, sanitary, conservation, heating) so we spent a major part of the experiment without a functioning solar water heater. Therefore, over this part of experiment, use is not indicative of actual conditions of use in a finished classic housing.



Summary

The solar water heater is by far the most complex system we have in the Low-tech Home. The solar thermal panels are simple to achieve but the rest of the circuit is not, plumbing requires knowledge and skills that we did not have.
With hindsight, we could have installed a much simpler plumbing system.
In addition, this low-tech has been the victim of experimentation bias; we could take our showers at our workplace or our usual residence, where we lived part time.
However, these thermal solar panels seem to be a very good option both financially and environmentally. With an efficiency slightly lower than the products on the market and a cost up to twenty times lower for the same unit area, this system has a lot of potential.

In France, depending on the region and the exposure, an average of 4m² of panels are needed for 2 to 3 people and 6m² for 6. In general, we have large sunny artificial surfaces such as roofs or facades facing south. What a shame to make solar thermal economically unattractive by offering expensive high efficiency systems when the sun is free and the space widely available.
Finally, following the heat waves of recent years, it is disturbing to use a fossil or nuclear energy source to heat water while the population seeks shade and freshness all summer long.

AREAS FOR IMPROVEMENT

DIY and open source regulator *• The regulator, which controls the circulator according to the temperature of the hot water tank and the panel, is expensive and difficult to repair. It would be interesting to replace it with a «homemade» version from free microcontrollers, for example Arduino.*

Thermosiphon *• • The regulator-circulator accounts for a significant part of the financial and environmental cost of the system. It would be interesting to study a water heater in thermosiphon. With the balloon above the panels, the heat transfer liquid circulates by convection. In that way, the initial investment would be reduced and the system passive.*

Frost protection *• Some systems purge automatically when the circulator is not running, i.e. the fluid is removed from the solar panel and is therefore protected from frost, which is very dangerous for the installation.*

Open vase *• An open vessel acts as an expansion vessel, it allows the system not to build up pressure which could degrade it. An open vase is positioned at the highest point of the installation. In addition to a conventional expansion vessel, an open vessel allows to remove potential air bubbles from the heat transfer fluid.*

Mass stove

A mass stove makes it possible to overcome the lack of thermal inertia of a light or wooden housing. Indeed, without heavy elements such as a screed or concrete, stone or earth walls, no material retains heat in the house.
As the air is constantly renewed, it is important to accumulate heat in a mass.

In mass stoves, the mass is made up of heavy materials (stone, brick or concrete) and stores the energy of a single and intense daily outbreak (between 1 and 3 hours) and restores the heat for a long time after the fire has been extinguished (up to 24h).
Its mass gives it thermal inertia which is conducive to smoothing the temperature differences inside a building.
All the quantity of wood necessary to heat the home is burned at once, which induces high temperatures in the hearth and makes it possible to obtain an almost complete combustion with little pollution.
The accumulator is designed to absorb most of the energy coming from the combustion and smoke.

With an efficiency greater than 80% for the most part, these stoves are among the most efficient wood-burning appliances.

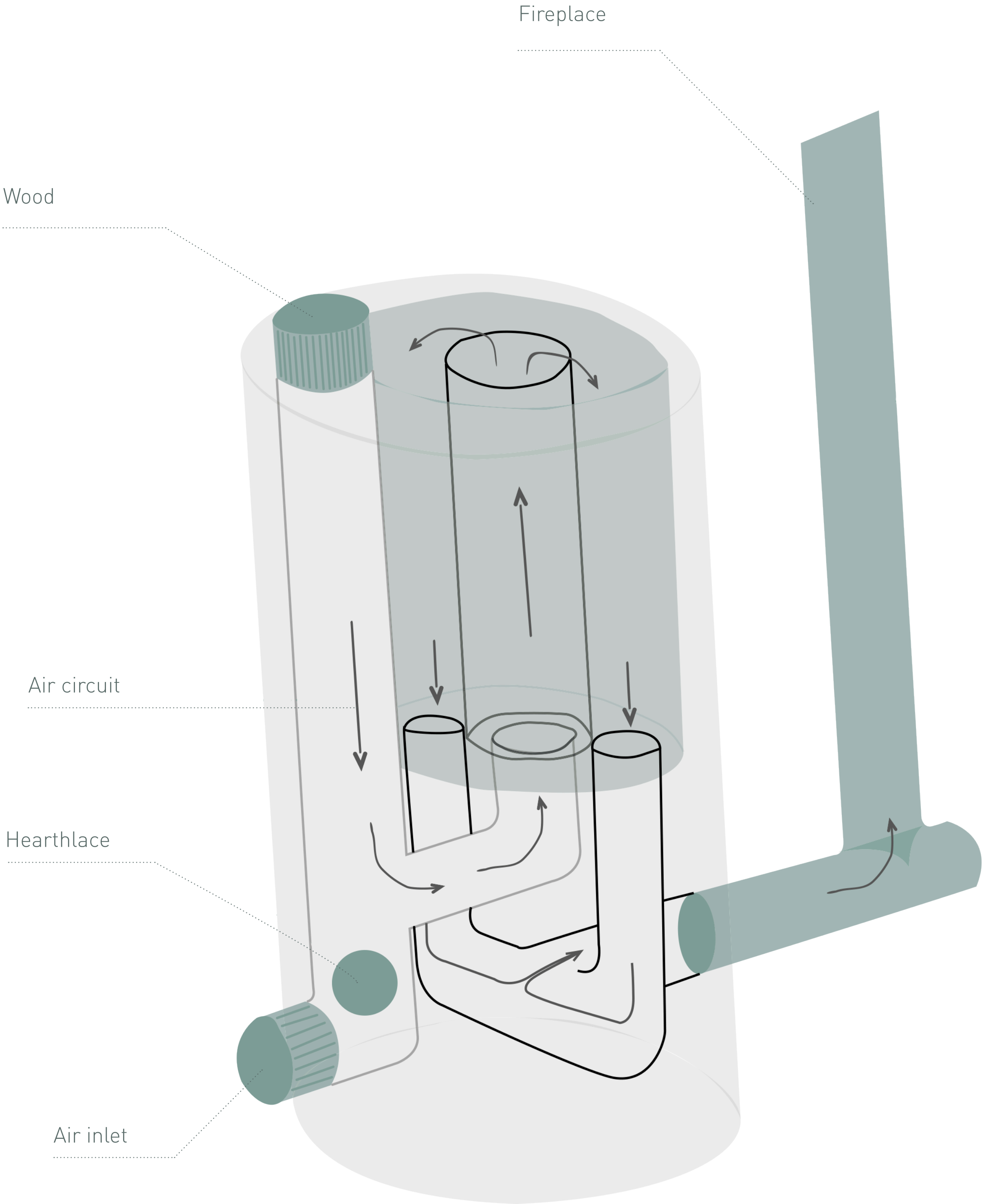
THE SEMI-REMOVABLE MASS STOVE BY VITAL BIES[1]

The principle of this stove is to combine «mass» and «mobility»: part of the inertia is produced by sand, which is easily removable.
The emptied stove is easier to move.
In use, the rocket stove works in vertical loading, which allows a self-feeding wood by gravity. Combustion, by aspiration of the flames, is lower lateral, which allows air to enter from above the fuel.
It is an original design that ensures very good performances but it takes time to get the correct handling.
This stove is available in 60, 120 or 200 liters which weigh 80, 160 or 250kg respectively.
Please note that fire insurance no longer covers a home with a self-built stove.

LOW-TECH HOME DIMENSIONING AND HYPOTHESIS

For the Low-tech Home and its 14 m², we installed the 60 liters stove.
The fireplace has a power of approximately 2 kilowatts, outbreaks last from one to two hours.

1. Low-tech Lab, *PSemi-removable mass stove* (2017). **[online]** https://wiki.lowtechlab.org/wiki/Poelito_-_Po%C3%AAle_de_masse_semi-d%C3%A9montable (consulted in 12/2019).


Fireplace
Wood
Air circuit
Hearthlace
Air inlet

16h

COST AND SOURCE OF MATERIALS

FUNCTION	THEORETICAL COST NEW	LTH COST (Euros)
Canster	50	0
Formwork	10	4
Smokehouse	100	100
Cement loaded	55	55
Sand	5	0
Painting	13	13
Braided	13	13
Vitroceramic glass	25	25
Total	**271**	**210**

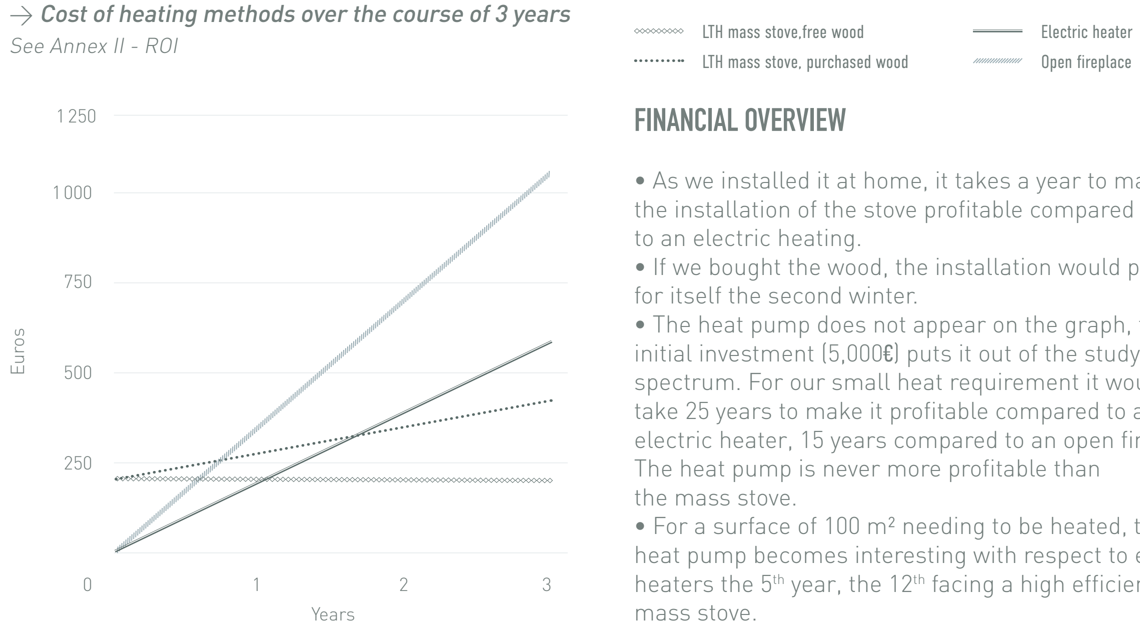
CALCULATION ASSUMPTIONS

• The presence of the solar air heater is not considered, the heat requirement of the house is still 1400 kW.h
• Wood collected in a natural environment or made up of offcuts (free)
• The heating period is 232 days (October 1 to May 20), conservative hypothesis
• The efficiency of a rocket stove is 75%
• The efficiency of an open fireplace is 15%
• The yield is purely from an energy point of view, it does not consider the additional greenhouse gas emissions linked to poor combustion, conservative hypothesis
• The efficiency of an electric heater is 100%
• The heat pump has a coefficient of performance of 3.9 and a power of 5.2 kW
• The price of the roof has not been included
• The cost of radiators, boilers and chimney is not considered (conservative hypothesis)
• A heat pump has a cost of 5000€ (conservative hypothesis)

2. abcclim, *Unified Degree-Day (DJU)* (2014)
[online] https://www.abcclim.net/degres-jour-dju.html (consulted in 12/2019).
3. Assos des 2 mains, *Le poelito* (2017).
[online] https://sites.google.com/site/assodes2mains/poele/le-poelito (consulted in 12/2019).
4. Alain, *How can I increase the efficiency of my open fireplace?* (2017).
[online] https://www.chauffageaubois.eu/comment-augmenter-le-rendement-de-mon-foyer-ouvert/ (consulted in 12/2019).

RETURN ON INVESTMENT

→ ***Cost of heating methods over the course of 3 years***
See Annex II - ROI



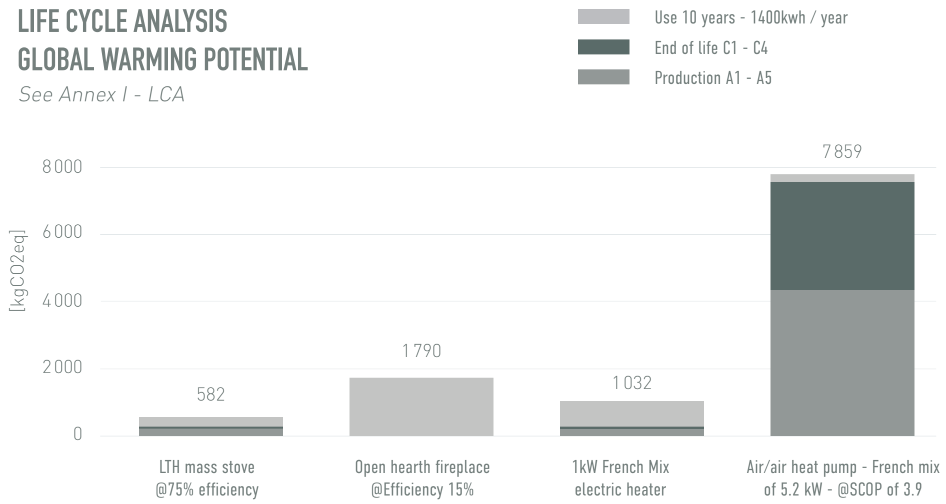
FINANCIAL OVERVIEW

• As we installed it at home, it takes a year to make the installation of the stove profitable compared to an electric heating.
• If we bought the wood, the installation would pay for itself the second winter.
• The heat pump does not appear on the graph, the initial investment (5,000€) puts it out of the study spectrum. For our small heat requirement it would take 25 years to make it profitable compared to an electric heater, 15 years compared to an open fireplace. The heat pump is never more profitable than the mass stove.
• For a surface of 100 m² needing to be heated, the heat pump becomes interesting with respect to electric heaters the 5th year, the 12th facing a high efficiency mass stove.

ENVIRONMENTAL IMPACT

LIFE CYCLE ANALYSIS
GLOBAL WARMING POTENTIAL

See Annex I - LCA



→ Global warming potential of heatibg methods, including production, end of lifem and 10 years of use

THE 3 ELEMENTS WITH THE HIGHEST GLOBAL WARMING POTENTIAL

See Annex I - LCA

Berkey stainless steel → 60 %
60 liter can → 16 % Cement melt → 6 %

ENVIRONMENTAL ASSESSMENT

These initial calculations show that over a period of 10 years the low-tech mass stove would have a potential to avoid greenhouse gas emissions from around 43% compared to electric heating, 67% for an open fireplace and 92% for a heat pump. Like the solar air heater, we have not integrated the boilers gas or fuel oil which have an even heavier environmental impact than other comparative solutions[5].
The performance of the stove is relative to the low impact of wood when coming from a sustainably managed forest which has a halved global warming potential.

Compared to the French energy mix, brought back to kW.h. It therefore seems interesting to heat with wood since the high efficiency stove generates little smoke and fine particles.
Heat pumps, although they consume little and therefore are considered as ecological systems, have a very strong impact during their production and at the end of life. In our "simulated" case, the use of the heat pump represents less than 10% of the impact of its entire life cycle!

5. Carbone4, *Are gas boilers compatible with the fight against c limate change?* (2019). **[online]** http://www.carbone4.com/analyse-chaudieres-gaz-climat/ (consulted in 12/2019).

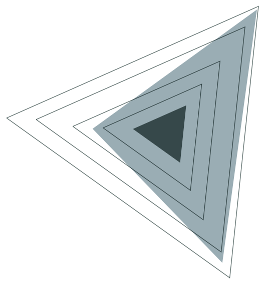
COMFORT AND USE

⊕

The stove is not very greedy, it needs about 2 kilos of wood per hour of fire. The firewood should be small. We carry out outbreaks of one to two hours in the evening, the temperature is comfortable and it is neither too hot nor too cold. Once turned off, the stove continues to radiate for four to six hours. In the morning, the stove is lukewarm. This small inertia is linked to the low mass of the device. Traditional mass stoves can weigh from several hundred kilograms up to a few tonnes, thus increasing the inertia of the system.
Seeing and hearing the fire crackle is very pleasant and during outbreaks it is possible to heat water, toast bread, reheat a dish...

⊖

Unsurprisingly, the stove is not useful in the summer. When the freshness returns we quickly take it back in hand, even if it requires to follow a rigorous and not very intuitive protocol for ignition. If the methodology is not followed, there is a risk of smoke in the house. The ash removal can generate dust. You must take care of the fire regularly to maintain good combustion.
We do not leave the fire unattended for a long time even if we have never had a problem with flames rising in the duct loading timber.



Summary

The mass stove is one of the main features of the Low-tech Home; it is simple, useful, efficient, and looks great in the house. Its thermal inertia means it is perfect for small homes, since no energy is wasted in heating up unused space. When a classic stove in a small space reaches its peak heat, doors and windows need to be opened so as not to turn the room into a sweat lodge.

This system is more environmentally and financially attractive than an electric heater or a heat pump, even when heating spaces are much larger than the Low-tech Home.

Particular attention must be paid to wood resources if its use increases significantly.

AREAS FOR IMPROVEMENT

120 litre stove • It would be interesting to replace this 60-litre stove with its 120 litre older brother and study its use and level of thermal comfort.
With a greater mass, the larger stove would heat later into the night; however, there is also greater risk of overheating. The wider wood loading duct of the 120-litre heater also means that larger pieces of wood can be used.

Boiler • The stove could also be used to heat the water from the hot water tank during periods of little sunlight.

Stainless steel • *In the life cycle analysis, the stainless steel flue pipe is by far the most environmentally harmful component of the stove. It would be interesting to replace it with materials emitting less GHG.*

Photovoltaic Solar Panels

Photovoltaic modules and storage batteries transform solar energy into electricity and ensure a continuous supply of electricity in the form of direct current.

These are non-low-tech systems which have yields around 20%.

For the use of electricity on an isolated site,the mounting is accompanied by an electronic module and a storage battery allowing a continuous distribution of current in the home.

THE LOW-TECH HOME'S PHOTOVOLTAIC SOLAR INSTALLATION

The photovoltaic solar panels allow, thanks to a regulator, to store the electricity produced in the batteries. The electricity can then be used with the lowest possible efficiency loss via a 12V DC circuit.
If required, an inverter can produce a 220V AC current. The inverter has an energy efficiency of around 90%.
A 12V DC circuit seems most appropriate for the Low-tech Home since we have no «power» devices such as kettles, electric plates, vacuum cleaners, etc., for which 12V would not be practical, as they would then need to be powered via cables having big sections.
The photovoltaic solar panels are south-facing, on the ground.
Placing them on the ground as opposed to the roof makes maintenance tasks much simpler, including cleaning the panels and adjusting the angle throughout the seasons.

LOW-TECH HOME DIMENSIONING AND HYPOTHESIS

We do not know of any low-tech that generates electricity in a way and that is, at the same time, simple, accessible, and eco-friendly.
We chose not to build home-made wind turbines for a variety of reasons (geographical, environmental impact, lack of necessary infrastructure). Inside the house, we strived to minimise our electricity consumption without compromising on comfort.
We followed the approach proposed by the négaWatt association[1]. As such, we only need power for lights, computers, phones, music, and a small refrigerator during peak heat, consuming on average 250 Wh per day.
By comparison, the average electricity consumption in France is 3000 Wh / day / person for electrical devices alone, not including heating and other costs[2].
Anything needing heat was redirected to the most appropriate energy source, thus minimising the use of electric motors.
We had a pump for water, and we occasionally used a small refrigerator.
We therefore installed 2x 290 watt-peak (Wc) photovoltaic solar panels, 4x 90Ah batteries, a charge controller that generates a 12V circuit and an inverter to occasionally power a 220V AC circuit.
Our energy profile (see Annex III - Energy profile) allowed us to work out the dimensioning.

1. Negawatt, *Achieving the energy transition* (2017). [online] https://negawatt.org/ (consulted in 12/2019).
2. Alice, *Average power consumption per day* (2018). [online] https://www.agence-france-electricite.fr/consommation-electrique/moyenne-par-jour/(consulted in 12/2019).

10h

COST AND SOURCE OF MATERIALS

FUNCTION	THEORETICAL COST NEW	LTH COST
Battery	1500	0
Cables	27	27
Charge controller	204	204
Inverter	184	184
Power generation	320	258
Total	**2235**	**673**

Euros

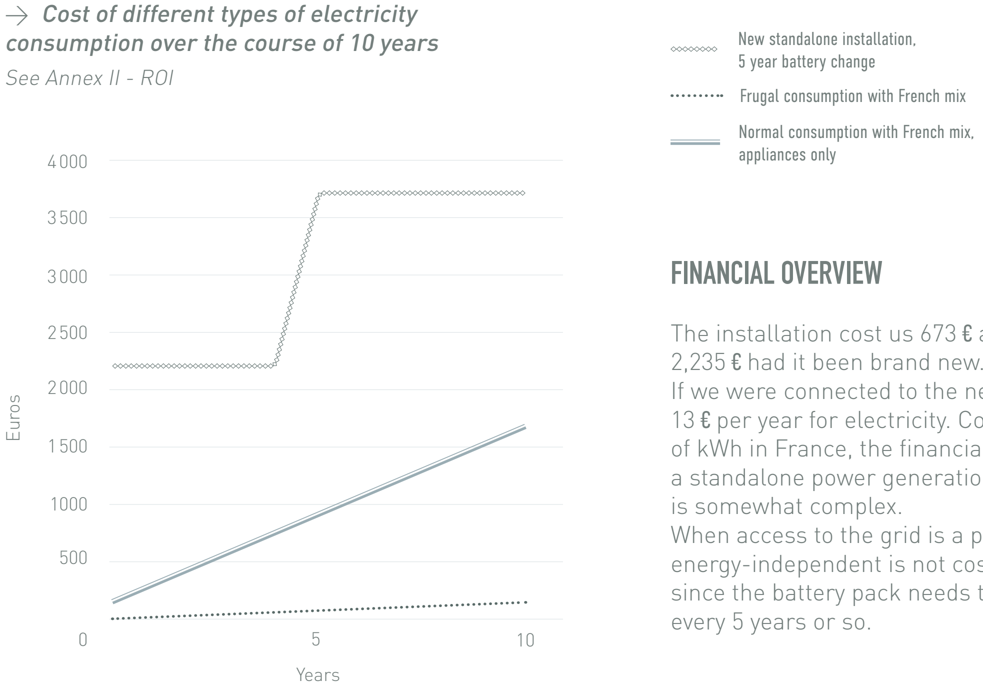
HYPOTHÈSES DE CALCUL

• We compare our system to a grid connection that uses a predominantly nuclear French mix and a predominantly coal German mix.
• To calculate the global warming potential of the photovoltaic solar panels, we use default data from the French Environment and Energy Management Agency (ADEME), referring to panels that can have up to twice as much environmental impact as other panels in the database.
• To calculate the global warming potential, we do not consider any battery change after 10 years of use.
• When endorsing to the negaWatt approach, our electricity demand has been 70 times lower than the average consumption; 100kWh per year compared to 7000 kWh per year, using a small fridge, LED lights, phone chargers, computers, etc.
• Our photovoltaic solar panels, which take up to 600 Wc (4m²) of space, are bigger than needed. They can produce around 600 kWh per year, whilst only 100 kWh is consumed.

RETURN ON INVESTMENT

→ ***Cost of different types of electricity consumption over the course of 10 years***

See Annex II - ROI



FINANCIAL OVERVIEW

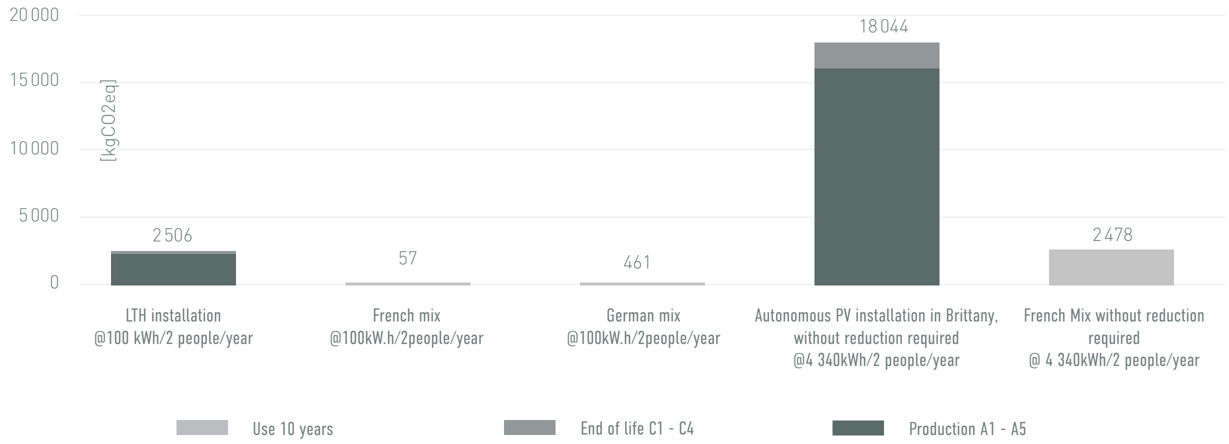
The installation cost us 673 € and would have cost 2,235 € had it been brand new.
If we were connected to the network, we would pay 13 € per year for electricity. Compared to the low cost of kWh in France, the financial profitability of a standalone power generation/consumption system is somewhat complex.
When access to the grid is a possibility, being energy-independent is not cost-effective, especially since the battery pack needs to be changed every 5 years or so.

ENVIRONMENTAL IMPACT

LIFE CYCLE ANALYSIS
GLOBAL WARMING POTENTIAL

See Annex I - LCA

→ *Global warming potential of each type of electricity consumption, including production, end of life and 10 years of use*



THE 3 ELEMENTS WITH THE HIGHEST GLOBAL WARMING POTENTIAL

See Annex I - LCA

2 photovoltaic panels 290 Wc → 56%
4 batteries 90 Ah → 25 % Inverter → 13%

ENVIRONMENTAL ASSESSMENT

By following the negawatt[3] approach and optimising our energy consumption, the level of GHG emissions produced by our photovoltaic solar panels is comparable to the average amount produced by photovoltaic solar panels connected to the grid.
If we consumed the same amount of electricity as the French average, our environmental impact would be almost 6 times higher than if we were connected to the network.

The best way to significantly reduce the amount of greenhouse gases emitted by standalone photovoltaic solar panels is for the user to change how they use energy.

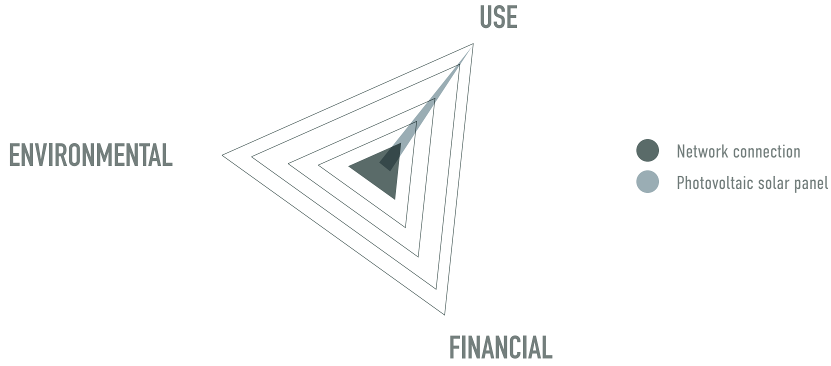
3. Negawatt, *Achieving the energy transition* (2017). [online] https://negawatt.org/ (consulted in 12/2019).

COMFORT AND USE

(+) Our electrical system was never a hindrance to our day-to-day lives; we continued to use our small refrigerator in summer, and we got by just fine with less sunshine in winter. We also had no problems listening to hours of music.

It is also rather satisfying to be able to lend substance to what exactly happens beyond an electrical socket. We have a "stock" of energy to manage, as you would do with characters in a video game. There is a sense of regaining control of the electricity.

(−) As for the maintenance, the panels are cleaned weekly during periods without rain to ensure the best possible performance; it only takes 5 minutes.



Summary

The panels are not low-tech, give a questionable return on investment, and have a negative impact on the environment; but it is not possible to live entirely without electricity. Added to this is the debate on nuclear energy.
Whilst it has very low «global warming potential», there are huge concerns about how radioactive waste is managed, and generally speaking, it carries many ethical implications.

What is really needed is to reduce energy consumption and to streamline energy sources as per the final energy form required: Thermal? Electric? Mechanic?
It is important to sensitize the general public by giving a tangible idea of what is electricity, wattage, and kWhs.

AREAS FOR IMPROVEMENT

Education • *Energy and kWh are abstract concepts. It is difficult to imagine an unlimited quantity of energy as it journeys towards an electrical socket; you cannot physically see electricity pass through wires in the way that you can see water travel through pipes, for example.*
An energy visualisation tool would be useful to help engage people in the topic of reducing electricity (without becoming a gadget).

Norwegian haybox

Norwegian haybox help to reduce the use of hobs and oven to cook liquid-based foods such as stews and soups. They are useful for food that cooks relatively quickly, such as pasta, rice, and potatoes, as well as for dishes that need to simmer longer, such as stews.

The food is first brought to boil, and kept warm inside the purpose-built container. It cooks thanks to the heat captured in the insulated container. Once cooked, the dish stays warm until ready to eat (public catering works in the same way). There are many ways to build a haybox cooker: from simply wrapping it up in an insulating material, to building a drawer for the specific purpose.

You can save up to 50% of cooking energy, which in France amounts to 135 kWh / year of useful energy on average, for a household of 1 to 2 people[1].

The term «Norwegian haybox» is misleading because it is not necessarily a box and its Norwegian origins are unconfirmed.

THE LOW-TECH HOME'S NORWEGIAN HAYBOX

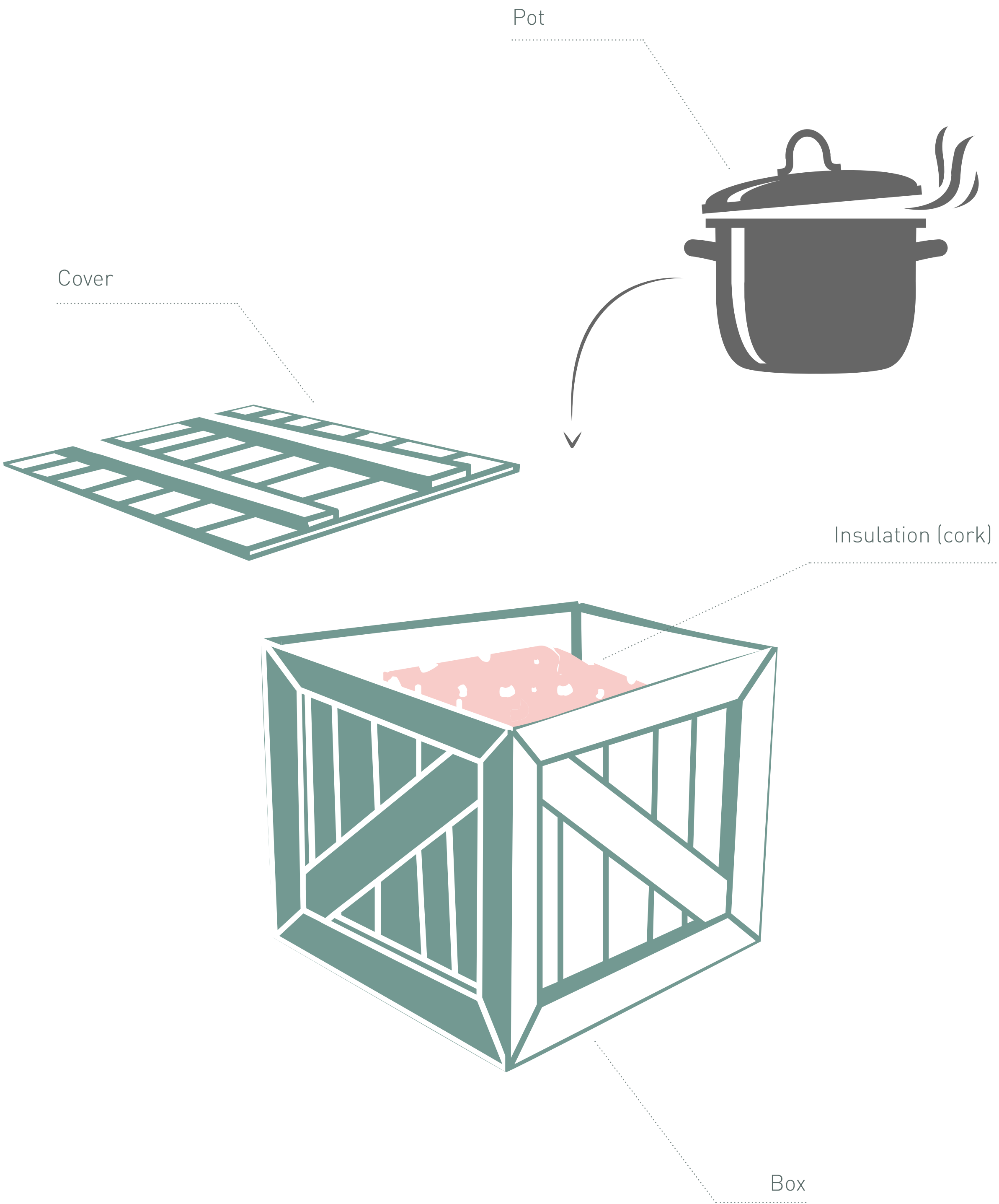
There is one drawer for the haybox within the home.
There is a double partition inside the drawer to accommodate the insulating material: expanded cork.
When making stews or rice, the cooking container is removed once the food has been brought to boil, and placed in the «Norwegian» drawer so that it finishes cooking gently, and stays warm until ready to be eaten.

LOW-TECH HOME DIMENSIONING

The expanded cork insulation is 5cm thick and sits within casing made of plywood.
The interior container insulates t he contentsof pots up to 5L in volume.

For cooking dishes such as casseroles that do not need to «brown», the use of the Norwegian haybox saves 50% of energy, compared to cooking them completely on a gas stove.

1. Selectra, *Electrical appliances: what consumption in kWh and in euros?* (2019). [online] https://selectra.info/energie/guides/conso/appareils-electriques (consulted in 12/2019).


Pot
Cover
Insulation (cork)
Box

2h

COST AND SOURCE OF MATERIALS

FUNCTION	THEORETICAL COST NEW	LTH COST
Insulating	5	5
Structure	36	0
Total	**41**	**5**

Euros

CALCULATION ASSUMPTIONS

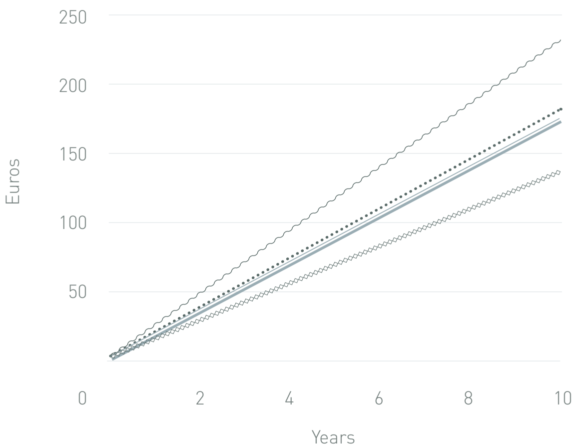
• Average energy consumption in France when cooking for one to two people: 135 kWh/year of useful energy, after efficiency loss of the cooking system
• Efficiency of induction hobs: 90%, thus 150 kWh / year of consumption
• Efficiency of a conventional electric hob: 70%, thus 192 kWh / year of consumption
• Efficiency of a gas hob: 60%, thus 225 kWh / year of consumption [2 &3]
• The pot allows us to save 25% of energy per meal: we rarely use the oven.
• We make some of our meals with a frying pan, which cannot be used in the Norwegian haybox.
Only saucepans can be placed inside.

2. Selectra, *Electrical appliances: what consumption in kWh and in euros?* (2019).
[online] https://selectra.info/energie/guides/conso/appareils-electriques (consulted in 12/2019).
3. Eneco, *Induction or gas? That is the question* (2017).
[online] https://blog.eneco.be/fr/economiser/induction-ou-gaz-telle-est-la-question/ (consulted in 12/2019).

RETURN ON INVESTMENT

→ ***Cost of cooking methods over the course of 10 years***

See Annex II - ROI



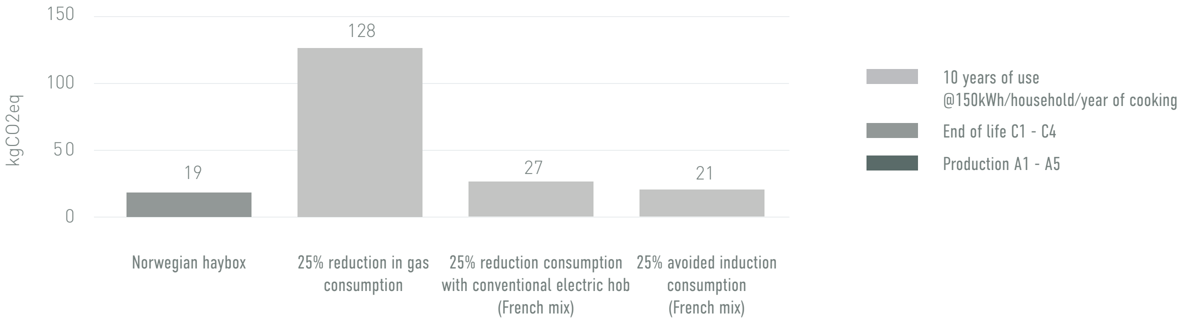
The pot as we made it i.e. with scrap metal, quickly pays for itself:
1 year with a gas cooker, 0.8 years with a conventional electric hob, and 1.3 years with an induction hob.
If we had made it from brand-new materials, the cost-benefit would be less obvious; 7.9 years (gas), 6.1 years (electric hob), and 9.8 years (induction hob).
These rough figures suggest that it is better to use materials that are both insulating and cheap, which can be found quite easily.

ENVIRONNEMENTAL IMPACT

LIFE CYCLE ANALYSIS
GLOBAL WARMING POTENTIAL

See Annex I - LCA

→ Global warming potential of cooking methods, including production, end of life and 10 years of use



THE ELEMENT WITH THE HIGHEST
GLOBAL WARMING POTENTIAL

See Annex I - LCA

Expanded cork → 90%

ENVIRONMENTAL ASSESSMENT

The Norwegian haybox is made predominantly of wood and expanded cork. The expanded cork is responsible for more than 90% of the system's adverse impact on the global warming potential. Expanding the cork consumes a lot of energy. We only used the cork because we had it available; however, it would be simple enough to find an eco-friendlier material with similar or even better efficiency.

For example, an idea could be to use dehydrated fungus mycelium.

By comparing the savings made using our Norwegian haybox with its carbon footprint, we realise that it is not really the best choice for the French energy mix.
Nonetheless, the haybox can still be profitable, provided that the materials are chosen wisely.

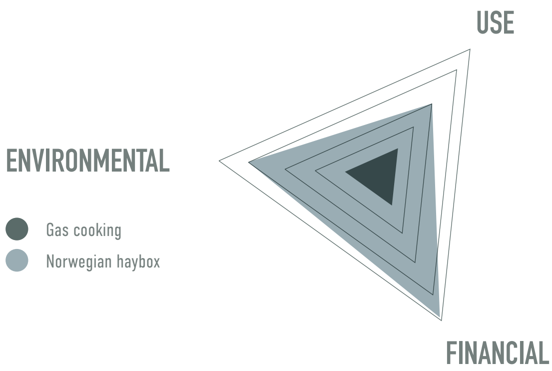
COMFORT AND USE

(+)

The system was installed in our kitchen at the very beginning, in a drawer near the hob.
Fitting the system was relatively quick and easy, and it looks great inside the house. We came to realise that we do not cook many dishes that require simmering, though we do often use a frying pan, which is not compatible with the Norwegian haybox.
So it is mainly starchy foods (pasta, rice, potatoes) that we use the system for. However, the presence of this low-tech allowed us to learn again how to cook some casseroles.
When cooking food like rice that does not take much time, aside from saving energy, the pot gives a better cooking quality than if we were to use the fire for the same length of time.
We no longer burn the bottoms of pans! It also keeps the food warm. The system is therefore more convenient, and requires very little effort: all you need to do is place the container inside the haybox.

(−)

Food that takes longer to cook requires some preparation and forward planning since it cooks more slowly than on a hob. As such, you need to plan the cooking in advance.
We make these observations based on our own experiences, though note that we are far from savvy cooks ourselves!
We would need to use the Norwegian haybox more frequently to determine whether there is any difference in the quality of taste compared to traditional cooking methods.



Summary

In our case, the gas cooker/Norwegian haybox combination is interesting because it accounts for the lowest energy cost and can greatly reduce GHG emissions.
The Norwegian haybox comes in a wide variety of shapes and sizes and can easily be adapted to fit in all homes: rural, urban, and rented accommodation.

**However, a lot of work needs to be done to reduce the cost of the new system and its carbon footprint.
Only then can it be tailored to suit all cooking methods, at which point it will be worth sharing with a wider audience.**

This low-tech can also be fun to use, and can act as a gateway to the world of low-tech cultivating environmental awareness, and encouraging positive action in turn.

AREAS FOR IMPROVEMENT

Insulating material • We used expanded cork as we already had some available.
It is primarily the expanded cork that is responsible for our system's environmental footprint, though this is not justified by its insulation performance. We would be interested in studying how well dehydrated mycelium brick performs as an insulator.

Flexible material • *Many kitchens, especially those in city homes, do not have enough space for a drawer like ours.
It would be worth finding out more about the availability of highly insulating and more flexible haybox models that do not take up as much space.*

Pantry

Pantries were once very popular, especially in the countryside. A pantry is usually a piece of furniture, with a grid, that sits outside a house. In our pantry, we can store certain types of food safely away from attacks (rodents, etc).
Pantries became much less widespread after the arrival of the refrigerator.

**Today, a lot of household food is wasted when stored in the refrigerator.
This is because people don't fully understand that each food should be stored in its own unique atmosphere; there are also issues with the design in that the oldest food often ends up at the back, and in general, people do not tend to organise their food very well.**

THE LOW-TECH HOME'S PANTRY[1]

«To preserve» is not synonymous with «To keep cold». Each food has its own ideal atmosphere for preservation.
Integrated into the design of the kitchen, the pantry in the low-tech house comprises 4 different atmospheres for conservation:

• Dry, airy, and light storage area created by wire drawers

• Dry, airy, and shady storage area created within a hessian-lined drawer

• Wet, cool, and shady storage area created within a wooden box hanging outside on the north-facing side of the house, accessible through a window in the kitchen.

• Wet and cold storage area produced by a 40L refrigerator, powered only during hot summer periods.

This range of storage atmospheres means fresh food can be better preserved, which reduces costs and keeps the environmental impact as low as possible.

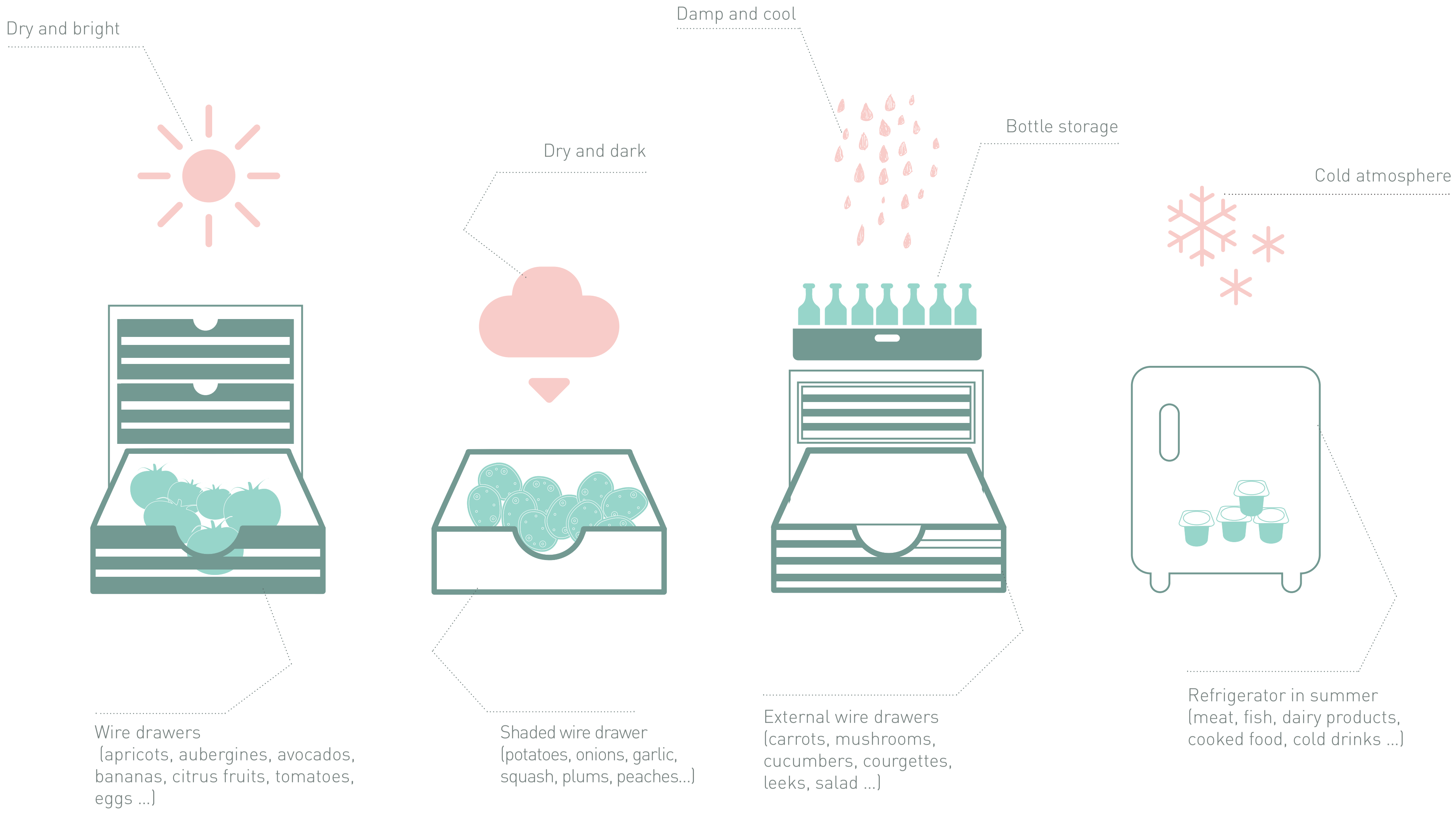
LOW-TECH HOME DIMENSIONING

The pantry in the low-tech house is designed for 2 people.
• Dry atmosphere, in the sunlight:
3 wire drawers measuring 600mm*600mm *150mm
• Dry atmosphere, in the shade:
1 shaded wire drawer measuring 600mm*600mm*250mm
• Humid and cool atmosphere:
2 wire drawers in an external unit measuring 250mm*500mm*150mm,plus a bottle holder.
• Cold atmosphere: a second-hand 40L refrigerator that is turned on in warm temperatures.

Everything is made primarily from poplar wood, which is safe to use when storing food.

These drawers are part of our kitchen, which is otherwise taken up by a worktop and jars for dry foods.

1. Low-tech Lab, *Pantry* (2019).
[online] https://wiki.lowtechlab.org/wiki/Garde-Manger (consulted in 12/2019).


Dry and bright
Dry and dark
Damp and cool
Bottle storage
Cold atmosphere
Wire drawers
(apricots, aubergines, avocados, bananas, citrus fruits, tomatoes, eggs ...)
Shaded wire drawer
(potatoes, onions, garlic, squash, plums, peaches...)
External wire drawers
(carrots, mushrooms, cucumbers, courgettes, leeks, salad ...)
Refrigerator in summer
(meat, fish, dairy products, cooked food, cold drinks ...)

10h

COST AND SOURCE OF MATERIALS

FUNCTION	THEORETICAL COST NEW	LTH COST
Adhesive	3	3
Collage	2	2
Keep	45	45
Cool	100	60
Total	**150**	**110**

Euros

CALCULATION ASSUMPTIONS

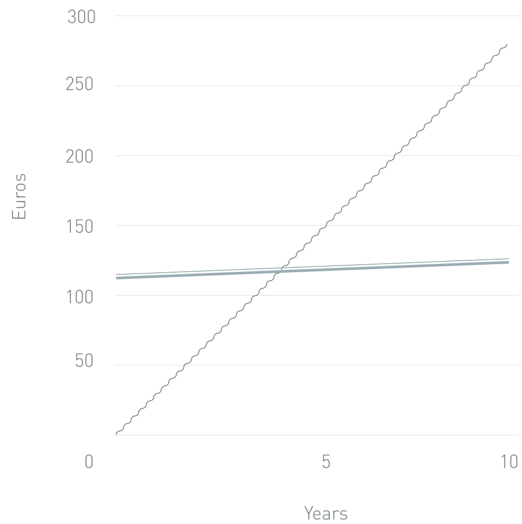
- Average annual energy consumption of a refrigerator in France: 200 kW.h/year[2]
- Average annual consumption of the 40L A+ refrigerator in the Low-tech Home: 8 kW.h/year (plugged in 1 month during summer 2019) [3 & 4]
- The ROI calculation is based solely on the electricity savings made by reducing the use of the refrigerator.
- Reduction of food waste has not been considered.

2. ADEME, *Reduce your electricity bill* (2019).
[online] https://www.ademe.fr/sites/default/files/assets/documents/guide-pratique-reduire-facture-electricite.pdf (consulted in 12/2019).
3. ENGIE, *All there is to know about the power consumed by your refrigerator* (2018).
[online] https://particuliers.engie.fr/economies-energie/conseils/bien-choisir-ses-equipements/tout-savoir-sur-la-consommation-de-votre-refrigerateur.html (consulted in 12/2019).
4. Energy consumed per year by a 40L refrigerator: 100kW.h so 8kW.h per month

RETOUR SUR INVESTISSEMENT

→ ***Cost of methods of food preservation over the course***

See Annex II-ROI



LTH pantry
Classic refrigerator

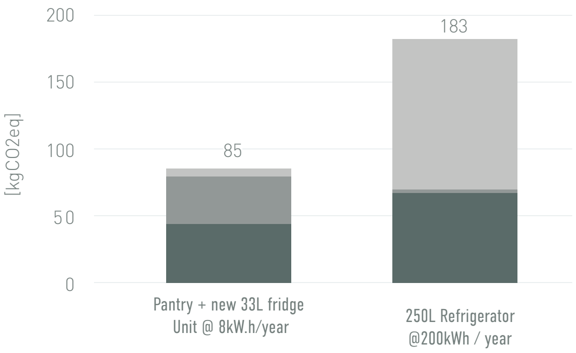
FINANCIAL OVERVIEW

It takes 4.1 years to notice the cost-benefit of our pantry, and 5.4 years when using new materials. It is only cost-effective when reducing the use of the refrigerator, which is turned off for a good part of the year.
Financially speaking, a pantry is therefore a good option; other savings not included herein will be made by minimising food waste.

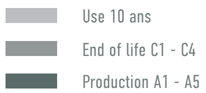
ENVIRONMENTAL IMPACT

LIFE CYCLE ANALYSIS
GLOBAL WARMING POTENTIAL

See Annex I - LCA



→ Global warming potential of the various methods of food preservation, including their production, end of life and 10 years of use



THE ELEMENT WITH THE HIGHEST GLOBAL WARMING POTENTIAL

See Annexe I - ACV

Refrigerator → 85%

ENVIRONMENTAL ASSESSMENT

Unsurprisingly, our 40L refrigerator has the highest environmental impact (85% carbon footprint).
So it's worthwhile getting hold of a second-hand refrigerator rather than a brand new.

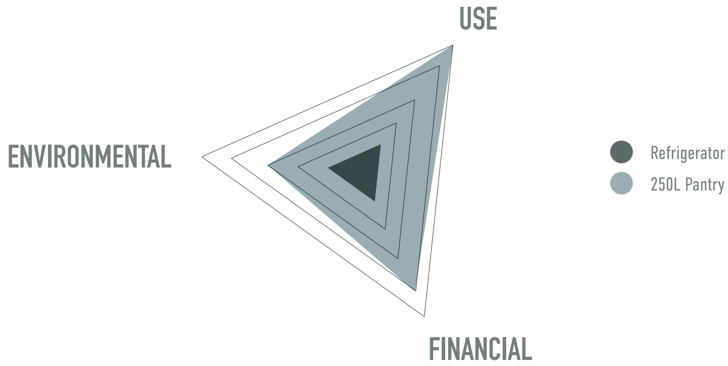
COMFORT AND USE

\+

Overall, the pantry in the Low-tech Home is quite good: the wire drawers make it easy to quickly identify the food that needs to be eaten first (unlike a classic refrigerator), in turn helping to reduce food wastage.
What is more, the wire drawers that are primarily intended for fruits and vegetables remind us to buy more raw foods and fruits and vegetables. This means not purchasing as many processed products that need to be kept cool. In general, the pantry was just as convenient, and also encouraged us to change certain habits; for example, it encouraged us to shop locally for high-quality food products.
Similarly, as we bought bulk vegetables, we noticed a decrease in the amount of packaging wasted.

−

As for food waste, we started the experiment without the 40L refrigerator. We eat dairy products including cheese and butter. During the first few days of the 2019 heatwave, these dairy products ended up being wasted. Therefore, we brought in a small refrigerator. It was plugged in for 1 month during the summer to conserve the dairy products and keep some drinks cool.



Summary

The pantry is portable, and could be adapted for use in any home, whether in the city, countryside, or in rented accommodation. Nonetheless, a rebound effect is possible.
It would be much better to reduce the use of an existing refrigerator, using it in addition to a pantry, rather than throwing away an old one and replacing it with a new one which, albeit better sized, would be more detrimental both financially and environmentally speaking.

This system can have myriad positive effects since it encourages users to rethink how they consume and what they waste.
Even though it is not immediately cost-effective, this low-tech is a good way to get accustomed to change without compromising on comfort.
A wider circulation of the low-tech pantry might have a lot of potential.

AREAS FOR IMPROVEMENT

The main areas for improvement are in the design of the system:
how could it be easily adapted to suit all kitchen types?
The system could be made more compact as there is a little too much drawer surface.

Rainwater

Depending on the region and season, collecting, storing and purifying rainwater can provide a free and even abundant resource.

A French person consumes on average 143 litres of water per day, including 7% for drinking and preparing meals, and 93% for: bodily hygiene (40%), toilet use (20%), laundry (12%), dishes (10%), and household maintenance[1].
Using drinking water for all these activities is unnecessary.

The simplest way of bringing water into the Low-tech Home without being connected to the mains supply, is to use the rainwater. There is a process to follow when using rainwater for domestic purposes:
Collection → pre-filtration → storage → filtration → network pressurisation → potabilisation

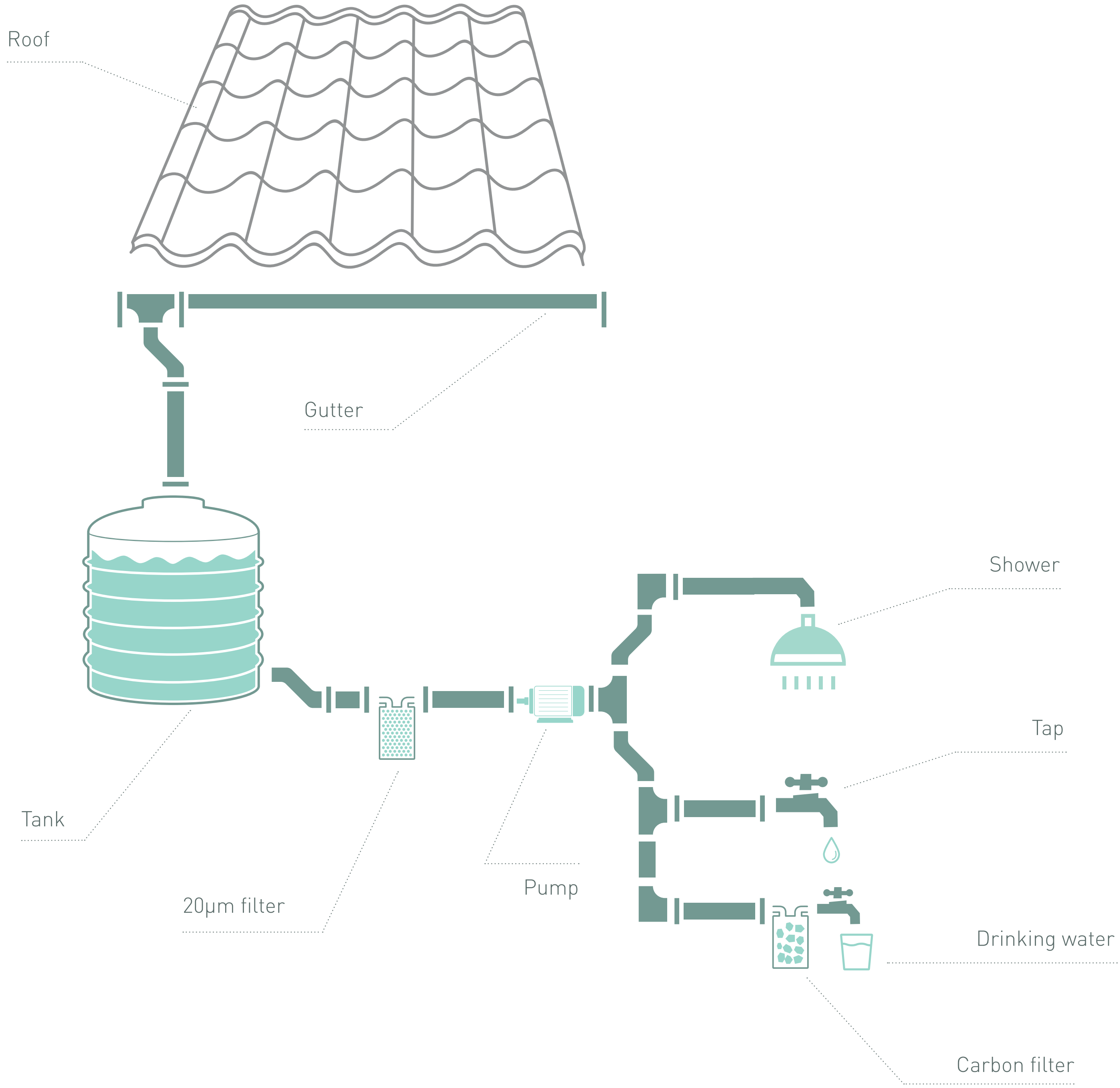
LTHE LOW-TECH HOME'S RAINWATER COLLECTION[1]

Rainwater is collected on the roof.
The gutter is equipped with a pre-filtration system (1mm) that removes large impurities (leaves, feathers, insects...) from the rainwater.
The water then flows into the storage tank. Ideally, rainwater should be stored in a large concrete tank that is buried underground. Since rainwater is slightly acidic and demineralised, concrete helps to correct this acidity and partially mineralise the water.
Having a large tank means that a lot of water can be stored during periods of heavy rain, and used during a drought. Burying the system underground blocks the sunlight and prevents temperature variations, both of which encourage growth of bacteria.
These three components, namely concrete, a large capacity, and necessity for excavation, do not align with the specifications of the Low-tech Home, which is intended to be a nomadic house that leaves no trace of any human activity at its departure. Our house is equipped with a plastic tank.
After filtering, the water is pressurised by a pump and is then ready to be used within the house. Only drinking and cooking water is « purified », by using activated carbon filters.

Warning: the use of rainwater for domestic use is regulated and restricted.
« The Ministry of Health remains vigilant in the application of this regulation, so as not to impact the progress made in public hygiene since drinking water was made availableto the entire French population »[2].

LOW-TECH HOME DIMENSIONING

To design the system, we studied our daily consumption along with the average monthly rainfall.
This calculation (see Appendix IV-water Profile) allowed us to work out the rainwater collection surface area, and the minimum volume required for storage.
The collection surface area is currently 14m2 (projection on the ground). It would likely double if we had a greenhouse.
There is a 200-litre tank and a 90 litre hot water tank in the house. There is also an additional 1,000 litre tank outside.
The water is filtered at 50 then 20µm.
The pump flows at a rate of 13 litres per minute. The drinking water is purified by an activated carbon filter.



CALCULATION ASSUMPTIONS

- The price of the roof has not been included
- The pump consumes 2 Wh/day
- The market price of installing a rainwater collection system is 5,000€ (for a concrete tank of several thousand litres). HC
- 100% of the water consumed was originally rainwater, hence is free.
- The activated carbon filters are not included in the life cycle analysis. They should be changed every 10 years[3]
- The costs and environmental impact of the initial excavation have not been included

1. ADEME, *Water and energy: What consumption?* (2019)
[online] https://www.ademe.fr/sites/default/files/assets/documents/infographie-economiser-eau-energie-2019.pdf (consulted in 12/2019)
2. Ministry of solidarity and health, domestic use of rainwater, *Domestic use of rainwater* (2015).
[online] https://solidarites-sante.gouv.fr/sante-et-environnement/eaux/article/usage-domestique-d-eau-de-pluie (consulted in 12/2019).
3. Berkey, *Black Berkey's water filter* (2019).
[online] https://www.berkeywaterfilterseurope.fr/filtres-a-eau-black-berkey (consulted in 12/2019).

5h

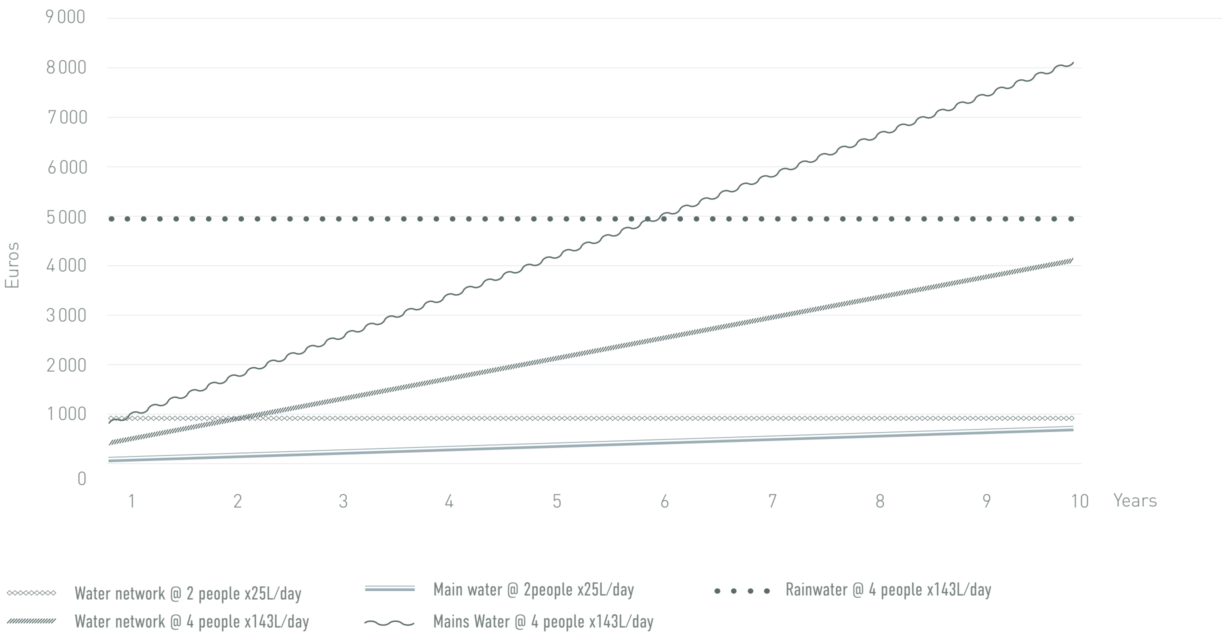
COST AND SOURCE OF MATERIALS

FUNCTION	NEW COST (Euros)
Gutter	10
Tanks	345
Filtration	55
Pressurization	220
Drinking water	300
Total	**930**

RETURN ON INVESTMENT

→ *Cost of methods of water consumption over the course of 10 years*

See Annexe II - ROI



FINANCIAL EVALUATION

•If two people live in the Low-tech Home, each consuming 25L of water per day, the return on investment by not consuming mains water would take effect after 13 years (if we were already connected to the network).

• If we each consumed 143 litres of water a day (in line with the French average) as two people, without consuming the mains water, the ROI would occurafter 2 years and a few months.

• If there were 4 of us living in the house consuming the French average and using a classic system with a tank holding several thousand litres of water, the system would become profitable after 7 years of use, without using the mains supply, if we were already connected to the network.

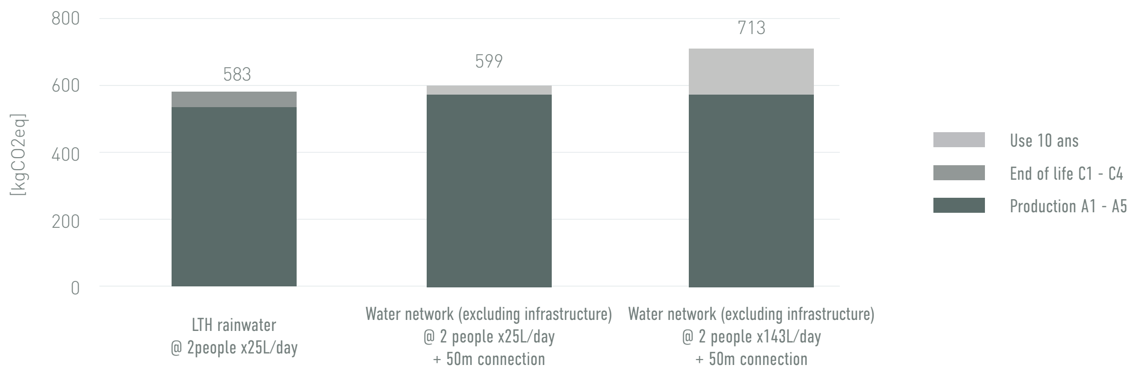
• If the plot of land is not serviced, the excavation, fitting of the network, and site preparation would cost at least 2000€. In this case, a standalone installation could be a worthwhile investment, especially if the public supply network is far away.

ENVIRONMENTAL IMPACT

LIFE CYCLE ANALYSIS
GLOBAL WARMING POTENTIAL

See Annexe I - ACV

→ Global warming potential of the methods of water consumption, including their production, end of life and 10 years of use



THE 3 ELEMENTS WITH THE HIGHEST GLOBAL WARMING POTENTIAL

See Annexe I - ACV

Tanks → 58% Pump → 39 % Stainless steel berkey → 3%

ENVIRONMENTAL ASSESSMENT

Collecting rainwater does not necessarily reduce GHG emissions, especially if the house is already connected to the drinking water network.
The mains water accounts for only 4% of the life cycle in the global warming potential.

Consuming rainwater as we do over the course of 10 years allows us to save 182,000 litres of water in total.
A household of 4 people with average water consumption would save more than two million litres of treated water.

COMFORT AND USE

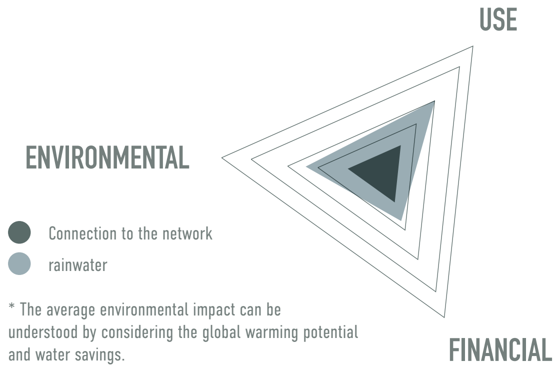
−

The greenhouse which was meant to double the collecting surface aera has not been constructed. The 1000-litre tank was installed at the end of summer when the heatwave hit, even in Brittany. We therefore ran out of water in July and August. To continue to live «normally" we had to bring back about 300 litres of water by hand. The lack of water is very restrictive.
With only a low volume of water stored up, it became quite stressful when the weather stayed consistently fine. Living with a limited supply of water makes you realise just how important this basic need really is. The «purification» by activated carbon filters takes a while and should be done ahead of time.

+

It is good for us to stop and think about what is really important, as it frees the mind from the vanities of everyday life. Adapting our water consumption according to the weather seems somewhat natural. Being independent from the complex and centralised water supply network is comforting. There is a certain pleasure that comes with enjoying rainwater; it makes you feel connected to the surrounding environment. Collecting rainwater makes it easy to appreciate the rain. Water tastes much better without the conventional chlorine taste. No one reported being sick after consuming water from the Low-tech Home.

Warning: consuming rainwater, even after mechanical purification, requires strong accountability on the part of the consumer, and requires regular checks. Pathogenic bacteria can develop rapidly.



* The average environmental impact can be understood by considering the global warming potential and water savings.

Summary

If the house is already connected to the water supply network, the returnon investment and in CO2 equivalent can take some time. Storing the water takes up a lot of space; it would be much easier to consider and implement the rainwater collection system when the individual or joint housing project is being designed. If there is available space in a cellar or nearby field, this system can be integrated into an existing house.

If the dimensioning and installation of the system are carried out properly, depending entirely on rainwater can lead to a high standard of living along with a sense of ecological accountability.

AREAS FOR IMPROVEMENT

Surface area *• If we are to adhere to the rainfall statistics whilst meeting our water needs, we need to increase the surface area.*
Concrete tank *• Although not suitable for a nomadic project, a buried concrete tank gives real added value.*
Visibility of water volume *• It would help to be able to know how much water is available.*
Minéralisation de l'eau de pluie *• To maintain a healthy and balanced diet, our bodies require a variety of essential minerals. Prolonged consumption of demineralised rainwater might lead to mineral deficiency. Storing the water in concrete tanks can only do so much to compensate for these missing minerals. It would be interesting to study the potential deficiencies associated with rainwater consumption and how these can be remedied. We are not aware of any reliable scientific data on the subject.*

Dry toilets

An average French person uses 10,000 litres of water per year to flush the toilet. This is 20% of the total water consumption of a household, or equivalent to 160€ per year for a household of 2 people.

Dry toilets could offer a solution to this problem, particularly in rural areas where compost and carbonaceous material such as untreated sawdust etc can easily be collected and provided. Dry toilets allow us to consider human waste as a valuable resource.

Urine and faeces are rich in nitrogen and other components that, when mixed with the right level of carbonaceous matter, produce a rich compost. The compost could be used for one and a half to two years to plant trees or decorative plants. As a precaution, we will avoid using human faeces to grow edible plants due to the hormones and antibiotics that may be present.

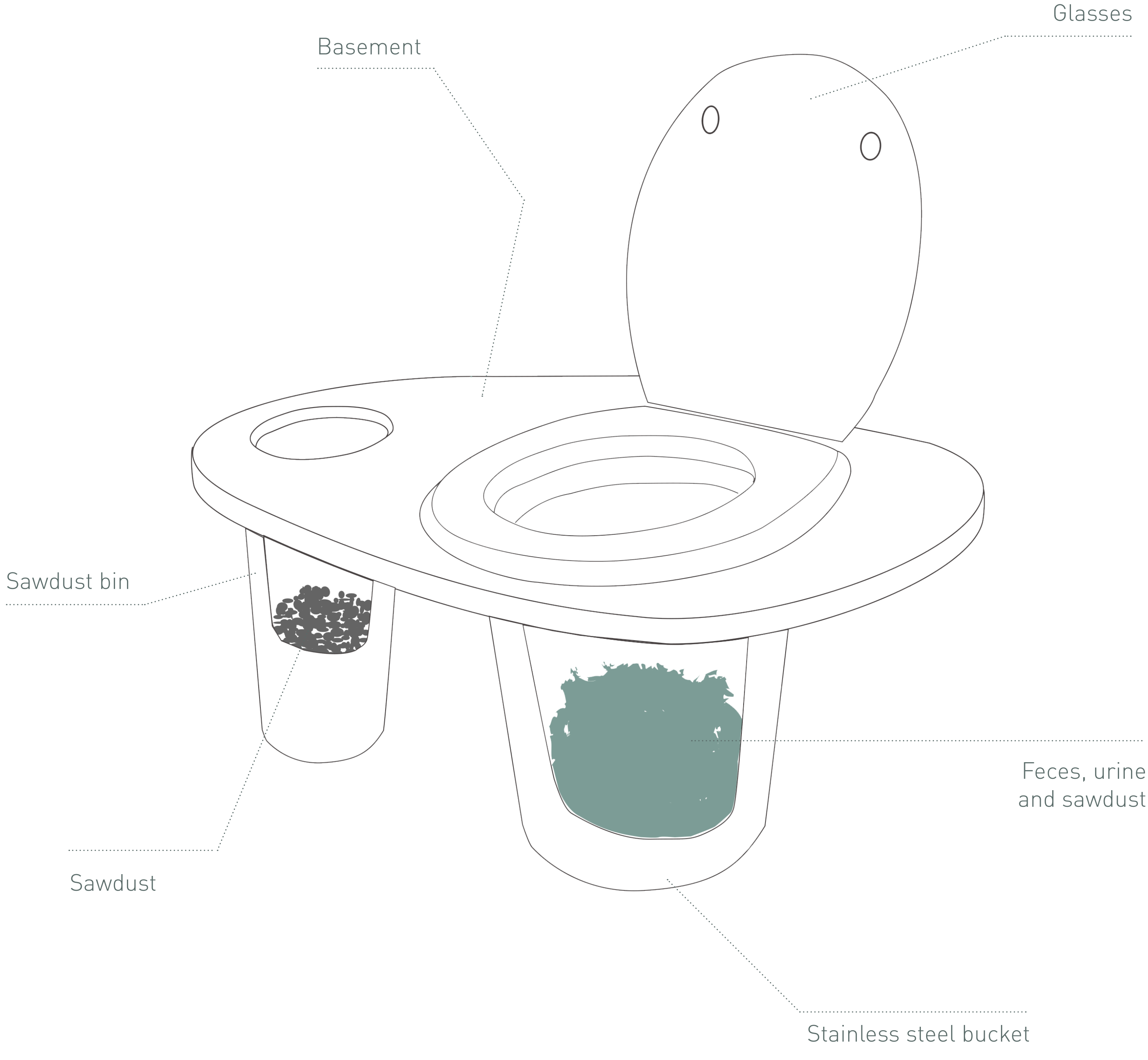
TOILETTES SÈCHES INSTALLÉES DANS L'HABITAT LOW-TECH

The dry toilets in the Low-tech Home are part of the so-called «BLT» (BioLitter Toilet)[1]. It comprises a wooden box with a stainless steel bucket inside, and a classic toilet seat on top.
There is a tray full of sawdust on the side. The sawdust is supplied by a local carpenter who does not need it. The wind ventilation system in the Low-tech Home is connected to the wooden box so that the air is sucked through the toilet thus ensuring no unpleasant odour.

DIMENSIONNEMENT DANS L'HABITAT LOW-TECH

Our toilet box is made of wood and poplar, plus thuja for the top tray.
We found the toilet seat at a depot.
The 15L stainless steel bucket is new.

1. Low-tech Lab, *Family dry toilets* (2017).
[online] https://wiki.lowtechlab.org/wiki/Toilettes_s%C3%A8ches_familiales (consulted in 12/2019).


Glasses
Basement
Sawdust bin
Feces, urine
and sawdust
Sawdust
Stainless steel bucket

3h

COST AND SOURCE OF MATERIALS

FUNCTION	THEORETICAL COST NEW	LTH COST
WC seat	50	0
Aeration	20	20
Seated	31	31
Adhesive	2	2
Dressing	3	3
Litter	0	0
Hardware	8	8
Seal	58	58
Sawdust stock	1	1
Structure	7	7
Total	**179**	**129**

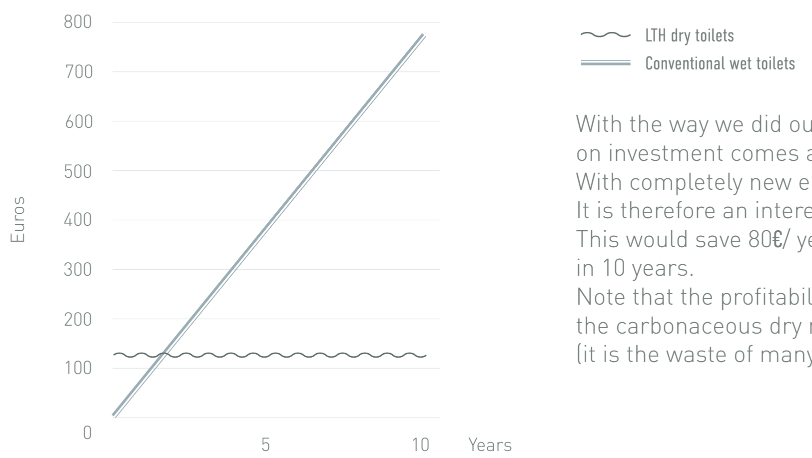
Euros

CALCULATION ASSUMPTIONS

- The average mass of human stools is 150 g / day
- A volume of sawdust replacing a flush in the case of a dry toilet weighs 0.15 kg
- 4 volumes of sawdust per person "equivalent to the water used for flushing" per day
- The profitability calculation for dry toilets is based on water savings
- Carbonaceous materials (here sawdust from untreated wood) are recovered free of charge
- Logistics related to the recovery of carbonaceous materials are not considered
- Composting or sanitation are considered, we do not count the mass of urine in the composting for LCA

RETURN ON INVESTMENT

→ ***Cost of different types of toilets over the course of 10 years***
See Annexe II - ROI

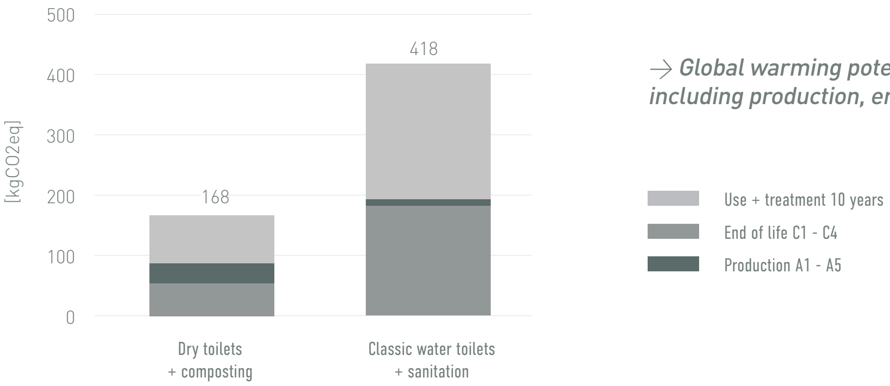


With the way we did our dry toilets, the return on investment comes at the end of 1.6 years of use. With completely new equipment, it would take 2.3 years. It is therefore an interesting solution for this aspect. This would save 80€/ year for 2 people or nearly 800€ in 10 years.
Note that the profitability is calculated by counting that the carbonaceous dry matter is recovered free of charge (it is the waste of many companies and woodworkers).

ENVIRONMENTAL IMPACT

LIFE CYCLE ANALYSIS
GLOBAL WARMING POTENTIAL

See Annexe I - ACV



→ Global warming potential of different toilets type, including production, end of life and 10 years of use

THE 3 ELEMENTS WITH THE HIGHEST GLOBAL WARMING POTENTIAL

See Annexe I - ACV

Galvanized steel ventilation tube → 63%
Stainless steel bucket → 21% WC seat → 7,5%

ENVIRONMENTAL ASSESSMENT

Good news about the environmental impact of our dry toilets: more than halfof the impact is achieved by a non-essential part of the system: the galvanized aeration tube installed before knowing its global warming potential. It is therefore easy to replace it with a material that has much less impact to divide the general impact by 2.

In any case, the dry toilets as we have installed them have a much better impact than the sole use of drinking water in conventional toilet flushing used over the same period.

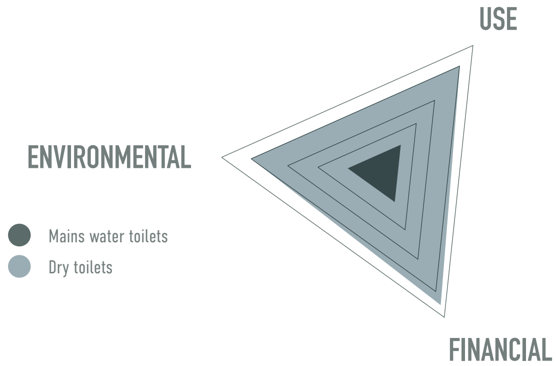
COMFORT AND USE

+

During the phase of the dry toilets use, we identified a gain in comfort compared to wet toilets: little noise, no odor and a higher level of hygiene than ceramic toilets.
We now also have a psychological embarrassment to use drinking water to flush toilets because of the waste it represents.
Dry toilets require emptying the bucket when it is full. The operation lasts five minutes, the time needed to cross the housing, to empty the bucket in the compost, to rinse it, to reinstall it and then to wash your hands properly.
In our case, we have no comfort problem with this stage, we even have a certain satisfaction in giving one of our waste to nature to transform it into a resource.

−

However, when there are guests at home, getting the bucket out in public can be embarassing for the uninitiated.
The only point that raised questions is the adjustment of the compost area to be able to empty the bucket without risk of projection on clothes as well as to have a place with an easy access to brushes, gloves, water, etc.



Summary

**Quickly profitable and ecologically more interesting than ceramic water toilets, this type of system deserves a good diffusion.
As soon as a few m² of plots are available to install compost, the use of dry toilets becomes relevant.**

However, in a mainly urban context, the real challenge is to both guarantee a supply of carbonaceous matter and a logistic of recovery of organic matter when space for composting is scarce.
It is perhaps up to the communities to organize this type of circuit in the same way as the sorting bins, knowing moreover that the compost can be upgraded.
Some towns like Lorient already offer an organic waste collection service.
In the aspect of appropriation by individuals, a great deal of awareness-raising work remains to be done to deconstruct the negative representations of this type of toilet, on taboos, hygiene, etc.

AREAS FOR IMPROVEMENT

Environmental aspect • *The most impacting factor is by far galvanized steel for ventilation. It seems easy to replace it with another material (cardboard tubes for example).*

Comfort aspect • *The emptying phase is really the one that can be a problem for the acceptance of this system. A reflection on how to manage the flow of organic matters must be carried out.*

Recycling shower

Who has never dreamed of spending time in the shower without having the guilt of a great ecological sacrifice? This feeling is justified, the shower is the biggest source of water consumption in the house. With, on average, 60 liters of water per day per French person, the shower represents 40% of our consumption. But the grim record of the showeror bath (200 liters), unfortunately does not stop there; the energy consumed in the bathroom to heat the water represents more than 10% of our annual energy bill, more than 300€/year per household.[1 & 2]

The recycling shower looks promising: it operates in a closed circuit for the duration of a shower to consume much less water and energy. The system is already well known because it is widely used in spas to reduce the consumption of massaging showers.

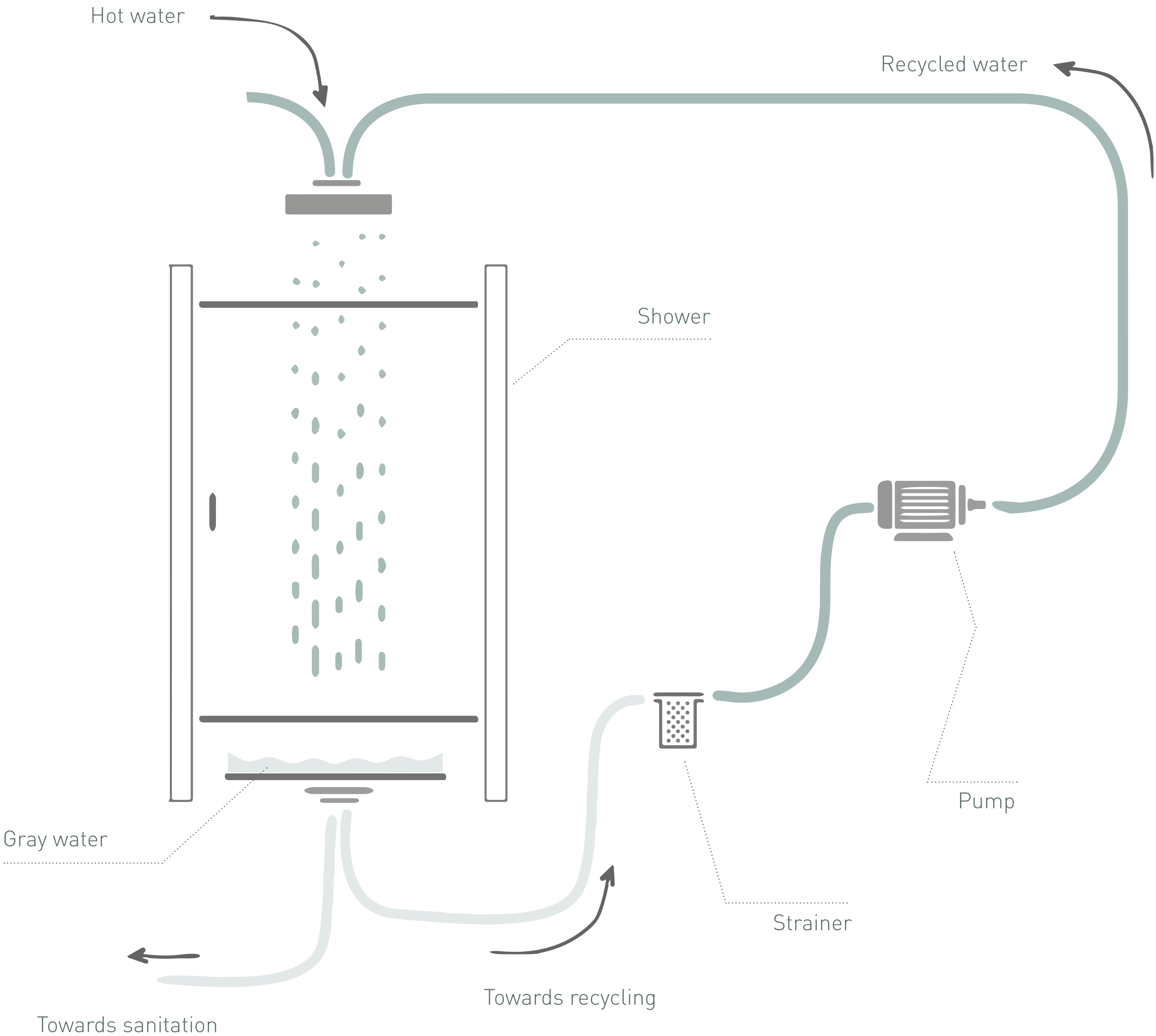
THE LOW-TECH HOME'S RECYCLING SHOWER

The recycling shower that we documented during the Low-tech Tour France did not convince us. In fact, separating the soap from the soapy water requires the use of filters which will quickly clog. To replace these filters increases greatly the financial and environmental costs of the installation.
In addition, in the independent house we have refrained ourselves to heat with electricity (see electrical installation and negaWatt). A gas water heater, instantaneous and with regulation, is very expensive. For the sake of simplicity we have therefore removed filtration and heating, and only recycled "clean" water.
The use is thus slightly different from the initial principle, relatively close to the operation of low consumption dishwashers[3]: contaminated water (washing, rinsing and rinsing of the shower) are evacuated to the sanitation, like a conventional shower.
If the user wishes to stay in the shower, he can go for recycling by plugging the bung and then activate the recycling pump.
The water from the closed circuit only passes through a strainer to remove large items such as hair.
The water is not being heated in this circuit, therefore a bit of very hot water is added to the recycled water to maintain a comfortable water temperature.

LOW-TECH HOME DIMENSIONING

In addition to the standard elements of a shower, this system includes an overflow to plug the drain and prevent overflows, as well as a removable floor, a strainer, a pump 12 liters/minute and a 3-way mixing valve.

1. ADEME, *Domestic hot water* (2019).
[online] https://www.ademe.fr/particuliers-eco-citoyens/habitation/bien-gerer-habitat/leau-chaude-sanitaire (consulted in 12/2019).
2. ADEME, *Water and energy: What consumption?]* (2019).
[online] https://www.ademe.fr/sites/default/files/assets/documents/infographie-economiser-eau-energie-2019.pdf (consulted in 12/2019).
3. Spareka, *How does a dishwasher work? The water circuit* (2016).
[online] https://www.youtube.com/watch?v=mjcwArj9nPs (consulted in 12/2019).


Hot water
Recycled water
Shower
Pump
Gray water
Strainer
Towards recycling
Towards sanitation

3h

COST AND SOURCE OF MATERIALS

Floor	20	Euros
Plumbing	60	
Pump	70	
Total	**150**	

FUNCTION — NEW COST FUNCTION

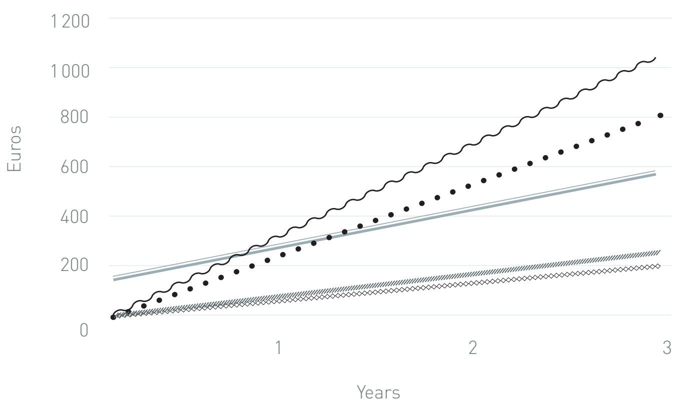
CALCULATION ASSUMPTIONS

- The elements of the shower itself such as the shower head, the mixer tap, the receptacle, etc., are excluded since they are common to all the systems compared.
- Water heaters are not considered
- Shower water is 37°C [4]
- "Cold" water is at 15°C
- It takes 1.16 Wh to increase 1 liter by 1°C
- On average, a French person's daily shower requires 60 liters of water and lasts 10 minutes
- In recycling, for a 60-liter shower, 20 liters are needed for washing and rinsing in 4 minutes, then 5 liters of water in a closed circuit for 6 minutes of pumping
- The pump has a charge of 75 Watts
- Electric and gas water heaters have an efficiency of 70%[5]
- The pump used for the LCA is largely oversized (conservative hypothesis)
- Network water and wastewater treatment are considered

4. ADEME, *Domestic hot water* (2019).
[online] https://www.ademe.fr/particuliers-eco-citoyens/habitation/bien-gerer-habitat/leau-chaude-sanitaire (consulted in 12/2019).
5. ADEME, *Domestic hot water* (2016).
[online] https://www.ademe.fr/expertises/batiment/passer-a-laction/elements-dequipement/leau-chaude-sanitaire (consulted in 12/2019).

RETURN ON INVESTMENT

→ *Cost of shower types over the course of 3 years*
See Annexe II - ROI



Normal shower - elec water heater @ 2pers x15L/day
Recirculation shower + elec water heater @ 2pers x60Leq/day
Normal shower - gas water heater @ 2pers x60L/day
Normal shower - gas water heater @ 2pers x15L/day
Shower normal - electric water heater @ 2pers x60L/day

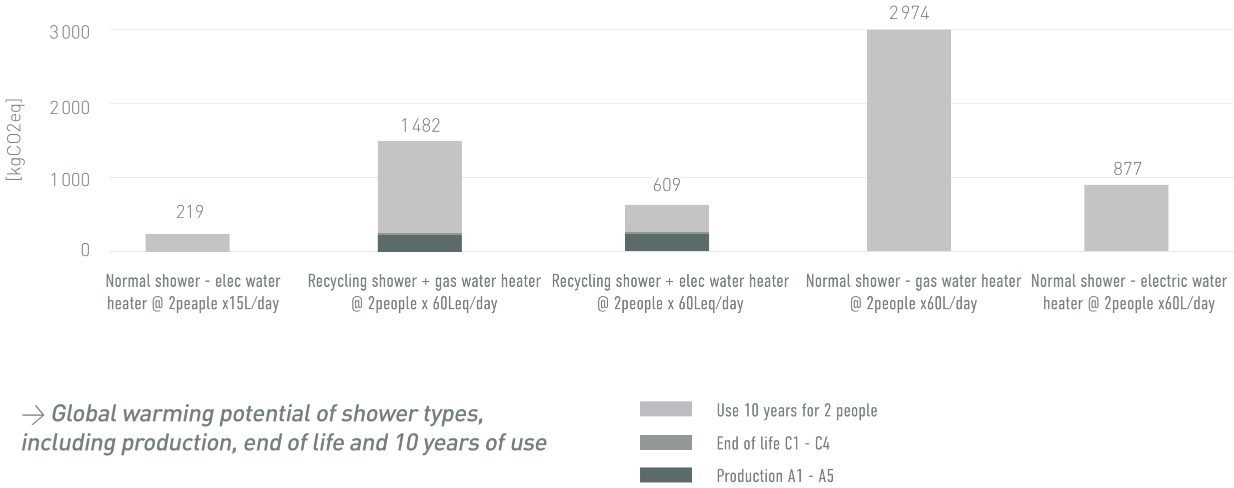
FINANCIAL EVALUATION

A liter of water at 37°C costs 0.8 cents (50% water, 50% energy). A normal shower of 60 liters costs 0.48€ ; for the same usable volume, the cost of a recycling shower is 0.20€ or 0.27€ saved per shower.
The return to the 150€ investment takes place after 555 showers, thus less than a year after installation if there are two daily users who do not reduce their consumption.

ENVIRONMENTAL IMPACT

LIFE CYCLE ANALYSIS
GLOBAL WARMING POTENTIAL

See Annexe I - ACV



→ Global warming potential of shower types, including production, end of life and 10 years of use

THE ELEMENT WITH THE HIGHEST GLOBAL WARMING POTENTIAL

See Annexe I - ACV

Pump → 93% Brass fittings → 3% Putty → 1%

ENVIRONMENTAL ASSESSMENT

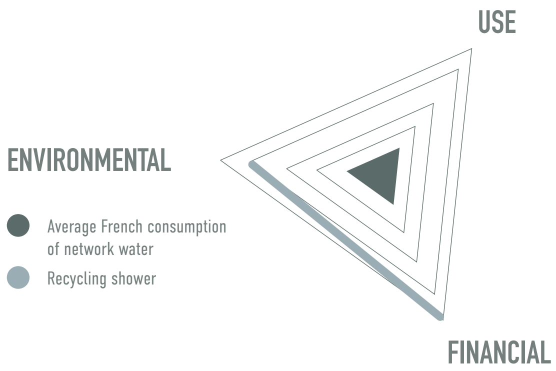
The installed recycling shower saves water and energy. Even if the ecological investment is important, in particular related to the installation of the pump, this system is interesting compared to a traditional shower in the medium term.

The more users take long and numerous showers, the more relevant the system.

Regarding water consumption, based on a 60 liter shower per day, the system saves nearly 13,000 liters of water per person per year.

COMFORT AND USE

The recycling shower underwent the late installation of the solar water heater which therefore resulted in the absence of hot water in the house for a large part of the experiment.
However, the teaching remains interesting, cold water is a very good way to consume very little water and no energy! But comfort is significantly reduced ...
For periods when the water was at a pleasant temperature, we made little use of the recycling system. Indeed, this system requires washing and rinsing before being able to relax for longer.
In our case, once clean, we usually get out of the shower.
The recycling shower is not interesting for us, being naturally fast and economical under the water jet.



Summary

The recycling shower makes it possible to make big savings in water and energy for people with a high consumption of hot water in the bathroom.
These savings are attractive from a financial and ecological point of view.

The recycling shower can be integrated into all types of housing. Be wary of a potential rebound effect which would encourage thrifty people to stay much longer in the shower than usual. Although reducing the consumption of water and energy required for heating, the recycling is not neutral.

Washing yourselves quickly is the best way to reduce your environmental footprint.

AREAS FOR IMPROVEMENT

Electric instantaneous water heater • In order not to oversize our solar electric installation, which has the biggest environmental impact in the house, we have refrained from heating with electricity. In a more traditional house, it would be interesting to study the relevance of an instantaneous electric water heater. It would heat up by a few degrees the water that has cooled in contact with the air, in the tank and the plumbing. By operating in this way, the water consumption would be further reduced.
Plug'n play recycling shower • It would be interesting to design a recycling shower that does not require any modification in the bathroom but simply a top-up. That could be added to the conventional installation.

Phyto-purification

**Phyto-purification is a wastewater treatment system.
Its objective is to transform wastewater into water that can be assimilated by the natural environment. The water is not drinkable at the sanitation outlet. It is very rich in minerals which can be assimilated by the soil and plants, comparable to a fertilizer.
The water returns to the natural environment by infiltration or spreading field.
This operation is similar to all types of sanitation, whether individual or collective: wastewater treatment plant, lagooning, septic tank, all-water tank, micro-station, etc.**

Phyto-purification, like all other systems, is based on the principle of separation of solids and liquids as well as the degradation of particles by bacteria.
Phyto-purification, or planted filters, relies on three players:

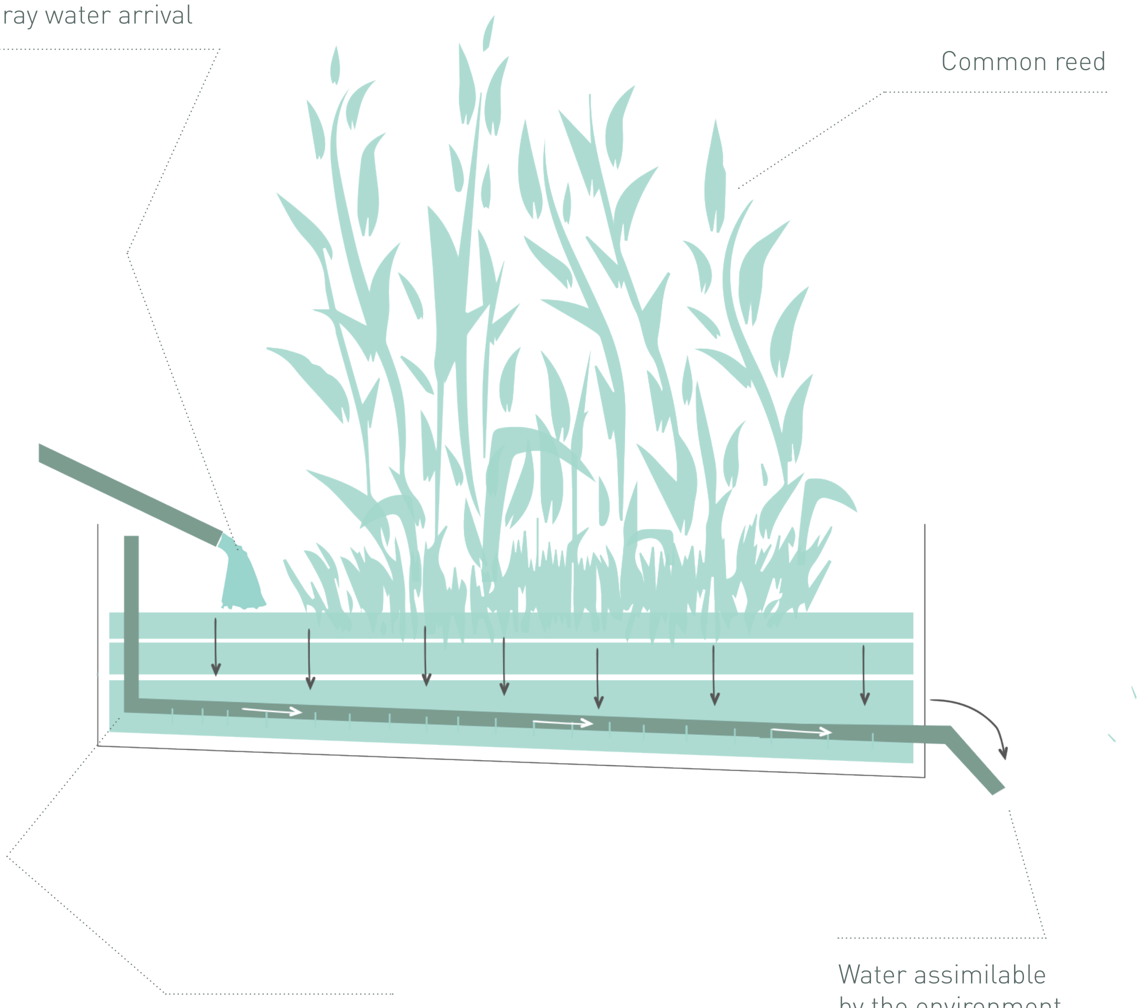
• bacteria: they degrade organic particles to make them assimilable by the natural environment,

• the substrate: made up of gravel or aggregates, it constitutes the habitat of bacteria which attach themselves to the surface of each element. It also plays an important role in the rooting of plants. With a grain size ranging from the finest to the coarsest, the substrate is also a filter allowing water to pass while blocking the largest elements,

• plants, with the development of their roots and the movement of their aerial parts, unclog the filter which, unlike all the other solutions, self-sustains. In addition, they stimulate bacterial activity around their roots: the rhizosphere.
They play a minor role in decontaminating water by absorbing a small proportion of minerals.

In a classic domestic phyto-purification system at least 2m² of planted filters per equivalent inhabitant are needed.

If a connection to collective sanitation of the «Mains drainage» is possible, it is compulsory.



NOMADIC MICRO-PHYTOPURIFICATION[1]

In general, phyto-purifications are landscaping, they are fixed installations that require the construction area to be terraced or even bricked.
In the case of the Low-tech Home project, we wanted to be able to leave the place of experimentation without leaving any human trace. We needed a light phyto-purification with reduced dimensions.
With the help of Aquatiris[2], we have worked to meet these specifications. By consuming little water and contaminating it to a minimum, with the use of dry toilets in particular, we could reduce the surface area of the filter. To lighten it, the substrate, normally made from gravel and chippings, has been replaced by cork stoppers and expanded cork. The sand has been preserved. The plants used are the common reed (phragmite australis) and water mint.

LOW-TECH HOME DIMENSIONING

In our case, the phyto-purification is 0.5m² (1mx0.5m) for two inhabitants.
From the start of the project, it is planned to increase the number of filters if the quality of the effluents does not comply with the regulations.
The installed system is passive, the filter being lower than the house outlet, it does not require a lift pump.

1. Low-tech Lab, *Phyto-purification* (2018).
[online] https://wiki.lowtechlab.org/wiki/Phyto%C3%A9puration_eaux_us%C3%A9es (consulted in 12/2019).
2. Aquatiris, *hyto-purification* (2019).
[online] https://www.aquatiris.fr/ (consulted in 12/2019).

6h

COST AND SOURCE OF MATERIALS

FUNCTION	THEORETICAL COST NEW	LTH COST
Sealing	40	0
Outlet	25	25
Dressing	70	0
Plants	35	0
Substrate	350	25
Structure	80	80
Total	**600**	**130**

Euros

CALCULATION ASSUMPTIONS

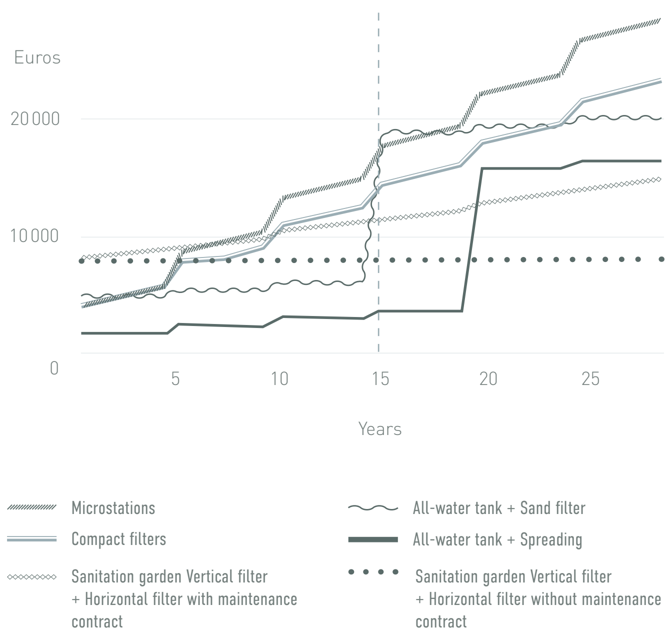
- Production of 40 liters of gray water per day for two inhabitants in the low-tech house
- Cork stoppers assimilated to expanded cork (conservative hypothesis)
- Phyto-purification cost for 5 equivalent-inhabitants: 7000€ /interview: 0
- Cost of sanitation microstation for 5 equivalent inhabitants: 5000€[3]/maintenance : 350€ per year[4]
- All-water tank cost for 5 equivalent-inhabitants: 3500€[5]/interview: 230€ over 4 years[6]

3. Quote-Bat, *How much does a micro-treatment plant cost* (2017).
[online] http://devibat.com/guide-prix/assainissement/prix-micro-station-epuration-individuelle.php (consulted in 12/2019).
4. Tricel, *Annual cost of Tricel Novo micro-station* (2019).
[online] https://www.tricel.fr/cout-annuel-micro-station-epuration (consulted in 12/2019).
5. Septic tank info, *Prix fosse septique* (inc).
[online] https://www.fosseseptique.info/prix-fosse-septique/ (consulted in 12/2019).
6. Travaux.com, *Septic tank price* (inc).
[online] https://www.travaux.com/guide-des-prix/plomberie/prix-de-vidange-dune-fosse-septique (consulted in 12/2019).

RETURN ON INVESTMENT

→ *Cost of sanitation systems over 15 and 30 years*[8]

See Annexe II - ROI



FINANCIAL OVERVIEW

- The installation of the low-tech house is very small due to our low water consumption (1/6 of the average consumption of a French person). The system is not approved.
The investment is therefore low and the maintenance cost zero.

For standard professional installations (phyto/pit/micro station):

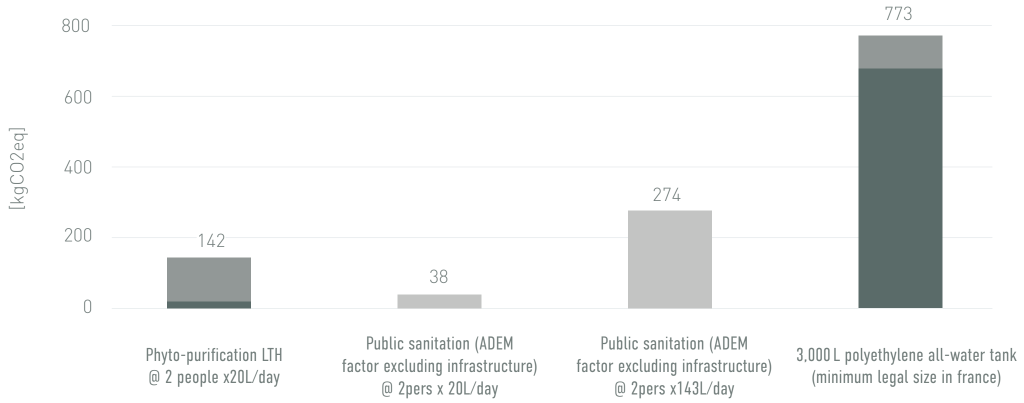
- Phyto-purification becomes financially more interesting than micro-stations after 5 years of use
- Compared to an all-water pit, you have to wait 20 years, i.e. the replacement of the tank[9].

7. Aquatiris, *Cost of sanitation systems over 15 and 30 years* (2012).
[online] https://www.aquatiris.fr/fr/comparatif.aspx
(consulted in 12/2019).
8. Source : SATAA of the departments of Rhône, Jura and Saône-et-Loire, in support of the working group of actors of the ANC of GRAIE.
Data concerning officially approved courses, for 5EH sizing.
Prices announced by the manufacturers in the user guides, and concerning the devices alone (excluding the collection network and outflow).
Compact filters and VSATs: average of devices approved on 12/31/12.
9.Aquatiris, *Frequently asked Questions* (Inc).
[online] https://www.aquatiris.fr/fr/La-phytoepuration-en-questions.aspx (consulted in 12/2019).

ENVIRONMENTAL IMPACT

LIFE CYCLE ANALYSIS
GLOBAL WARMING POTENTIAL

See Annexe I - ACV



→ ***Global warming potential of sanitation methods, including production, end of life and 10 years of use***

THE ELEMENT WITH THE HIGHEST GLOBAL WARMING POTENTIAL

See Annexe I - ACV

Cork stoppers→ 35% Expanded cork → 26%
EPDM membrane → 20%

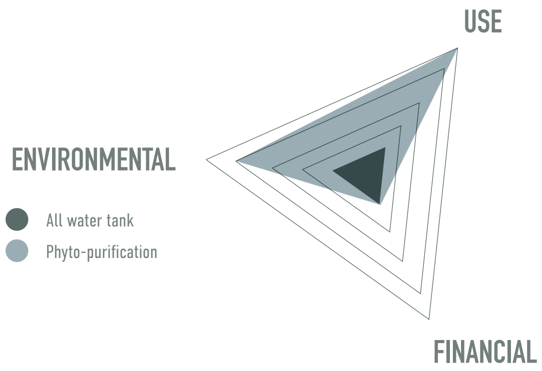
ENVIRONMENTAL ASSESSMENT

Details in Annex XVIII
Regarding the life cycle analysis in terms of global warming potential, the micro-phyto-purification that we have installed seems relevant compared to a conventional all-water tank. However, our systemis very undersized compared to the other systems. Aquatiris will share cycle analysis lifetime of its solutions in 2020. It will be interesting to study it. For identical water consumption (40 liters per day), public sanitation has a lower impact (note that the ADEME factor does not consider the cost of infrastructure public).

For a consumption of 150 liters/day for 2 people, the plant filters have a lower impact than public sanitation over 10 years.
From a less computational point of view, on-site wastewater management coupled with a visible living system encourages very strongly the reduction of pollutants in the water (cleaning products and hygiene, chemicals).
The environmental impact of wastewater management is therefore greatly reduced by a behavioural modification linked to the use of a plant filter.

COMFORT AND USE

Phyto-purification is a passive system, it does not require any activity on our part except to contemplate the growth of plants and the life that develops there.
As said previously, the use of a phyto-purification encourages the modification of uses. It is always good to remember that the sink is not a liquid bin.



Summary

Compared to other individual sanitation systems, phyto-purification will pay off in the medium or long term (five to twenty years).
Plant filters are generally landscaped structures that blend in perfectly with living spaces. They demystify the management of wastewater normally recorded in «black boxes», thus promoting accountability in water consumption.

PISTES D'AMÉLIORATION

Relief of sanitation • In the context of a nomadic habitat, the micro-phyto-purification of the low-tech house remains heavy, in particular because of the use of sand (75 kg) for filtration and bacterial life. It may be interesting to study the system "Lombri-bois" which uses lighter, non-resinous wood chips and sawdust.

Slow flow • Today, the bacterial activity at the exit of phyto-purification is slightly higher than the regulations, in particular due to a too rapid flow of waste water in the filter. The filter should be plugged, potentially with compost or sawdust, to increase processing time.

Cork replacement • *The use of cork in our phyto-purification represents 70% of the environmental impact in terms of global warming potential. It would be interesting to use other light, local and less impactful materials.*

Bokashi

Each year, a French person produces 320kg of waste, of which 120kg is potentially recoverable organic waste. They can be used in particular as fertilizer for crops.
In the countryside, it is easy to compost your organic waste.
In the city, it is more problematic. However, more than ¾ of French people live in urban areas, so the development's potential is very important.
The production of compost via organic waste could lead to growing more plants and vegetables at home.

In urban areas, the objectives are varied:
- **reappropriate the cultivation methods**
- **strive for food sovereignty**
- **clean up the surrounding air**
- **eat quality and local products**

Bokashi («fermented organic matter» in Japanese) is a very efficient composting method, which can be adapted to the urban context.
The bokashi implements what are called effective microorganisms (called EM).
Their use for compost makes it possible to imitate the functioning of a very healthy humus and to optimize the good degradation organic matter.

The result of composting is:
- a very nutritious juice for plants (dilute to 1% with water)
- a solid compost rich in minerals and micro-organisms

By using a waterproof and airtight container, the bokashi is particularly suited to an urban context, above ground: it is closed, does not smell, composting is fast, allowing the use of a small bin, and the juice can be used directly for soil-less cultivation (in earthen pots or on substrate). Léon-Hugo Bonte and Bertrand Grevet accompanied us in the discovery and use of bokashi composting during the Low-tech Tour France[1].

1. Low-tech Lab, *Kitchen Bokashi* (2017).
[online] https://wiki.lowtechlab.org/wiki/Compost_Bokashi_de_cuisine (consulted in 12/2019).


Hermetic lid
Compost bin
Organic waste
Micro-organisms
efficient
Receptacle
Fertilizer
Tap

1h

COST AND SOURCE OF MATERIALS

In our case we recovered a food bucket from collective catering, it is possible to buy bokashi composters in the trade. For effective microorganisms we bought wheat bran seeded at 22€ the 2 kg.

CALCULATION ASSUMPTIONS

- 2kg of wheat bran is used to sow the compost for a year
- Organic matter after bokashi composting will either be composted or considered as conventional waste collected in the absence of a composter

RETURN ON INVESTMENT AND ENVIRONMENTAL IMPACT

Bokashi juice can replace the use of commercial fertilizers (natural or synthetic). The economy is that of products not consumed.

COMFORT AND USE

We did not have a green thumb in this experiment, the management of living things was not our strong point.
Quickly, bokashi composting began to smell bad which is not synonymous with success.
of fermentation. After a few tries we abandoned this method, especially since it was not useful to us; in fact we did not have any soilless culture.
Our organic waste goes directly to the outdoor composter.

Summary

Although interesting on paper, we did not know how to manage well the bokashi composting method. In addition, as we do not do soilless cultivation, we have no need for liquid fertilizer.
The context of the experimentation, in a rural-country setting, did not encourage us to persevere in this direction.
It nevertheless seems relevant for people with a high production of soilless plants, whether for culture in pots or in hydroponics.

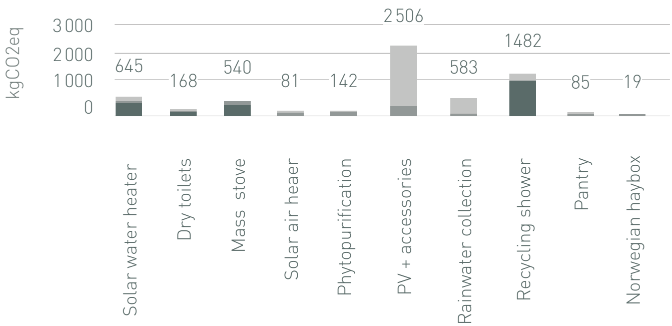
LOW-TECH HOME

A Low-tech Lab project

INTERPRETATIONS & PERSPECTIVES

GENERAL INTERPRETATION

On all the systems installed in the house, it is notable that the photovoltaic solar installation represents half of the total environmental impact, despite its small size (see graph below). This information is crucial when the subject of energy transition takes center stage. Although renewable energies (sun, wind, currents) are virtuous, the means of capturing them, transforming them into electricity or even storing them have a very high environmental cost. There is no low-tech solution to generating electricity.
The energy transition therefore requires above all a very strong reduction in our energy needs and particularly in our electricity needs before changing source.



→ *Global warming potential of each type of electricity consumption, including production, end of life and 10 years of use*

Production A1 - A5 End of life C1 - C4 Estimate of use phase

For the other systems, the results seem very encouraging to us. The ratings, generally positive, validate the work of recent years and a quality monitoring.
For this experiment, we did not integrate all the systems that we have documented in recent years, the selection was judicious.

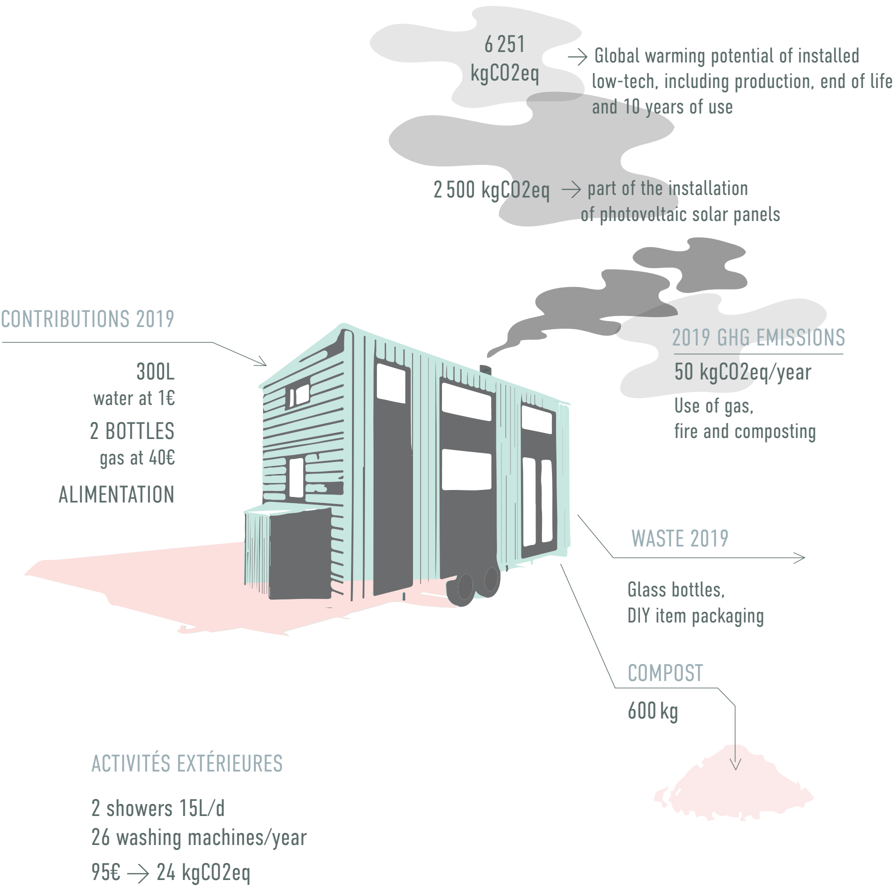
However, this study still had some surprises in store for us, particularly for the Norwegian pot.
Reducing cooking energy consumption so simply seemed obvious to us, it was a system easy to integrate to all kitchens. Ultimately the result is not so obvious.
The choice of materials is important to avoid the ecological "false good idea".

For the rest, some low-tech stand out by being relevant from all points of view, this is particularly the case for the pantry and the solar air heater.
Phyto-purification and the mass stove are the great champions of the environment.
For small wallets looking for minor investments and big savings, we recommend the dry toilets and the Norwegian haybox made from recycled materials.
The solar water heater, the solar air heater and the phyto-purification are invisible in everyday use, they do not require any particular activity or maintenance.

Finally, the phyto-purification, the pantry and the Norwegian pot have been remarkable for their beneficial influence on our behaviour and lifestyles.

30 000€

TOTAL COST OF THE HOME
INCLUDING € 3,500 FOR LOW-TECH



→ *Cost and global warming potential of the Low-tech Home*

CONCLUSION OF THE PROJECT

This report is the completion of 3 years of work on low-tech in Western housing. The results of this series of experiments are imperfect, they are the fruit of the study of a particular case, ours. We wished to be the most neutral in our computational approach.
Despite this attention, we are not immune to errors or mistakes in reasoning. If so, we thank you for your kindness and especially for your help in the next update of the document.

Nevertheless, this study is a first approach to the subject, it allows to address the major trends in the relevance of a low-tech approach to think about a sustainable future. The tools created can also be used and adapted to other contexts, for other people.

The first important point to note is that, very often, it is the combination of an approach of sobriety and a low-tech which makes it possible to draw the best potential of these systems. In other words, we should only expect from technology what it can bring us: a mean of responding to the lifestyle that we have chosen as an individual.
The first step for everyone is therefore to reassess their needs.

In this context, our results show that, for the most part, low-tech are relevant on the environmental and financial aspect. It is possible to significantly reduce your carbon footprint while making significant financial savings.

For the use of low-tech, we cannot generalize because this point is very subjective and specific to each one. The only thing that we can do is share our feelings: we have changed some of our bad habits, but we have not lost comfort at all living in this house.

On the contrary, we have derived deep satisfaction from drastically reducing our carbon footprint and our expenses by living just as well, or even better, than in a conventional habitat.

In our societies we associate the word "comfort" with material ease, security. Life in this house has allowed us to touch another notion of comfort: that of having the mind freed from the material by aiming for the essential, that of reducing our dependence on a complex, obscure and sometimes destructive system, that of feeling safe because included in an ecosystem, allowing us to have an autonomy in water and energy thanks to local natural resources.

Originally, we were not particularly favourable to this quest for autonomy in energy and water. An amalgam continues between autonomy and ecology: an autonomous habitat has a much higher environmental impact than its equivalent linked to networks. If there is no considerable reduction in consumption, an autonomous site is a real ecological calamity (cf. impact of photovoltaic solar panels). In addition, autonomy is opposed to pooling, which, by optimizing access to resources and their profitability, is very relevant from an ecological and financial point of view.
In doing so, the educational scope of the project led us to the choice of a nomadic micro-habitat, so we opted for an independent house of the networks, acceptable thanks to a strong reduction in our needs. This partial autonomy has been an accelerator, a catalyst, in reconnecting us with our environment. But even without seeking autonomy, taking advantage of locally available resources allows to connect with the near universe and is virtuous.

The objective of our experiment was to validate the relevance of low-tech for the context of Western housing. Goal achieved! We will be able to move on: participate in disseminating more widely these systems which have convinced us.

This experimentation also brought us a lot individually, it invited us to live differently.
We would like to share with you our personal feelings, testimonies of our transformations.

PIERRE-ALAIN INDIVIDUAL REPORT

At the end of this project, I tell myself that I have spent the last 4 years observing the low-tech world from my window.
It was only this year that I was able to open the door and see what was going on there. I did not realize the potential hidden behind these systems and this approach:

The man, the object, who owns whom?

I work with guts, it's my second brain! First info from stomach to head: a funny feeling of mental relief sets in when passing through the meadow of the low-tech home. Material sobriety, encumbering only what is necessary, is the first step in a process low-tech. With Clément, we asked ourselves the question "What do we need?". We designed this house to live well, with no frills.
I took the opportunity to tidy up and take stock of the items I own. Listening to my words, the experience takes shape: "I forgot that thing over there, I really have to sell it ...", "Arf, it's broken, I have to fix it", "But what is this pile of clothes doing here?" "I must get rid of it". Hours consumed and mental load.
As things progress, I purify.
I am convinced that this "quest for the little" is one of the most important parameters in this feeling of lightness. It can allow everyone to strive for a better being. I cannot wait to hear as a slogan "He doesn't have a Rolex at 50, he's made a success of his life!" Autonomy: choose who to be dependent on.

Second message from the belly to the brain: whence that feeling of security and satisfaction in the evening when the lights go out? I am looking for the autonomy that low-tech gives us.
We don't have food, but energy and water are within reach.
The word is misleading: autonomy invites you to create your dependencies: We chose rain for water, sun and wood for energy, earthworms for our organic waste and local producers for the rumen.

My sense of satisfaction and security comes from these choices. In our world drawn by barbed wire in the meadow, whatever the weather, I'm happy. I am part of a composting company where the worms are my colleagues. I was able to discuss the bad season with the producer of the carrots that I eat.
I know how much my electric kW.h weighs as well as my liter of water. I'm starting to understand the matrix and I'm part of it: we can count on each other in case of glitches!
This proximity dependence leads to respect for the actors and resources on which we are dependent.
All together, we are moving towards a palpable, viable and secure ecosystem.

Surprise, this time for my head and my wallet: 1 year of charges for the low-tech Home, 150€.
I let the reflection run on what could entail an ideal of life freed from the burdens, in particular financial, that the low-tech partly leave to promise.
I imagine where everyone could free up the time to explore their passions, invest their energy in acting for their values: Low-tech can help unlock everyone's potential.

But the low-tech require the link to the other for them to work. From links are born the mixtures of ideas, actions, energies:

As long as it is oriented towards common sense, the low-tech approach can participate in the release of collective potential. The road is long, but I feel on the move, I am happy.

CLEMENT
INDIVIDUAL REPORT

The results of this experimental work delight me. Yes, low-tech have a meaning, they respond to this promise that a life at a lower cost and with greater respect of the world is possible.

But my enthusiasm, my deepest satisfaction, is all the more personal, I found appeasement by reconnecting with my direct environment.

As a kid, I marvelled at the living, the wild, from the scale of the leap of frogs, to the lightning of a flying dragonfly, through the mighty grip of crabs. I was sometimes intrusive, clever, lifting slabs and rocks in search of ant-hill architecture or beetle shelters.

Probably with age, I forbade myself, I muzzled this wonder. The world is serious, hard and cold. You have to devote yourself to serious things and not to the admiration of the bugs or vegetable.

My error is there, to give up the enchantment of the natural because reserved for the child or the naturalist. Not really a child anymore and not a specialist in living things, I broke with nature, my nature, like many of us. What foolishness!
Vincent Munier[1] quotes GK Chesterton: "The world will never die for lack of wonders but only for lack of wonder."
This experience allowed me to rediscover the living, my part of wildness. Wonder has made a comeback, in its simplicity and greatness.

1. Vincent Munier, *Eternal amazed, Pass me the binoculars*, RTS 2019

This little house encouraged me to ease off and observe, observe myself. Finding a natural, seasonal rhythm with the impermanence of the elements allows to return to a superior balance, which I think I needed. We all got a big pleasure from living with less, more simply, as testify travellers on foot, by bike or by sail, living on little to live more, connected to the elements.

So why retain this well-being to a few rare escapades when it could elevate our daily lives?

But it is true that this way of life must result from a choice and not be suffered. It should not be a renunciation but an opening. So, it only asks each one of us, to take this step, this choice to depend a little more of the environment, to, I hope, share the same observation and the desire to encourage our neighbours to evolve.
Of course, it takes a little humility to accept the sky's refusal to rain or to adapt to the persisting grayness, but it is also for the pleasure of accelerating in fine weather and then slowing down in winter. More generally, Nature is generous and handing her part of my needs is great.
I feel less responsible for all of my individual satisfactions, I play the response to my basic needs with the environment, I partly externalize my sources of well-being. This great everyday game sweeps away many worries and misplaced interests. It offers an unusual and welcome refocus and calm.

Ultimately, as naive and childish as it sounds, I think this is our place. The proof is the balance that we have found to depend on this Nature, like many others in transition or already transformed.
So I marvel at the savage that reveals itself with each new raindrop, for each solar ray, which offer me the comfort of a simple life.
And if everyone, by taking advantage of the water offered to them as of the sun bathing them, could reconnect to their nature, regain awareness of the global chain of which they always are part, then maybe the world would work better.

OPENING

This report, in addition to the video series "In Search of a Sustainable Habitat" [2], *concludes our Low-tech Home experiment and opens the door to new projects.*

SHARING THE PHILOSOPHY AND PEDAGOGY

Sharing the low-tech mindset, the education to change, the understanding of the impact of each and the possibilities for action is the first step for a set in motion.
Before changing, it is important to understand why we must renew our lifestyles. Then, you have to take ownership of your environment, discover what is "toxic" and what is less so. And finally choose, replace our obsolete objects and habits with virtuous approaches and systems and why not low-tech!

This is why we are leaving the keys of the house to Romane who takes over to take the Low-tech Home on tour throughout France to meet associative, professional and school students who are sensitive to this approach; to allow the greatest number to put, by desire, the foot in the stirrup towards a sustainable world.

2. Low-tech Lab, *In search of a sustainable habitat* (2018).
[online] https://www.youtube.com/playlist?list=PL16ZDrU18TC1DrpGL0n6iHjX6Ubgwv-hc
(consulted in 12/2019).

TRAINING AND PRODUCTION OF LOW-TECH SYSTEMS

Today, the systems studied in this report are the fruit of the documentation work of the Low-tech Tour France. Tutorials, videos and manufacturing instructions are available for free on the Low-tech Lab wiki platform[3] thanks to the generosity of their inventors.
Everyone can therefore, as they wish, duplicate or adapt these low-tech to their housing.

However, we know that implementing these systems requires tools, skills and time, which not necessarily everyone has.

In order to allow as many people as possible to benefit from these systems, we wish to devote part of our activities to support professionals and associations to take them in hand.
We are also convinced that the local network of material deposits (resource centers, actors recycling), micro-production space and sales areas would be a good way to disseminate these techniques while promoting a local economy. The change of scale also implies a quality approach. We will work on the study of a pilot project in this direction.

3. Collective, Low-tech Lab (inc).
[online] https://wiki.lowtechlab.org/wiki/Explore (consulted in 12/2019).

STUDY OF OTHER CONTEXTS OF USE

Obviously, our core business remains unchanged at the Low-tech Lab. Our attraction to experimentation and everyday adventure happily persists.

Like others who will wish to join the process, we will test new systems in different contexts, more representative of contemporary lifestyles.
What is my power to act in an apartment?
What systems could be integrated into collective housing?
How to renovate my house? are all questions to which, like you, we look forward to exploring the answers.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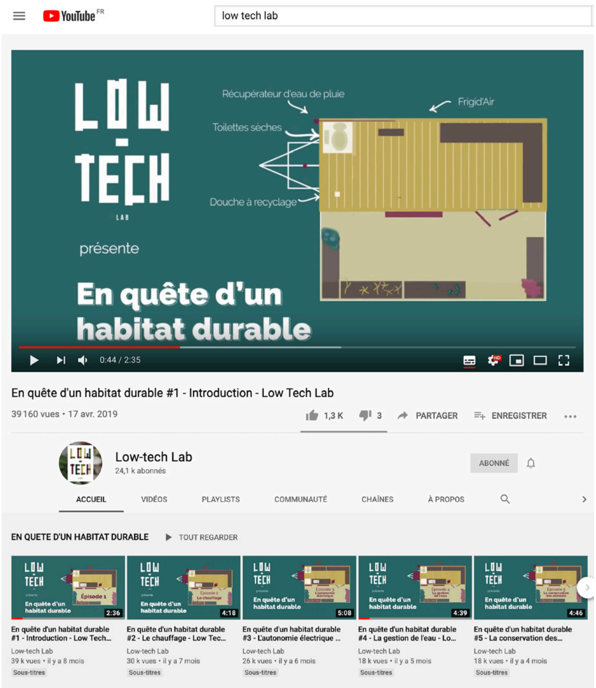
MEDIA

THEY RELAYED THE ADVENTURE



France 2 : Télématin • France 3 Bretagne • France 3 National : We have the solution • France Inter : Campaign book and La terre au Carré • France Culture Hit West • Libération • L'ADN • The Ecological House The Hummingbird Movement • Ouest France Phosphorus • Without Transition • RFI • Tébéo Le Télégramme • We tomorrow • 6.39pm and many more!

The achievement
of such a project is not done
with 4 arms and 2 heads!

For their trust and financial support, we would like to thank the ADEME, the Ministry for the Ecological and Inclusive Transition, the Fontaine Institute, the THETYS Foundation, Crédit Mutuel ARKEA, the MACIF Bretagne / Normandy Foundation.

The Low-tech Home weighs 3.5 tons, it took equipment to achieve it!
We would like to thank Jean-Daniel Blanchet / Atelier Bois d'Ici for making the workshop available and for supporting our first steps as a carpenter.
SpeedNautic, Fenetrea, Leroy Merlin Quimper and Schneider Electric for equipment donations.

The low-tech that we have installed in this house were transmitted during the Low-tech Tour France by enthusiasts open to the free sharing of their work.
We would like to thank Léon-Hugo Bonte for the bokashi, Gilles Planchon and En- kidou Burtschell for the spirulina, Aurélie Guibert for the wind turbine, Vital Bies and David Mercereau for the mass stove, Guy Isabel and Jean-Daniel Blanchet for the solar air heater, Eric Lafont and the Grand Moulin collective for the solar water heater, Kévin Quentric and Aquatiris for the phyto-purification, Arieh and David for their advice on energy, Claire Yobé for lactofermentation, Pierre and Thomas de Picojoule for biogas.
Many hands have participated in putting the Low-tech Home on wheels and making our deliverables.
We thank Jean-Baptiste Poivre, Jérôme, Mathilde and the many volunteers who participated in the construction and the open days.
Thanks to François Legrand and Clément Isaia for their help in the setting up of our measuring tools; Axel Lattuada and Hélène de Vestèle / EDENI for their participation in our videos.
Special mention to Lorélia le Gouvello for her invaluable help in analyzing the life cycle of the low-tech. Thanks to Camille / Pipalouk for formatting this report.
Thanks to Gildas for lending us free of charge the best meadow in Concarneau.
Our thanks are also addressed to Alexis, Manon, Michka, Lorelia, Kévin, Isabelle, Michèle and Dominique for reviewing this report.

We would like to thank Romane and Mewen, with whom we formed the "hard core" of this project and who knew how to bring their two cents and their good humor!
We thank the friends of the Low-tech Lab with a special dedication to Martine who succeeds in making all our ideas fit into the right administrative and legal framework!

Finally, we warmly thank Sophie, Bilou, Emmanuel and the Explore Fund team, who support us daily in Concarneau since the beginning of the Low-tech Lab.
They allow us to carry out our projects in the best conditions.

THANKS

January 2020